AV-8 TACTICAL MANUAL

NWP 3-22.5-AV8B

VOLUME I

A1-AV8BB-TAC-000

THIS PUBLICATION IS INCOMPLETE WITHOUT NWP 3-22.5-AV8B VOLUME II (A1-AV8BB-TAC-050), AND NWP 3-22.5-AV8B VOLUME III (A1-AV8BB-TAC-100/(S))

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OFFICE OF THE CHIEF OF NAVAL OPERATIONS

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AUGUST 2002

A1-AV8BB-TAC-000

DEPARTMENT OF THE NAVY
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
WASHINGTON, D.C. 20350

April 1996

LETTER OF PROMULGATION

1. NWP 3-22.5-AV8B, Vol. I (NAVIR A1-AV8BB-TAC-000), the AV-8B TACTICAL MANUAL, Chapters 1 through 4, is an Unclassified publication which is effective upon receipt. It supersedes NWP 55-3-AV8B, Vol. I (Rev. E) (NAVIR A1-AV8BB-TAC-000), the AV-8B TACTICAL MANUAL, Chapters 1 through 4, of September 1994, which shall be destroyed without report.

2. Aircraft tactical manuals provide the latest and most accurate tactical information to aircrews and tactical commands. These manuals are designed to promote the development of efficient and sound tactical doctrine and to eliminate the need for promulgation of doctrine by individual squadrons. The tactics published herein are to be considered as a guide to better operations, not as the only way and final authority in tactical evolutions. It is both desirable and necessary that new ideas and new techniques be expeditiously evaluted and incorporated if proven to be sound. To this end, Operational Commanders should encourage innovative thought and the use of effective tactics not reflected herein. These manuals are complied using Fleet inputs and are kept current to achieve maximum combat readiness. To provide the lates data, Navy and Marine Corps Fleet/Type/Air Wing Squadron Commanders are directed to review these procedures on a continuing basis and submit recommended modifications as outlined under "Change Recommendation."

DENNIS V. McGINN
Rear Admiral, U.S. Navy
Director, Air Warfare

May 1998

PUBLICATION NOTICE

ROUTING

1. NWP 3-22.5-AV8B, Vol. I , AV-8B Tactical Manual, is available in the Naval Warfare Publications Library.

2. Summary. Major changes to this publication include:

   a. Incorporated UIC-16, M904E4 Nose Fuse Code change.
   b. Incorporated UIC-17, Clarification of aircraft loading and delivery profiles.
   c. Incorporated Omnibus 7.1 software.
   d. Incorporated Omnibus C1 software.

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Note to Naval Warfare Publications Custodian

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RECORD OF CHANGES

Change No. and Date of Change	Date of Entry	Page Count Verified by (Signature)

INTERIM CHANGE SUMMARY

The following Interim Changes have been canceled or previously incorporated in this manual:

INTERIM CHANGE NUMBER	REMARKS/PURPOSE
1 through 3	Previously Incorporated.

The following Interim Changes have been incorporated in this Change/Revision:

INTERIM CHANGE NUMBER	REMARKS/PURPOSE
16	M904E4 Nose Fuse Code Change.
17	Clarification of aircraft loading and delivery profiles.

Interim Changes outstanding - To be maintained by the custodian of this manual:

INTERIM CHANGE NUMBER	ORIGINATOR/DATE (OR DATE/TIME GROUP)	PAGES AFFECTED	REMARKS/PURPOSE

SUMMARY OF APPLICABLE TECHNICAL DIRECTIVES

Information relating to the following historical record of applicable technical directives has been incorporated in this manual

CHANGE NUMBER	DESCRIPTION	DATE INC. IN MANUAL	VISUAL IDENTIFICATION
AFC-219	Throttle redesigned to switch position of TDC and speedbrake switches.	July 1984	Position of TDC speed-brake switches reversed on throttle.
AFC-241	Installs HUD video recording system to provide near real time playback of HUD and DDI displays for post-flight debrief.	March 1985	HUD video camera is located next to CDC and video recorder is mounted in right console.
AFC-263	L/R Aileron servocylinder	August 1986	None
AFC-263 Part 2	Increase Aileron and Rudder SAS Authority (Departure resistance)	August 1986	Departure resistance caution
AFC-269	Adds ships inertial navigation system (SINS) sea alignment mode.	August 1986	SINS legend appears on DDI when sea alignment selected.
ASC-032	Armament control panel (ACP) software configuration change	August 1987	Program identification number 7108542-010
ASC-030	Stores management computer (SMC) software configuration change	August 1987	Program identification number 7108579-012
ASC-026	Display computer (DC) software configuration change	August 1986	Program identification number 980045
ASC-031	Avionics software changes	August 1987	MC OFP IDENT/ MOFE000
AFC-286 AYC-873	Throttle grip modification, relocates cage/uncage and emergency flaps button	August 1988	None
ASC-034	Incorporate Omnibus V mission computer OFP	August 1988	MC OFP IDENT/88-D
ASC-035	Display computer (DC) software configuration change	August 1988	D980045-003
ASC-037	Armament control panel (ACP) software configuration change	August 1988	Program identification number 7108542-011
ASC-036	Stores management computer (SMC) software configuration change	August 1988	Program identification number 7108579-013

CHANGE NUMBER	DESCRIPTION	DATE INC. IN MANUAL	VISUAL IDENTIFICATION
AFC-318	Stores Management Single Point Failure Correction	August 1988	Master Arm Caution
ASC-043	Incorporate Omnibus VII Mission Computer OFP	February 1993	MC OFP IDENT/90-D
ASC-045	Incorporate Omnibus VII Stores Management Computer (SMC) software change	February 1993	Program Identification Number D70514
ASC-046	Incorporate Omnibus VII Armament Control Panel (ACP) software change	February 1993	Program Identification Number AF-013
ASC-053	Incorporate Omnibus VI mission computer OFP	February 1993	MC OFP IDENT/90-N
—	Incorporate Omnibus VI Stores Management Computer (SMC) software	February 1993	Program Identification Number 7108940-001
—	Incorporate Omnibus VI Armament Control Panel (ACP) software	February 1993	Program Identification Number 7108542-012
ECP-129-C2/C3	Wider Field of View Head-Up Display	February 1993	Night Attack HUD
ECP-134-C1/C2/C4	Production Night Attack Installation	February 1993	Night Vision Goggle Compatible Cockpit
ECP-143-C1/C2	Stores Management System Enhancement	February 1993	Upward Firing Loadout Panel switches on SMC
ECP-168-C1	Incorporation of GPS Provisions and Mini-Tacan	September 1994	None
ECP-200R1	Production Incorporation of AN/APG-65 radar and Wiring Provisions for Smart Weapons	September 1994	Radar switch on Miscellaneous Switch Panel Program Idendification Number 94-ROFE1205
TDL0007 (DO-27)	Incorporation of Omnibus 6+C Software	September 1994	Program Identification Number 94-NOFE070F
DO-26	Incorporation of Omnibus 6+B Software	September 1994	None
ASC-76	Incorporation of Omnibus 7.1 Software	May 1998	MC OFP 96-DOFE060C
ASC-78	Incorporation of Omnibus C1 Software	May 1998	MC OFP 96-COFE060L
ECP-301	Incorporation of Litening II Targeting Pod	Aug 2002	Pod

Information relating to the following historical record of applicable technical directives will be incorporated in a future change.

CHANGE NUMBER	DESCRIPTION	VISUAL IDENTIFICATION

GLOSSARY

AA. Anti-Aircraft.

A/A. Air-to-Air.

AAA. Anti-Aircraft Artillery.

AAC. Aircraft Armament Change.

AACQ. Auto Acquisition.

AAM. Air-to-Air Missile.

AAW. Anti-Air Warfare.

ABF. Annular Blast Fragmentation.

ACC. Air Control Center; Air Combat Command.

ACD. Attack Cone Distance.

ACE. Air Combat Element.

ACM. Air Combat Maneuvering.

ACNIP. Auxiliary Communication Navigation Identification Panel.

ACP. Armament Control Panel.

ACQ. Acquisition.

acquisition cursor. Two small parallel vertical lines on the radar display, positionable with the TDC when it is assigned to the radar. The acquisition cursor may be used with the TDC to designate a target or to HOTAS radar modes and operating parameters. This cursor will not be present unless the TDC is assigned to the radar.

ADC. Air Data Computer.

ADL. Armament Datum Line.

ADSID. Air Delivered Seismic Intrusion Detector Device.

adverse yaw. Yaw away from the intended turn.

AEW. Airborne Early Warning.

AFC. Airframe Change.

A/G. Air-to-Ground.

AGC. Automatic Gain Control. AGC is the continuous adjustment of the radar receiver gain so as to keep the average level of the output more or less constant. AGC is internally determined based on radar operating mode, range, antenna beam, altitude, and antenna elevation angle. In all surface radar modes, except MAP and the expand modes, the radar set uses AGC to set receiver gain. In the MAP and expand modes, the radar uses AGC to set the initial gain setting, however, the pilot may manually adjust gain via the GAIN option.

AGL. Height Above Ground Level (e.g., release height AGL).

AGM. Air-to-Ground Missile. An air-launched, guided missile for attacking surface targets.

AGR. Air-to-Ground Ranging. The AGR mode is selected whenever the sensor select switch is actuated forward (also selects the INS sensor mode and assigns the TDC to the HUD). The AGR mode provides accurate slant range along the commanded LOS. Valid AGR is the priority altitude source for determining height above target for weapon delivery computations. In addition to slant range, a velocity error (VEL) is displayed on the AGR radar display. The velocity error, which is the difference between the target closing velocity measured by the radar and the best available system velocity (i.e., INS), serves as an advisory to the pilot that a precision velocity update (see PVU) may be required.

AHRS. Attitude Heading Reference System.

AI. Air Intercept.

AIC. Air Intercept Controller.

AIM. Air Intercept Missile.

aim error. The deviation of the actual aim point from the desired aim point.

airburst. An explosion of a bomb or projectile above the surface as distinguished from an explosion on contact with the surface or after penetration. (JCS Pub 1)

airspeed. The speed of an aircraft relative to its surrounding air mass. The unqualified term "airspeed" can mean any of the following:

(a) Calibrated Airspeed - Indicated airspeed corrected for instrument installation error.

(b) Equivalent Airspeed - Calibrated airspeed corrected for compressibility error.

(c) Indicated Airspeed - The airspeed shown by an airspeed indicator.

(d) True Airspeed - Equivalent airspeed corrected for installation error due to air density (altitude and temperature). (JCS Pub 1)

air-to air. Used or occurring between aircraft in the air, as air-to-air communication, air-to-air gunnery, air-to-air interdiction, etc.

air-to-ground. Used or occurring between aircraft and the ground, as air-to-ground communication, air-to-ground gunnery, air-to-ground interdiction, air-to-ground rocket, etc.

AIZ. Aircraft Intercept Zone.

ALT. Altitude; MSL unless specified AGL.

AMRAAM. Advanced Medium Range Air-to-Air Missile.

angels. A code meaning aircraft altitude (in thousands of feet). (JCS Pub 1)

angels OK. Radio call for asking if your altitude is satisfactory for the intercept.

angle off. The angle between the longitudinal axis of a defender and the line of sight of an attacker.

angle of incidence. See "aspect."

angstrom. A unit of length equal to one hundred-millionth of a centimeter used to specify radiation wavelengths.

angular resolution. The ability of a radar to separate the returns received from two or more objects on the basis of the angular separation of the objects as viewed from the radar. In other words, the minimum angle by which two objects at the same range may be separated and their radar returns displayed as two separate returns on the display. In the real beam modes (i.e., MAP, SEA, GMT), angular separation is a function of the radar's beamwidth (azimuth and elevation). However, in the expand modes angular separation is greatly improved by using DBS (see Doppler Beam Sharpening) processing techniques which utilize the differences in doppler shift between ground returns to determine azimuth resolution.

antenna size. As a general rule, antenna size is governed by the radar operating frequency. The lower the frequency, the larger the antenna must be in order to achieve acceptable angular resolution. For example, large, bulky, fixed sites such as Early Warning/Ground Control Intercept (EW/GCI) radars have low operating frequencies while compact radars, such as Airborne Intercept (AI) radars, have high operating frequencies. A radar's operating frequency and antenna size have a direct relationship on radar beam size. The AV-8B radar has a 23.2 inch diameter antenna.

AO. Area of Operation.

AOA. Angle Of Attack. The angle between the fuselage reference line and flightpath.

AOTD. Active Optical Target Detector.

APAM. Anti-Personnel and Material weapon.

APC. Armored Personnel Carrier.

APF. Aircraft Parachute Flare.

API. Armor Piercing Incendiary.

APS. Air Program Select.

APU. Auxiliary Power Unit.

ARBS. Angle Rate Bombing System.

area bombing. Bombing of a target that is in effect a general area rather than a unitery target.

area target. A target consisting of an area rather than a single point.

ARM. Anti-Radiation Missile.

arming. As applied to explosives, weapons, and ammunition, the changing from a safe condition to a state of readiness for initiation. (JCS Pub 1)

arming delay. The time from bomb release to the fuze becoming armed.

arming device. Device for arming a fuze under controlled conditions.

arming wire. A cable, wire, or lanyard attached to the aircraft (usually at the arming unit) and routed to a weapon system (e.g., fuze, fin, parachute pack) to prevent arming initiation prior to weapon release. Also called safety wire, arming lanyard, safety lanyard. (JCS pub 1)

A/S. Air-to-Surface.

AS. Anti-Spoofing.

ASE. Allowable Steering Error; Aircraft Survivability Equipment.

ASL. Azimuth Steering Line.

ASM. Air to-Surface/Anti-Ship Missile.

aspect. When discussing the surface radar, aspect refers to the aspect angle of the radar beam reflecting off of ground features. A basic concept of radar reflectivity (see Reflectivity) is that the angle of reflection is equal to the angle of incidence. In simple terms, radar energy bounces off a reflecting surface at the same angle at which it strikes it. The radar beam's vertical and horizontal aspect angles affect the amount of radar reflection. Maximum reflection occurs when the aspect angle is 90°.

aspect angle. The angle between the longitudinal axis of the target (projected rearward) and the line of sight to the interceptor measured from the tail of the target. (JCS Pub 1)

aspect ratio. Wingspan squared divided by surface are.

ASR. Auto Scene Reject.

ATAP. Anti-Tank Armor Piercing.

attack heading. The interceptor heading during the attack phase that will achieve the desired track crossing angle.

AW. Automatic Weapons.

AWACS. Airborne Warning and Control System.

AWLS. All Weather Landing System.

Az. Azimuth.

bandit. Aircraft identified as an enemy.

bang bang control. A guidance control system wherein the corrective control applied to the missile is always applied to the full extent of the servo motion.

BARCAP. Barrier Combat Air Patrol.

BDA. Bomb Damage Assessment. The determination of the effect of all air attacks on targets (e.g., bomb, rockets, or strafing). (JCS Pub 1)

BDU. Bomb Dummy Unit.

beam intercept. An intercept in which the track crossing angle at missile launch is between 60° and 120°.

BF. Ballistic File.

BFL. Bomb Fall Line.

BFM. Basic Fighter Maneuver.

BIT. Built-in Test.

BLU. Bomb Live Unit.

bogey. An air contact that is unidentified but assumed to be enemy. (Not to be confused with unknown.) (JCS Pub 1)

bogey altitude.

Low - less than 5,000 feet
Medium - 5,000 to 35,000 feet
High - above 35,000 feet

bomb release point. The point in space at which bombs must be released to reach the desired point of detonation. (JCS Pub 1)

bombing errors. Errors which cause bombs to miss the desired mean point of impact. These include aiming errors, release errors, aircraft system errors, and ballistic dispersion.

BPE. Baro Plane Error.

break. A command to instantly execute, or the execution of, a maximum rate turn.

BRU. Bomb Release Unit.

B-SCAN. A radar display format presented in a rectangular, range vs. azimuth format. Most of the air radar modes are presented in a B-Scan format, however, none of the surface radar modes are displayed in a B-Scan format (see PPI (sector) & Patch).

BST. Boresight.

BSU. Bomb Stabilizing Unit.

buster. Maximum thrust.

buzzer. Electronic countermeasures jamming.

BVR. Beyond Visual Range.

BW. Beam Width. Beam width is the horizontal and vertical "thickness" of the radar beam. In general, the more precision or azimuth resolution required of a radar, the narrower the beam must be. The APG-65 has two beam selections, pencil and fan (see FAN), however, the horizontal BW of both is about 3.9°. Beam width governs the azimuth accuracy of the real radar beam in the same way that pulse width (see PW) governs a radar's range accuracy. The Expand modes (EXP1, EXP2, EXP3) improve BW azimuth resolution by utilizing DBS processing techniques (see DBS & SAR).

c. Speed of light.

CAP. Combat Air Patrol.

carrier frequency. The carrier frequency is the RF (see RF) on which the radar transmits. The carrier frequency should not be confused with PRF (Pulse Repetition Frequency) which is the number of pulses transmitted each second. The APG-65 operates in the I band (8 - 10 gigahertz). The radar is capable of transmitting on a number of frequencies or channels within this band. This serves to reduce mutual interference from nearby aircraft and allows some small scale frequency agility for ECCM.

CAS. Calibrated Airspeed.

CAS. Close Air Support. Air action against hostile targets that are in close proximity to friendly forces and that require detailed integration of each air mission with the fire and movement of those forces. (JCS Pub 1)

CATF. Commander, Amphibious Task Force.

CBIT. Continuous BIT.

CBR. California Bearing Ratio. Measure of surface hardness.

CBU. Cluster Bomb Unit.

CCD. Charge Coupled Device.

CCG. Command Control Group.

CCI. Carrier Controlled Intercept.

CCIP or CIP. Continuously Computed Impact Point.

CCM. Counter-Countermeasures.

CCRP. Continuously Computed Release Point.

CEP. Circular Error Probable. An indicator of the delivery accuracy of a weapon system used as a factor in determining probable damage to a target. It is the radius of a circle within which half of the missiles/projectiles are projected to fall. (JCS Pub 1). Also used as a measure of INS terminal positional error.

CFA. Coherent Frequency Agility.

cg. Center of Gravity.

chick. Friendly aircraft. (JCS Pub 1)

CIC. Combat Information Center. The agency in a ship or aircraft manned and equipped to collect, display, evaluate, and disseminate tactical information for the use of the embarked flag officer, commanding officer, and certain control agencies. Certain control, assistance, and coordination functions may be delegated by command to the combat information center. (JCS Pub 1)

CINT. Cold Scene Integration.

C_L. Coefficient of lift.

clutter. Unwanted returns from the ground, precipitation, or chaff. In the case of ground returns, clutter is subdivided into that produced by the mainlobe of the radar antenna (MLC), and that produced by the sidelobes, sidelobe clutter (SLC). The portion of the sidelobe clutter received from directly below the radar is called the altitude return. In the air radar modes, extensive processing is required to eliminate clutter so that airborne threats can be detected, whereas in surface ground mapping clutter is not so much a problem since that is what is basically displayed.

CM. Countermeasures.

CNI. Communication, Navigation, Identification.

CNIDC. CNI Data Converter.

coherence. A continuity or consistency in the RF phases of successive radar pulses. Coherency of pulse transmission is achieved in the APG-65 by, in effect, chopping the pulses from a continuous wave of highly stable frequency. Coherency of pulse transmission allows the radar to compare the return signals with a reference signal for frequency (doppler) shift evaluation. By sensing a return's doppler shift, a radar can not only measure range rates, but it can also separate target echoes from clutter or produce high resolution ground maps (i.e., expand modes).

collision course. A course that will maintain a constant bearing decreasing range.

COMPEX. Competition Exercise.

contact. In air intercept, a term meaning an unknown target.

corner reflector. A radar reflector consisting of two or three flat conducting plates joined together at right angles to one another so as to form a corner. A corner reflector will reflect most of the RF energy it intercepts, over a wide range of angles, back in the direction of the radar which is illuminating it. Cultural objects which form right angles can present corner reflectors to the radar. In addition, groups of objects such as buildings can form relationships which create corner reflectors.

corral. See ″footprint.″

course. Intended direction of movement in the horizontal plane. (JCS Pub 1)

CP. Control Point.

CPS. Computer Power Supply.

CPU. Central Processor Unit.

CRS. Course.

CRT. Cathode Ray Tube.

CW. Continuous Wave.

C^3. Command, Control, and Communications.

DACT. Dissimilar Air Combat Tactics.

DAFIF. Digital Aeronautical Flight Information File database.

DAS. Deep Air Support. Air action against enemy targets at such distances from friendly forces that detailed integration of each air mission with fire and movement of friendly forces is not required. (NWP-3)

DASC. Direct Air Support Center. A subordinate operational component of a tactical air control system designed for control and direction of close air support and other tactical air support operations, and normally collocated with fire-support coordination elements. (JCS Pub 1)

DAT. Display Alternate Toggle.

DBS. Doppler Beam Sharpening.

DC. Display Computer.

DDI. Digital Display Indicator.

DECM. Defensive Electronic Countermeasures.

DEFCON. Defensive Conditions.

deflection error. In bombing, the distance between the point of impact (single bomb) or between the mean point of impact (salvo) and the desired point of impact measured at right angles from the line of the aircraft approach.

deg. Degree.

delivery error. The inaccuracy associated with a given weapon system resulting in a dispersion of shots about the aiming point. (JCS Pub 1)

designating cursor. Also known as the ″in-video cursor″, this is a cross hair symbol composed of a range arc and a bearing line that allows the pilot to identify a return on the radar display for designation or track. The range arc and azimuth lines of the in-video cursor extend to the edges of the scope and are positionable with the TDC.

DF. Direction Finding.

directivity. The ability of an antenna to concentrate the RF energy in a given direction and to emphasize the returns received from that direction. Generally a function of the ratio of the wavelength to the size of the antenna's frontal area or aperture (real beam modes).

DMC. Digital Map Computer.

DME. Distance Measuring Equipment.

DMT. Dual Mode Tracker.

DMU. Digital Memory Unit.

DOP. Direction Of Pass.

doppler beam sharpening. A processing technique used by the radar to improve (″sharpen″) the real beam's angular resolution and provide high resolution ground mapping of selected areas. DBS takes advantage of the doppler effect by sensing differences in the doppler frequencies of points on the ground at slightly different angles within the real antenna beam. There is little or no difference between the doppler frequencies of objects at the same range directly ahead of the aircraft, therefore the area 6° either side of aircraft ground track is not displayed (black) and is called the ″notch″. At greater than 6° either side of ground track, the doppler shift between objects at different azimuths is enough to be detected and processed. In DBS processing, the angular resolution is the same at all ranges, hence the azimuth resolution distance increases with range. EXP1 and EXP2 maps are therefore the same as those produced by a real beam having a very narrow beam; hence the name ″beam sharpened″.

doppler filter. A narrowband filter tuned to a given doppler frequency; generally part of a bank of such filters whose passbands collectively cover a band of doppler frequencies.

doppler frequency. A shift in the radio frequency (RF) of the return from a target or other object as a result of the object's radial motion relative to the radar.

DP. Display Processor.

DR. Dead Reckoning.

DRT. Down Range Travel. The horizontal distance the weapon travels from release to impact.

DSL. Depressed Sight Line.

DSS. Data Storage Set.

DST. Destructor.

DSU. Data Storage Unit.

DTL. Designator to Target Line.

DUD. Weapon fails to detonate.

duplexer. A high speed passive switching device used to connect the antenna to the transmitter and the receiver. Sensitive to the power of the signals passing through it, the duplexer passes the high power transmitter pulses to the antenna, while blocking their path to the receiver, and passes the low power returns to the receiver, while blocking their path to the transmitter.

DVMS. Digital Video Mapping Set.

E & E. Escape and Evasion.

early sight picture. When the cursor arrives on target prior to planned release conditions.

ECCM. Electronic Counter-Countermeasures.

eclipsing. Eclipsing is the partial or complete blocking of a target's (air or surface returns) echoes when they are received while the radar is transmitting and the receiver is blanked. In the surface radar system, eclipsing is eliminated by using low PRFs for all surface radar modes and matching the radar's PRF to the selected mode and range.

ECM. Electronic Countermeasures.

ECS. Environmental Cooling System.

ECU. Environmental Control Unit.

EF. Engaged Fighter.

effective range. The maximum distance at which a weapon may be expected to inflict casualties or damage.

EHF. Extremely High Frequency.

EHSD. Electronic Horizontal Situation Display.

EHSI. Electronic Horizontal Situation Indicator.

elevate . Radio call meaning climb to specified altitude.

ELINT. Electronic Intelligence.

EM. Electromagnetic.

E-M. Energy Maneuverability.

EMCON. Emission Control.

EMERG. Emergency.

EO. Electro-Optical.

ephemeris. A table giving the coordinates of a celestial body at a number of specific times during a given period.

EPI. Engine Performance Indicator.

error sensitivity. The miss distance that can be expected when one of the preplanned delivery conditions is not achieved. The sensitivity of a given delivery parameter to produce an impact error.

ERU. Ejector Rack Unit.

ESM. Electronic warfare Support Measures.

EW. Electronic Warfare; Early Warning.

expand modes (EXP1, EXP2, & EXP3). EXP1, EXP2, and EXP3 are the high resolution ground mapping modes of the surface radar.

FAAD. Forward Area Air Defense.

FAC. Forward Air Controller. An officer (aviator/pilot) member of a tactical air control party who, from a forward ground or airborne position, controls aircraft in close air support of ground troops. (JCS Pub 1)

FAC(A). Forward Air Coordinator (Airborne). A specifically trained and qualified aviation officer to perform the dual tasks of conducting aerial reconnaissance/surveillance and of exercising control from the air of aircraft engaged in close air support of ground troops. (NWP 22-2).

FAD. Fighter Air Direction.

FAE. Fuel-Air Explosive.

famished. Radio call meaning I need information.

fan beam. A radar beam that is spread out to cover a larger area at one time. The fan beam is spread out in a vertical direction (10°) but retains its 3.9° horizontal beam width. Beam selection is normally controlled by the radar, however, the pilot can manually override beam selection via the PEN/FAN option.

FBST. FLIR Boresight.

FC. Fire Control.

FEBA. Forward Edge of Battle Area.

FEI. Firing Error Indicator.

FEU. FLIR Electronic Unit.

FF. Free Fighter.

FFAR. Folding Fin Aircraft Rocket.

firebomb. A light cased bomb filled with a thickened aviation fuel which bursts on impact and spreads burning fuel over an area.

FLIR. Forward Looking Infrared.

FLOT. Forward Line of Troops.

FM. Frequency Modulation.

FOD. Foreign Object Damage.

footprint. Term used to describe the area on the ground that is covered by radar energy. Aircraft altitude, the type of beam (PEN/FAN), scan angle, and radar operating range will affect the footprint. Footprint, or "corral" also refers to the Expand mode indicator outline which is displayed when an Expand mode is selected while undesignated. The corral outlines the area that will be processed and displayed if the appropriate expand mode is selected. A graphic depiction or outline of the radar footprint (corral) for the expand modes can be displayed on the EHSD by selecting the OLR option on the MAPM.

FOR. Field of Regard.

FORCAP. Force Combat Air Patrol.

forward quarter intercept. An intercept in which the track crossing angle at missile launch is between 120° and 150°.

FOV. Field of View.

fox. Air-to-air missile.

fox 1/2/3. In air intercept, a code meaning, "Missile has fired or been released from aircraft." (JCS Pub 1)

FPM. Feet Per Minute.

fps. Feet Per Second.

freefall. Unretarded bomb.

frequency. Frequency (f) is the number of complete oscillations an energy wave exhibits in one second.

frequency agility. Ability of a radar to switch among a number of different operating frequencies or channels. Frequency agility can be used to avoid countermeasures, interference from other radars, etc.

FRL. Fuselage Reference Line. A fixed reference line parallel to the longitudinal axis of the aircraft.

FSCC. Fire Support Coordination Center. A single centralized location in which communications facilities and personnel incident to the coordination of all forms of fire support are located. (JCS Pub 1)

FSCL. Fire Support Coordination Line.

FTT. Fixed Target Track.

fuzing range. The maximum distance from a target at which a proximity fuze can be expected to function.

g. Force of gravity or load factor.

GACQ. Gun Acquisition; radar automatic acquisition mode.

gain. Video gain is a measure of the radar's signal-to-noise sensitivity.

GB. Gyro Bias.

GBU. Guided Bomb Unit.

GCA. Ground Controlled Approach.

GCE. Ground Combat Element.

GCG. Guidance and Control Group.

GCI. Ground Controlled Intercept.

GCS. Guidance Control System.

GP. General Purpose.

GMT. Ground Moving Target. The operating mode of the radar that detects moving objects over the ground. Ground and fixed target returns are not displayed. Moving targets are displayed as synthetic target symbols (rectangles) at the proper range and azimuth. If desired, the pilot can overlay the synthetic targets on a ground map display by selecting the IMAP (Interleaved MAP) option.

GMTT. Ground Moving Target Track. The operating mode in which the radar antenna remains pointed at a GMT target and thereby tracks the target. While tracking, direction of movement and target ground speed are displayed along with the synthetic symbol. In addition, target data (position and movement) is utilized in weapon delivery computations.

GS. Groundspeed.

GTWT. Gridded Traveling Wave Tube. The device in the APG-65 transmitter employed for high powered amplification of the RF signals.

guidance time. The total time that a missile is able to guide itself.

harp angle. The angle between the horizontal and the line of sight to the impact point.

HD/LD. High Drag/Low Drag.

HE. High Explosive.

head-on intercept. An intercept in which the track crossing angle at missile launch is between 150° and 180°.

HEAT. High Explosive Anti-Tank.

HEI-T. High Explosive Incendiary with Tracer.

HERO. Hazards of Electromagnetic Radiation to Ordnance.

HE-T. High Explosive with Tracer.

HEU. Heat Exchange Unit.

HF. High Frequency.

HINT. Hot Scene Integration.

HOF. Height-of-Function.

homeplate. Radio call meaning your base of operation.

HOTAS. Hands On Throttle And Stick.

HPRF. High Pulse Repetition Frequency.

HSI. Horizontal Situation Indicator.

HT. Height.

HUD. Head-up Display.

hung bomb. Bomb fails to release from aircraft. (The opposite of live release.)

Hz. Hertz.

IADS. Integrated Air Defense System.

ID. Identification.

IF. Intermediate Frequency. In the APG-65 receiver, a frequency that lies between the RF of the signals received by the antenna and the video frequency range. The radar returns are translated to an IF to facilitate amplification and filtering.

IFA. In-Flight Alignment.

IFF. Identification Friend or Foe.

IFM. Inflight Monitor.

IFOV. Instantanious Field of View.

IFR. Instrument Flight Rules.

IMC. Instrument Meteorological Conditions.

IMN. Indicated Mach Number

IMU. Inertial Measuring Unit.

INS. Inertial Navigation System.

INTL. Interleaved.

INU. Inertial Navigation Unit.

in-video cursor. See ″designating cursor.″

IP. Initial Point. A visual reference point in the vicinity of the target.

IR. Infrared.

IRCCM. Infrared Counter-Countermeasures.

IRCM. Infrared Countermeasures.

ISU. Inertial Sensor Unit.

ITER. Improved Triple Ejector Rack.

ITP. Initial Target Placement.

IU. Interface Unit.

JEM. Jet Engine Modulation.

jinking. Continuous random change of heading and altitude along a base course.

JMEM. Joint Munitions Effectiveness Manual.

JPTL. Jet Pipe Temperature Limiter.

KCAS. Knots Calibrated Airspeed.

KIAS. Knots Indicated Airspeed.

klick. Kilometer.

KTAS. Knots True Airspeed.

LAT. Low Altitude Tactics.

late sight picture. Cursor arrives on target after passing release point.

LAU. Launcher Unit.

launcher angle. The angle between the launcher line of a rocket and the ADL.

launcher line. The longitudinal axis of a rocket when attached to the launcher.

launching factor (f). Represents the initial jump of the rocket at launch, as the rocket turns to align with the relative wind.

lb. Pound.

LBA. Limits of Basic Aircraft without external stores.

LCOS. Lead Computing Optical Sight.

LCS. Liquid Cooling System.

L/D. Lift over Drag.

LD. Low Drag.

LDGP. Low Drag General Purpose (Bomb).

lead collision course. A vector that, if maintained by an interceptor aircraft, will result in collision between the interceptor fixed armament and the target. (JCS Pub 1)

lead pursuit. An intercept vector designed to maintain a course of flight at a predetermined point ahead of a target. (JCS Pub 1)

LF. Low Frequency.

LFD. Longitudinal Fuselage Datum.

LGB. Laser Guided Bomb.

LGW. Laser Guided Weapon.

LHA. Amphibious Assault Ship (Landing Helicopter Assault).

LHD. Amphibious Assault Ship

LIDS. Lift Improvement Device System.

linear. Maximum range airspeed.

LLLTV. Low Light Level Television.

LO. Local Oscillator

LOC. Line of Communication.

LOI. Letter of Instruction.

LOP. Line Of Position.

LOS. Line of Sight. The line from the eye to the aiming point, through the optical sight.

lost contact. Radio call by pilot indicating that he desires further control information for target intercept.

low-order detonation. Explosive fails to detonate; instead, the explosive burns.

LPA. Lead Prediction Angle.

LPD. Amphibious Transport Dock.

LPH. Amphibious Assault Ship (Landing Platform Helicopter).

LPRF. Low Pulse Repetition Frequency.

L&S. The Launch and Steering Target.

LSD. Laser Spot Detector.

LST. Laser Spot Tracker.

LSS. Laser Spot Search.

LTD. Laser Target Designator.

LZ. Landing Zone.

M. Air Force/Army designation for model.

MAB. Marine Amphibious Brigade.

MACCS. Marine Air Command and Control System.

MAD. Magnetic Azimuth Detector.

MAE. Mean Area of Effectiveness.

MAF. Marine Amphibious Force.

MAG. Marine Aircraft Group.

MAGTF. Marine Air Ground Task Force.

mainlobe. The central lobe of a directional antenna's radiation pattern. Basic physics dictates that the size of this lobe is a function of wavelength and the size of the antenna's frontal area, or aperture.

mainlobe clutter. The clutter of ground return attributable to the mainlobe of the radar antenna. This return is referred to as clutter only when discussing A/A radar applications. In surface radar applications, such as ground mapping, mainlobe clutter return is the desired received signal. MAP (Real Beam Ground Map) - The basic terrain mapping mode of the APG-65. The radar's real beam is used to map a large sector of the terrain ahead of the aircraft. Major features of the MAP mode include the ability to display prominent cultural targets (i.e., cities, complexes, bridges, etc.), land/water contrast, and mountains. The MAP mode is normally used for general navigation ("big picture") and finding the approximate location of targets. It is also used for weather detection and as a terrain avoidance reference (radar shadowing). In addition, it can be used when the Expand modes are unavailable. However, resolution of the MAP is fairly poor when compared to the expand modes.

Maltese Cross. Indication on display that RF power transmission of radar is inhibited.

MAP. Minimum Attack Perimeter.

MAPM. Map Menu.

MATCS. Marine Air Traffic Control Squadron.

MAU. Marine Amphibious Unit.

maximum range. The greatest distance a weapon can fire without consideration of dispersion. (JCS Pub 1)

MC. Mission Computer.

MDI. Miss Distance Indicator.

MEB. Marine Expeditionary Brigade.

MEM. Memory.

MEF. Marine Expeditionary Force.

MER. Multiple Ejector Rack.

METT. Mission, Enemy, Tactics, and Terrain.

MEU (SOC). Marine Expeditionary Unit (Special Operations Capable).

MEZ. Missile Engagement Zone.

MF. Medium Frequency.

MHz. MegaHertz.

MiGCAP. MiG Combat Air Patrol.

mil. Milliradian. A unit of angular measurement which subtends 1 foot at 1,000 feet.

mission profile. A pictorial presentation of the flightpath of the attack airplane as seen in the vertical plane.

mj. Millijoules. Measurement of energy output for laser designators.

MLC. Main Lobe Clutter.

MLM. Marine Location Marker.

MK. Mark. Navy designation for model.

MMH/FH. Maintenance Man-Hours Per Flight Hour.

MOD. Navy designation for modification.

monopulse lobing. A method of automatic tracking whereby the received signals are split into overlapping lobes during reception. The lobes produced by the array always point in the same direction because they are created by dividing the antenna into quadrants. If the antenna is not pointed directly at the target, an angular error exists in that the amplitude and phases of the returns will differ because of the difference in mean distance from the target to each half of the antenna. By continuously sensing the tracking errors (amplitude and phase comparison) and continually correcting the pointing direction of the antenna to reduce the errors to zero, the antenna can be made to track a target with much greater precision than beamwidth alone could provide.

MPCD. Multi-Purpose Color Display.

MPRF. Medium Pulse Repetition Frequency.

MRI. Minimum Release Interval.

MRS. Medium Range SAM.

MRSAR. Medium Resolution Synthetic Aperture Radar.

msec. Millisecond. (0.001 second equals one msec.) Also ms.

MSL. Mean Sea Level.

MTI. Moving Target Indicator.

MUA. Make-Up Angle.

3M. Maintenance Material Management.

NATOPS. Naval Air Training and Operating Procedures Standardization.

NAV. Navigation.

NAVFLIR. Navigational Forward Looking Infrared

NIRD. Normalized In-Range Display.

nm. Nautical Miles.

NOHD. Nominal Ocular Hazard Distance.

NPA. Nonpropulsion Attachment.

NRAS. Nozzle rotation airspeed.

NTK. Number of Targets Killed.

NVD. Night Vision Device.

NVG. Night Vision Goggles.

OAS. Offensive Air Support.

OAT. Outside Air Temperature.

OCE. Officer Conducting the Exercise.

ODU. Option Display Unit.

offset point. In air interception, a point in space relative to a target flightpath toward which an interceptor is vectored and from which the final or a preliminary turn to attack heading is made. (JCS Pub 1)

OFP. Operational Flight Program.

ORE. Operational Readiness Evaluation.

ORT. Operational Readiness Test.

OTC. Officer in Tactical Command.

overshoot. A turn in which the radius of turn is larger than desired, resulting in lateral separation from the desired position.

patch map. A patch map is a detailed map of a specific area of interest at a given range and azimuth angle. The patch map display format is presented in a range vs. cross-range format. The Expand modes are presented in a patch format. Indeed, although all expand modes are patch maps, Expand 2 is often referred to as the ″patch″ map.

PCC. Pilot's Confidence Check.

PCO. Power Changeover.

P_{EB}. Early Burst Probability.

PEC. Position Error Correction.

pencil beam. Also referred to as the main beam, it is a comparatively narrow, more or less conically shaped antenna beam which is the basic radar operating beam. Generally speaking, beam size is a function of operating frequency and the size of the antenna. The Harrier II Plus pencil beam is a cone shaped beam about 3.9° in diameter.

P_H. Hit Probability.

PID. Positive Identification.

P_k. Kill Probability. The probability of damaging a target to the desired extent.

planar array antenna. A flat (planar) surface antenna which is comprised of a number of individual radiators (array). The APG-65 radar utilizes a planar array antenna.

point target. A target of such small dimension that it requires the accurate placement of ordnance in order to neutralize or destroy it. (JCS Pub 1)

POL. Petroleum, Oil, Lubrication.

pop up. A rapid climb from a lower altitude to an entry position.

PP. Penetration Procedures.

PPI. Plan Position Indicator. PPI (sector) is the familiar range vs. azimuth, pie shaped format of the basic radar (MAP) display. The Map, GMT, SEA, and TA modes all use a PPI (sector) format.

pps. Pulse Per Second.

PRF. Pulse Repitition Frequency. PRF is simply the number of radar pulses transmitted each second.

PRI. Pulse Repetition Interval. PRI is the time between each transmitted pulse.

PRL. Pressure Ratio Limiter.

P_s. Specific Excess Power.

PSU. Power Servo Unit.

pullup point. The point at which an aircraft must start to climb from a low level approach in order to gain sufficient height from which to execute the attack or retirement. (JCS Pub 1)

pulse - delay ranging. Determining the range to a target by measuring the time delay between transmission of a pulse and reception of its echo. All Air-to-Surface radar applications utilize pulse-delay ranging.

pulsed radar. The name pulsed radar describes the process of transmitting discrete bursts of RF energy. The bursts are transmitted at the PRF of the radar system by rapidly turning on and off an RF generator (i.e., GTWT). A pulsed radar whose transmission is noncoherent measures range by pulse delay techniques. Range is determined by the time it takes for a pulse to go to a target and return, while elevation and azimuth is determined by where the target is in relation to the antenna each time the radar beam strikes. A pulsed radar is capable of very accurate data, however, it is sensitive to background clutter.

pulse doppler radar. A pulsed radar whose transmission can be coherent and thereby measure doppler frequencies. This allows the radar to discriminate against background clutter, measure range rates directly (target opening and closing velocities), and/or perform high resolution ground mapping on the basis of the doppler frequencies of the radar returns. Depending on the situation, a pulsed doppler radar can utilize doppler frequency or simple pulse delay techniques (non-doppler) to optimize the radar for the operational requirement.

pursuit course. The aircraft is being flown on a pursuit course if its weapons are always pointed directly at the target.

PVI. Pilot Vehicle Interface.

PVU. Precision Velocity Update. The mode in which the radar works as a doppler only radar to precisely measure the aircraft's ground speed (+ 2 knots or better). The PVU mode provides an In-Flight Alignment (IFA) capability and a velocity update (VEL) feature. If the velocity update (VEL) correction is accepted by the pilot, it is used by the MC for weapon delivery computations for a short period of time (10 minutes with the correction being phased out over the last 5 minutes).

PW. Pulse Width. PW is the length of time that the radar is on for each pulse transmitted, normally expressed in microseconds.

q. Aerodynamic pressure.

R_a. Missile Aerodynamic Range.

radar signature. Identifying features of or patterns in the returns a radar receives from targets of a given type.

RADHAZ. Radiation Hazard.

range bin. A memory location in which the returns received at a given point in the interpulse period are stored. Depending on whether range is unambiguous, the returns stored in a given range bin may have been received from a given range, or a given set of ambiguous ranges. All returns in the Air-to-Surface radar modes are unambiguous.

range gate. In radars employing digital signal processing, sampling the returns received at a given point or successive points in every interpulse period is correspondingly referred to as range gating.

range specifics. Range specifics are fuel consumption quantities for cruise segments. They are presented in pounds of fuel per mile.

RDVU. Rendezvous.

rear-quarter intercept. An intercept in which the track crossing angle at missile launch is between 30° and 60°.

reflectivity. Radar reflectivity is a basic concept which determines if and when an object will be seen on the radar display.

release altitude. Altitude of an aircraft above the ground at the time of release of bombs, rockets, missiles, tow targets, etc.

release height. Release altitude AGL (used interchangeably).

RESCAP. Rescue Combat Air Patrol.

resolution cell. A resolution cell can be defined as the smallest in-plane volume of airspace in which a radar cannot determine whether one or more targets are present.

resolution distance. The minimum distance by which two objects may be separated and still be individually resolvable by a given radar. It is commonly expressed as azimuth resolution distance (the minimum angular resolution times the range) and range resolution distance.

RF - radio frequency. RF refers to that portion of the EM spectrum classified as radio waves. For most radar purposes, the shortest radio waves begin at 1 millimeter (EHF) and continue out to the VLF (Very Low Frequency).

R_{max}. Maximum Firing Range.

R_{min}. Minimum Firing Range.

RO. Reference Oscillator.

ROC. Rules Of Conduct.

ROE. Rules Of Engagement.

RP. Rendezvous Point; Receiver Processor.

RRC. Radar Resolution Cell.

RSS. Roll Stabilized Sight.

RTDP. Radar Target Data Processor.

RWR. Radar Warning Receiver.

RWS. Range While Search.

SA. Selective Availability. Semi-active. Situation Awareness.

SA. Semi-Active, Situation Awareness.

S-A. Safe and Arming device.

SAAHS. Stability Augmentation and Attitude Hold System.

salvo. (1) In naval gunfire support, a method of fire in which a number of weapons are fired at the same target simultaneously. (2) In close air support/air interdiction operations, a method of delivery in which the release mechanisms are operated to release or fire all ordnance of a specific type simultaneously. (JCS Pub 1)

SAM. Surface-to-Air Missile.

SAP. Semi-Armor Piercing.

SAR. Synthetic Aperture Radar. SAR is a high resolution ground mapping technique where advantage is taken of the forward motion of the radar (aircraft movement). SAR synthesizes the equivalent of a very long sidelooking array antenna from the radar returns received over a period of several seconds or more. The large size of this synthetic antenna results in greatly increased azimuth resolution.

SAR. Search and Rescue.

SAR. Synthetic Aperature Radar.

SAS. Stability Augmentation System.

SATS. Short Airfield for Tactical Support.

scan angle. The azimuth coverage of the radar antenna sweep measured in degrees.

scan rate. The rate at which the radar antenna sweeps back and forth measured in degrees per second.

scintillation. The rapid fluctuation in the amplitude of the return received from a target (or point on the ground in Air-to-Surface radar). Scintillation is due to changes in the relative distances of the various scattering elements making up the target. These changes may be the result of changes in the range, angle, or aspect of the target, even vibration. (Slower fluctuations of the return are called “fading”. Changes in the apparent center of reflection from the target are called ″glint.″)

SEA. Sea Surface Search. A special operating mode that is optimized to detect and display discrete targets (ships or small islands) on large bodies of water. The targets are displayed as synthetic symbols which may be overlayed on the MAP mode video by selecting the IMAP (Interleaved MAP) option.

sector. Sector is a PPI display format which gives an undistorted picture of the region being scanned in azimuth. PPI sector is the familiar pie-shaped range vs. azimuth format used in the MAP, SEA, GMT, and TA modes. In addition, the Expand 1 mode is often referred to as the ″sector″ mode, although it actually uses a patch map format.

SDC. Signal Data Converter.

SEAD. Suppression of Enemy Air Defenses.

SEAM. Sidewinder Expanded Acquisition Mode.

SEU. System Electronics Unit.

SFC. Specific Fuel Consumption.

shackle. Radio call for a 45° turn to close up section.

shadow. A term used with ground mapping radars to describe an area that is blanked out from radar energy. Shadows may be caused by terrain or weather.

shaped charge. A charge shaped so as to concentrate its explosive force in a particular direction. (JCS Pub 1)

SHF. Super High Frequency.

SHORADIZ. Short Range Air Defense Identification Zone.

SIF. Selective Identification Feature.

sight angle. The angle between the zero mil sight line and the line of sight.

spoke or spoking. Spoking describes a phenomena on a PPI display which consist of bright lines emanating from the apex of the display, and may be accompanied by a degraded or incomplete radar picture. This is a malfunction in the radar and may not be correctable in flight. (The pilot may be able to eliminate spoking by changing channels and or channel control mode (MAN/AUTO).

SMC. Stores Management Computer.

SMCS. Stores Management Control Set.

SOP. Standard Operating Procedure.

SR. Slant Range. The line-of-sight distance between two points not at the same level relative to a specified datum. (JCS Pub 1)

SRS. Short Range SAM.

SRT. Standard Rate Turn (3° per second).

SSC. Stores Station Controller.

SSP_d. Single Weapon Probability of Kill.

stabilized cue. Also referred to as simply the ″stab cue″, this is a small cross hair symbol that marks the position of any navigation stabilized designated target (i.e., WYPT, HUD, radar, etc.) on the radar display.

STC. Sensitivity Time Control. Programmed variation in the sensitivity of the radar’s receiving system, designed to keep it and the following stages from being saturated by return from close-in targets and sources of ground clutter. Following the transmission of each pulse, the receiver gain is increased at the same rate as the amplitude of the return received from increasingly distant targets would decrease. In this manner, STC is used to attain a nearly uniform target and clutter power level for all ranges by setting receiver gain as a function of range.

STD. Standard.

stick. A number of bombs released from an aircraft so as to impact in train. A multiple release.

STO. Short Takeoff.

STOL. Short Takeoff and Landing.

STT. Single Target Track.

synthetic video/target. Refers to the type of video presented on the display. The synthetic video or target is computer generated symbology in which all targets are displayed at maximum intensity. By contrast, real beam video is a direct representation of the intensities of the various radar returns. In the Air-to-Surface radar modes, the SEA, GMT and TA modes utilize synthetic video. However, real video (MAP) can be overlaid over the SEA and GMT video when IMAP (Interleaved MAP) is selected.

TAC. Tactical Air Commander. The officer (aviator) responsible to the landing force commander for control and coordination of air operations within the landing force commander's area of responsibility when control of these operations is passed ashore (JCS Pub 1)

TAC(A). Tactical Air Coordinator (Airborne). An officer who coordinates, from an aircraft, the action of combat aircraft engaged in close support operations of ground or sea forces. (JCS Pub 1)

TACAN. Tactical Air Navigation.

TACC. Tactical Air Control Center. The principal air operations installation (land or ship-based) from which all aircraft and air warning functions of tactical air operations are controlled. (JCS Pub 1)

TACTS. Tactical Aircrew Combat Training System.

TAD. Tactical Air Direction Network.

TAOC. Tactical Air Operations Center.

TAR. Tactical Air Request.

TARCAP. Target Combat Air Patrol.

target elevation. The elevation of the target base above mean sea level.

TAS. True Airspeed.

TCA. Track Crossing Angle. Also, Tactical Control Area.

TCP. Tactical Control Point.

TD. Target Designator. Also, Trajectory Drop.

TDC. Target Designator Control.

TDD. Target Detecting Device.

TER. Triple Ejection Rack.

TFOV. Total Field of View.

TIS. Thermal Imaging System.

TOF. Time of Fall.

TOGW. Takeoff Gross Weight.

TOO. Target of Opportunity.

TOT. Time On/Over Target.

TP. Thermal Protective coating. Also, Target Practice.

TPOD. Targeting Pod.

track crossing angle. In air intercept, the angular difference between interceptor track and target track at the time of intercept. (JCS Pub 1)

trajectory drop. The effect of gravity and drag on the weapon after release. Trajectory drop is the angle in mils between the line of sight to the impact point and the aircraft flightpath for bombs; for rockets the launcher line is used.

TRAM. Target Recognition Attack Multisensor.

TRP. Tactical Rendezvous Point.

TTT. Time to Target.

TV. Television.

TVC. Thrust Vector Control.

TWS. Track While Scan.

Tx. Transmitter.

UFC. Up Front Control.

UFCS. Up Front Control Set.

UHF. Ultra High Frequency.

unambiguous range. Another name for the maximum unambiguous range; the range for which the round-trip transit time equals the interpulse period, hence the maximum range from which any target echoes may be received without the ranges of all of the targets detected by the radar being ambiguous.

UTM. Universal Transverse Mercator.

VACQ. Vertical Acquisition; Radar Automatic Acquisition Mode.

VC. Video Camera.

V_c. Closing Velocity.

VCR. Video Cassette Recorder.

vector. In air intercept, close air support, and air interdiction usage, a code meaning, "Alter heading to magnetic heading indicated." Heading ordered must be in three digits; e.g., "vector" zero six zero (for homing, use "steer".) (JCS Pub 1)

V_f. Velocity of Interceptor.

VEL. Velocity.

VFR. Visual Flight Rules.

VHF. Very High Frequency.

VID. Visual Identification.

VISCAP. Visual Combat Air Patrol.

V_m. Velocity of the Missile.

VLF. Very Low Frequency.

VMC. Visual Meteorological Conditions.

VRS. Video Recording System.

VS. Velocity Search.

V/STOL. Vertical/Short Takeoff and Landing.

V_t. Velocity of the Target.

VT. Variable Time fuze. A proximity fuze.

VTO. Vertical Takeoff.

VTOL. Vertical Takeoff and Landing.

VTR. Video Tape Recorder.

WACQ. Wide Acquisition, Radar Automatic Acquisition Mode.

waveguide. Flattened, hollow metal tubes which are used to channel RF pulses from the transmitter to the antenna and guide return echoes to the receiver.

wavelength. Wavelength is simply the distance between two identical points on adjacent EM energy waves.

WCS. Weapon Control System.

W/L. Wing Loading.

WOF. Waypoint Over Fly.

WP. White Phosphorous.

WPNS. Weapons.

WRA. Weapon Replaceable Assembly.

WTL. Weapon to Target Line.

WX. Weather.

WYPT. Waypoint.

ZUNI. 5.0-Inch rocket.

PREFACE

SCOPE

The AV-8B Tactical Manual, prepared under the direction of Commander Operational Test and Evaluation Force with AIRTEVRON FIVE designated as Model Manager and approved by the Chief of Naval Operations, contains the latest information regarding the tactical employment of the AV-8B aircraft. Information contained in this manual has been derived from many sources to provide one main source for procedures, techniques, and suggested data to enable the pilot to most effectively employ the aircraft and its weapons system most effectively in combat. The NATOPS Flight Manual standardizes ground and flight training procedures and contains the information to thoroughly acquaint the pilot with the aircraft. Information in this manual is primarily oriented to tactical employment of the aircraft which presupposes a thorough knowledge of the NATOPS Flight Manual. A description of the Aircraft Tactical Manual program is contained in NWP Ø.

For expanded threat data, also refer to NWP 12-7-2, Recognition Guide to Aircraft (U); and MCM 3-1, Vol II, Threat Reference Guide and Countertactic (U).

HOW TO OBTAIN COPIES

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POCKET GUIDE

The AV-8B Tactical Manual Pocket Guide, NWP 3-22.5-AV8B PG is not distributed automatically with this manual and, therefore, must be ordered as a separate publication using the previously described procedures for Tactical Manuals. The Pocket Guide is printed on cardboard stock and is designed to be fastened to the Pilot's knee pad. The Pocket Guide contains the essential data required to provide in-flight flexibility.

CHANGE RECOMMENDATIONS

Recommended changes to this manual may be submitted by anyone in accordance with NWP Ø. Submit Routine change recommendations to the Model Manager on OPNAV Form 3710/6 (See the following sample form). Address Routine changes to:

Commanding Officer
AIRTEVRON 9
Naval Weapons Station
I Administration Circle
China Lake, California 93555-6001
Attn: AV-8B TACMAN Model Manager
AV 437-4857/5764

Submit recommendations of an Urgent nature directly to your Type Commander by Priority message (see the following sample message form).

INTERIM CHANGE SUMMARY

The Interim Change Summary is provided for the purpose of maintaining a complete record of all Interim Changes issued to the manual. Each time the manual is changed or revised, the Interim Change Summary will be formally updated to indicate disposition and/or incorporation of previously issued Interim Changes. When a regular change or revision is received, the Interim Change Summary should be checked to ascertain that all outstanding Interim Changes have been formally incorporated or cancelled. Those changes that were not incorporated should be noted as applicable. The Tactical Publications Status Report published monthly by the Navy Technical Support Activity contains a summary of latest changes to all tactical manuals.

WARNINGS, CAUTIONS AND NOTES

The following definitions apply to "WARNINGs", "CAUTIONs", and "NOTEs", found throughout the manual.

WARNING

An operating procedure, practice, or condition, etc., which may result in injury or death if not carefully observed or followed.

CAUTION

An operating procedure, practice, or condition, etc., which may result in damage to equipment if not carefully observed or followed.

NOTE

An operating procedure, practice, or condition, etc., which is essential to emphasize.

WORDING

The concept of word usage and intended meaning which has been adhered to in preparing this Manual is as follows:

"Shall" has been used only when application of a procedure is mandatory.

"Should" has been used only when application of a procedure is recommended.

"May" and "need not" have been used only when application of a procedure is optional.

"Will" has been used only to indicate futurity, never to indicate any degree of requirement for application of a procedure.

CHANGE SYMBOLS

Revised text is indicated by a black vertical line in either margin of the page, like the one printed next to this paragraph. The change symbol shows where there has been a change. The change may be material added or information restated. A change symbol in the margin by the chapter number and title indicates a new or completely revised chapter.

AIRCRAFT

Any reference to AV-8 aircraft in this publication implies the AV-8B aircraft.

DDI vs MPCD

The term DDI is used throughout this manual when reference is made to either the digital display indicator (DDI) or either of the multipurpose color display (MPCD) indicators. This is because of their commonality in function and operation.

INTRODUCTION

This Tactical Manual is broken into a three volume set. The information contained in this manual is designed to allow the AV-8B pilot to employ his aircraft to it's fullest capabilities. The current Tacman was not updated for 6 years, this update consists of a near complete rewrite and the entire structure of the manual was changed to flow more smoothly and present only pertinent information in a logical manner. It is imperative that all users of this manual constantly work to keep it up to date by keeping the model manager informed of mistakes and recommended changes. Any user of this manual can submit change request directly to the model manager (VX-9) via any form of communications available (i.e., ccmail, US mail, message, fax or telephone). These change requests will be compiled and presented at the next Tacman review conference where their incorporation will be considered and action taken as deemed appropriate.

The Day Attack aircraft is used as the baseline throughout these manuals and only where the Night Attack or Radar Attack aircraft differs are they discussed separately.

The following provides as outline of the Tacman and how the volumes are structured:

Volume I - Weapon systems

Chapter 1 - Weapon Systems (Fundamentals, Theory and Equipment).

Chapter 2 - Air-to-Surface Weapons Delivery and Employment.

Chapter 3 - Air-to-Air Weapons Delivery and Employment.

Chapter 4 - Aircraft Performance.

Volume II - Air-to-Ground Weapons.(All weapons data and a chapter on tactical planning).

Chapter 1 - Weaponeering

Chapter 2 - Weapons Description and Delivery Data

Chapter 3 - Fuzing

Chapter 4 - Carriage Equipment

Chapter 5 - External Stores Limitations

Volume III. Secret supplement (encompasses all tactical discussions regarding the various weapons and systems).

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NATOPS/TACTICAL CHANGE RECOMMENDATION
OPNAV/FORM 3710/6(4-90) S/N 0107-LF-009-7900 DATE

TO BE FILLED IN BY ORIGINATOR AND FORWARDED TO MODEL MANAGER

FROM (originator)		Unit			
TO (Model Manager)		Unit			
Complete Name of Manual/Checklist	Revision Date	Change Date	Section/Chapter	Page	Paragraph

Recommendation (be specific)

CHECK IF CONTINUED ON BACK

Justification

Signature	Rank	Title

Address of Unit of Command

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FROM	Date
TO	

REFERENCE
(a) Your change Recommendation Dated ______________

Your change recommendation dated ______________ is acknowledged. It will be held for action of the review conference planned for ______________ to be held at ______________

Your change recommendation is reclassified URGENT and forwarded for approval to ______________ by my DTG ______________

/s/ ______________ MODEL MANAGER | ______________ AIRCRAFT

URGENT CHANGE RECOMMENDATION MESSAGE FORMAT FOR NWP 3-SERIES TACTICAL MANUALS

Precedence: Action: PRIORITY
Info: ROUTINE
Message handling instructions: ADMIN

FROM	Your Unit//***//	
TO	Your Type Commander//***//	
INFO	CNO WASHINGTON DC//N88O//	
	COMNAVAIRSYSCOM WASHINGTON DC//511/53O/54O//	
	COMOPTEVFOR NORFOLK VA//5O//	
	TACMAN Model Manager Unit//***//	(For NWP involved)
	Your Chain of Command//***//	(As appropriate)
	NAVTACSUPPACT WASHINGTON DC//6O//	
	COMNAVAIRWARCEN PATUXENT RIVER MD//SA8O/SA84//	
	COMNAVSAFECEN NORFOLK VA//11//	
	CG MCCDC QUANTICO VA//C423/C461A//	(When USMC activities involved)
	NAVAIRWARCENACDIV WARMINSTER PA//6O51//	
	MWATS ONE YUMA AZ/JJJ//	(When USMC activities involved)
	Other activities as appropriate//***//	(See Appendix A of NWP Ø)

UNCLAS//NO3511//
MSGID/GENADMIN/ (Originator's Unit)//
% SUBJ/URGENT CHANGE RECOMMENDATION TO NWP 3-___-___. , (Aircraft/Title) TACTICAL MANUAL(S) (*)//
REF/A/DOC/OPNAV/ (Date of latest change or revision)//
AMPN/REF A IS NWP Ø (REV ___) DTD ______ CHGD ______ //
REF/B/DOC/NAVAIR/ (Date of latest change or revision)// (AIR TACMAN publication)
AMPN/REF B IS NAVAIR (Pub identification) DTD____ CHGD____ // (AIR TACMAN pub identification- Include NAVAIR number, NWP number, volume and revision, as applicable (eg., NAVAIR A1-AV8BB-TAC-OOO, NWP 3-22.5-AV8B Vol I
REF/C/............// (Additional references as necessary)
AMPN/............//
NARR/............//
POC/............//

RMKS/1. (*) IAW REF A, RECOMMEND CHANGE(S) TO REF B AS FOLLOWS:

A. (*) Identify PART/SECTION/CHAPTER, PAGE, FIGURE/PARAGRAPH/SENTENCE beginning, LINE NUMBER, etc.
(1) (*) DELETE: (Always indicate material to be deleted. If no deletion is necessary, indicate by NA).
(2) (*) ADD: (Indicate new or changed material. If no new material is necessary, indicate by NA).

B. (*) (Continue with change recommendations).

2. (*) (Enter remarks or comments necessary to substantiate the change recommendations.)//

DECL/ (Downgrading or declassification instructions)//

*** Show message routing code(s) or ``JJJ'' when appropriate.

% Add phrase ``/SAFETY OF FLIGHT'' to subject line when appropriate.

* For classified messages, include classification marking of subject line and each paragraph and subparagraph.

Include additional references, with amplification sets or narrative set, as necessary to provide a complete background on the change recommendation.

PART I

CONVENTIONAL AIR-TO-GROUND WARFARE

CHAPTER 1

Weapons Systems

1.1 INTRODUCTION

The AV-8B aircraft is designed to provide responsive close air support by combining the speed and firepower of a jet attack aircraft with a unique basing flexibility. The aircraft incorporates an integrated weapons system which utilizes inputs from various sensors and subsystems to provide enhanced target acquisition and accurate weapon delivery. This gives the pilot an improved first pass kill capability, which increases combat effectiveness, reduces vulnerability, and enhances survivability.

The Night Attack aircraft provides this capability during more hours of the day and allows the use of a passive mode under the cover of darkness. This is due to the addition of the digital moving map, a navigational forward looking infrared system (NAVFLIR) and third generation night vision goggles (NVG).

Radar aircraft, with the addition of the APG-65 radar, provides an improved mission effectiveness over the night attack aircraft through improved navigation, air-to-surface and air-to-air weapon system capabilities.

1.2 THE ELECTROMAGNETIC SPECTRUM

1.2.1 Electromagnetic (EM) Energy and the EM Spectrum. Electromagnetism is the force that arises between particles with an electric charge. It is one of the fundamental forces that governs the behavior of all matter in the universe. This force defines the mutually regenerating oscillating electric and magnetic fields generated by an oscillating electric charge.

Electric and magnetic fields are inextricably interrelated. For an electric current to flow, an electric field must exist, and whenever an electric current flows, a magnetic field is produced. See Figure 1-1.

This dynamic relationship between electric and magnetic fields was defined in the 19th century by Maxwell's theory which states that a time-varying electric field will generate a magnetic field. Conversely, a time-varying magnetic field will generate an electric field. Thus, a changing electric field produces a changing magnetic field which produces a changing electric field and so on.

An energy transfer is taking place in which energy is transferred from an electric field to a magnetic field to an electric field and so on indefinitely. This energy transfer process also propagates through space as it occurs. Propagation occurs because the changing electric field creates a magnetic field which is not confined to precisely the same location in space, but extends beyond the limit of the electric field. Then the electric energy created by this magnetic field extends somewhat farther into space than the magnetic field. The result is a traveling wave of energy which exists partly in the form of an electric field and partly in the form of a magnetic field, hence the waves are called EM energy.

Because of the relationship between electric and magnetic fields, EM energy is generated by the oscillating electrical charges (frequencies) inherent in all molecules. The frequency of oscillation of these fields is identical to the frequency of the force which generates them. All objects with a temperature above absolute zero (−273 °C) have molecular motion, consequently they radiate EM energy, much of which is in the form of thermal energy. See Figure 1-2.

Many different types of natural EM energy are present in everyday life, such as light, heat and invariably a tiny fraction is in the form of radio waves. The range of EM energy extends from that produced by electrical oscillations to cosmic rays and is collectively known as the EM spectrum. See Figure 1-3.

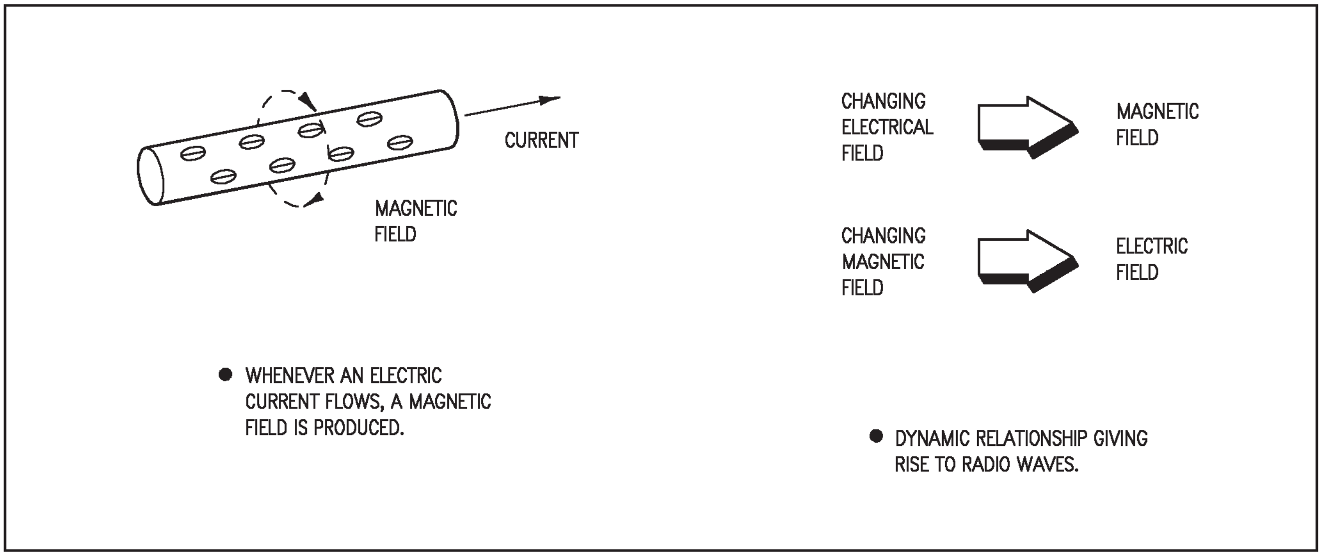

Figure 1-1. Electromagnetic Energy

In contrast to natural radiation, which cannot be turned on and off like a light bulb or radio, the EM waves radiated by a radar are produced by exciting a tuned circuit with a strong electric current (i.e., gridded traveling wave tube (GTWT) in the APG-65). The waves, therefore, all have substantially the same wavelength and contain vastly more energy than that fraction of the natural radiation having the same wavelength.

1.2.2 Basic Characteristics of EM Energy. EM energy manifests itself in two ways; as particles of energy called quanta or as waves transmitted through a medium (i.e., air). There is thus a duality between waves and particles in defining energy. The particle theory is illustrated by Plank's theorem (circa 1901) which states that EM radiation is not emitted continuously but in discrete packets or quanta whose energy is a

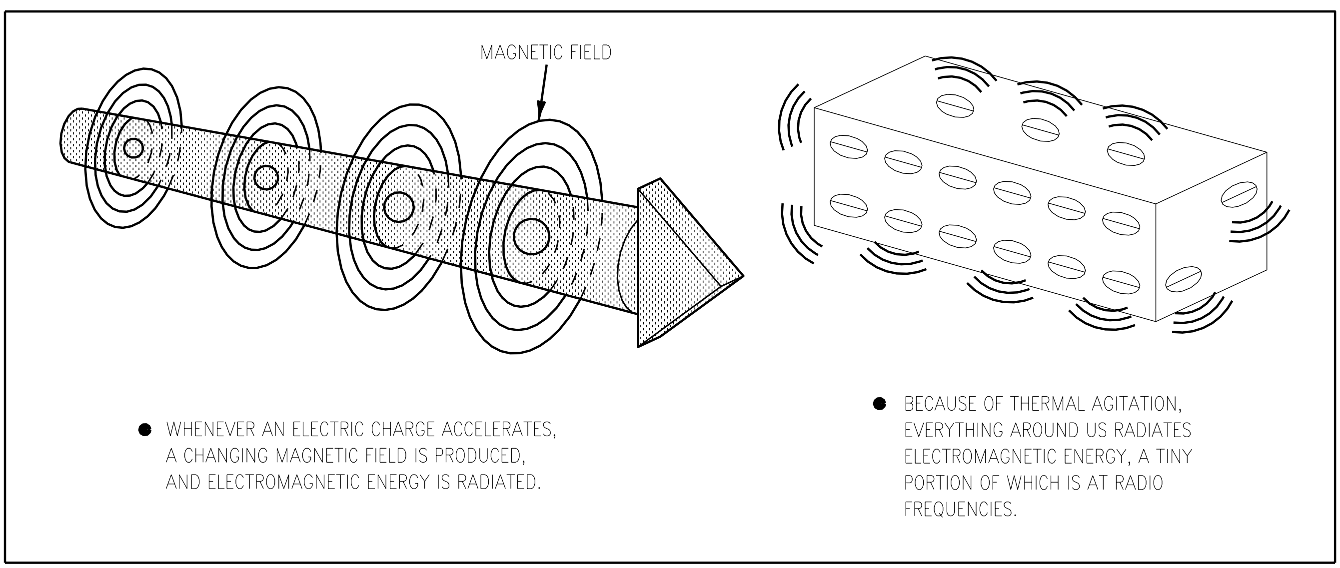

Figure 1-2. Electromagnetic Radiation

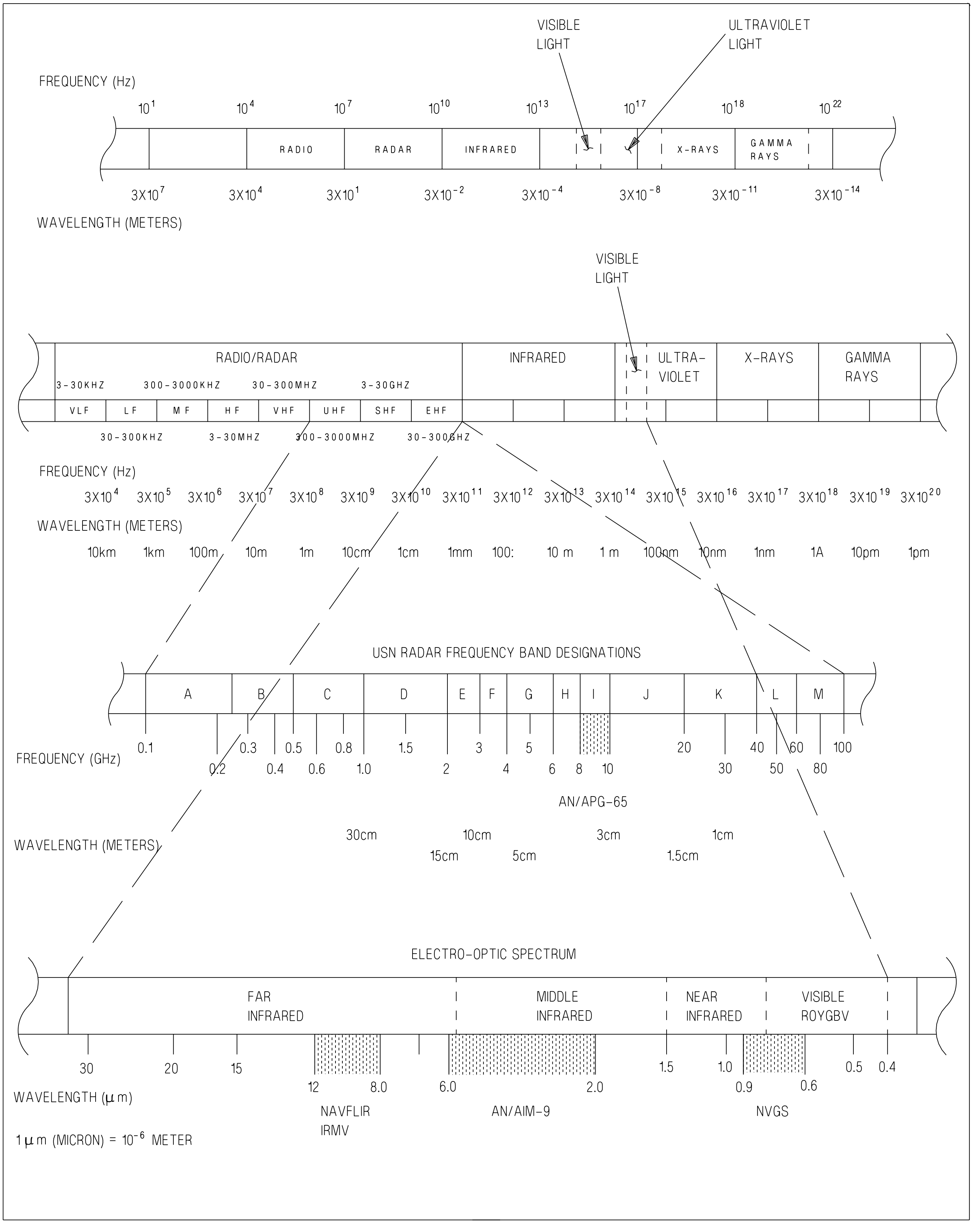

Figure 1-3. Electromagnetic Spectrum

function of the radiation's frequency. This theorem is given by the following equation:

$$E = hf$$

where:

E = energy
h = Planck's constant
f = Frequency

For some purposes it is helpful to think of the energy used by the sensors (i.e., NVGs, radar, NAVFLIR, etc.) as discrete particles (quanta) of energy called photons, while for other purposes it is better to think of their energy as waves. For the radar, energy is invariably thought of as waves.

A radio wave has several fundamental characteristics: speed, direction, polarization, amplitude, wavelength, frequency, and phase.

1.2.2.1 Speed. In a vacuum, EM (i.e., radar) waves travel at a constant speed; the speed of light, represented by the letter, c. In the atmosphere, waves travel slightly slower and the speed varies because of atmospheric composition, pressure and temperature. This can create anomalous propagation of radio waves (i.e., radar) under certain atmospheric conditions. This will be addressed in greater detail later in this chapter under the heading of atmospheric refraction.

For most practical purposes, radio waves can be assumed to travel at a constant speed, the same as that in a vacuum. This speed is equal to 3.0×10^8 meters per second (984 feet per microsecond).

1.2.2.2 Direction. This is the direction in which an EM wave travels; the direction of propagation. It is always perpendicular to the directions of both the electric and the magnetic fields. These directions, naturally, are always such that the direction of propagation is away from the radiator. In simple terms, EM energy travels in straight lines outward from the radiating source. See Figure 1-4.

When a wave strikes a reflecting object, the direction of one or the other of the fields is reversed, thereby reversing the direction of propagation. Which field reverses depends on the electrical characteristics of the object. One of the fundamental concepts that defines radar reflectivity is that the angle of incidence of the radar energy to a surface equals the angle of reflectivity. In other words, radar energy is reflected from a target at the same angle which it strikes it.

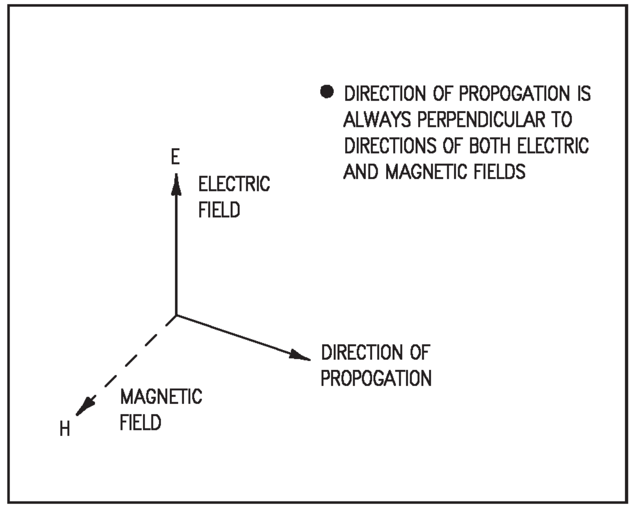

Figure 1-4. Wave Propagation

1.2.2.3 Polarization. Polarization is the term used to express the orientation of an EM energy wave's fields. By convention, it is taken as the direction of the electric field; the direction of the force exerted on an electrically charged particle. In free space, outside the immediate vicinity of the radiator, the magnetic field is perpendicular to the electrical field; and, as explained earlier, both are perpendicular to the direction of propagation. When the electric field is vertical, the wave is said to be vertically polarized. When the electric field is horizontal, the wave is said to be horizontally polarized.

If the radiating element emitting the wave is a length of thin conductor, the electric field in the direction of maximum radiation will be parallel to the conductor. If the conductor is vertical, therefore, the element is said to be vertically polarized; if horizontal, the element is said to be horizontally polarized.

A receiving antenna placed in the path of a wave can extract the maximum amount of energy from it if the polarization (orientation) of the antenna and the polarization of the wave are the same. If the polarizations are not the same, the extracted energy is reduced in proportion to the cosine of the angle between them. When a wave is reflected, the polarization of the reflected wave depends not only upon the polarization of the incident wave but upon the structure of the reflecting object. The polarization of radar echoes can, in fact, be used as an aid in discriminating classes of targets.

1.2.2.4 Frequency. The frequency of an EM energy wave is expressed in cycles per second or Hertz (Hz) and is a measure of the number of complete oscillations which the energy wave exhibits in one second.

A measure of frequency is period. Period is the length of time a wave or signal takes to complete one cycle. If the frequency is known, the period can be obtained by dividing 1 second by the number of cycles per second.

For example, if the frequency is 1 megahertz; i.e., the wave or signal completes one million cycles every second, it will complete one cycle in one-millionth of a second. Its period is one-millionth of a second, that is 1 microsecond.

1.2.2.5 Wavelength. EM wave motion is further described by wavelength, which is simply defined as the distance between two identical points on adjacent waves (normally crests). For a traveling wave, it is also a measure of the distance covered by the wave during one complete cycle.

Normal wavelength measurements of different types of EM energy range from as short a unit as angstroms, which is the diameter of a single hydrogen atom, up to thousands of kilometers. Since the velocity of propagation of all EM energy is the same (i.e., the speed of light - c), a relationship between frequency and wavelength can be expressed in the following equation:

$$\lambda f = c$$

where:

λ = wavelength
f = frequency (Hz)
c = wave propagation velocity (speed of light)

Thus, the shorter the wavelength, the higher the frequency and vice versa. Frequency and the resulting wavelength is a major factor in defining the basic nature of different types of EM energy since the frequency of the EM wave will be identical to the frequency of the energy source which generates them. See Figure 1-5.

1.2.2.6 Phase. A concept that is essential to understanding many aspects of radar operation is phase. Phase is the degree to which the individual cycles of a wave or signal coincide with those of a reference signal of the same frequency. Phase is commonly defined in terms of the points in time at which the amplitude of a signal goes through zero in a positive direction. The signal's phase, then, is the amount that these zero-crossings lead or lag the corresponding points in the reference signal. See Figure 1-5.

The ability to maintain continuity or consistency in the radio frequency (RF) phases of successive radar pulses is known as coherence. Coherence is an essential element of extracting doppler information from the signals received by a radar. See Figure 1-5.

1.2.2.7 Amplitude. Another characteristic of wave propagation is amplitude. This may graphically be defined as the maximum displacement of any point on the wave from a constant reference value. Displacement is also a direct indication of the level of energy at any point on a propagating wave. The losses in amplitude of EM energy are primarily due to spreading and atmospheric attenuation. As the wave travels outward from its source, its energy is spread over an increasingly larger area, like an expanding circular wave in a pool of water.

The energy per unit area of the wave front of EM energy transmitted in a vacuum is proportional to $1/R^2$ where R is the distance from the transmitting source. This means that a receiver

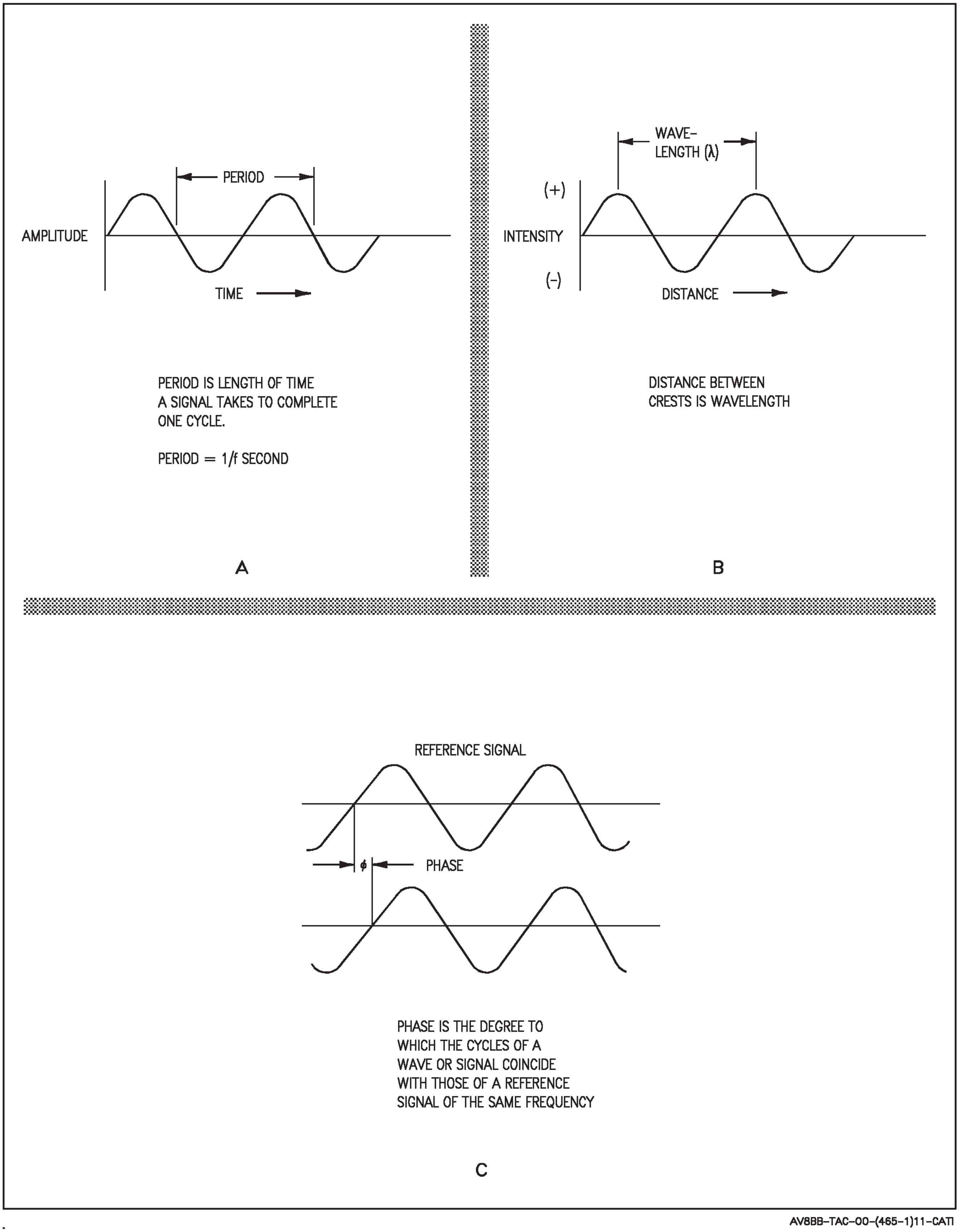

Figure 1-5. Wave Characteristics

would sense only 1/4 the intensity of identical EM energy received from twice the distance, 1/9 the intensity from three times the distance, and so on. Since the radar is an active system, the radio waves are attenuated over the path they are transmitted as well as the path the echoes travel as they return to the receiver. RF energy from the radar is therefore attenuated by a factor of $1/R^4$ which means that only a very small fraction of the transmitted energy is actually received, especially at long range. As range from the target decreases, the energy level of the echoes increases exponentially.

1.2.3 Principles of Reflection, Refraction, and Diffraction. There are three basic mechanisms which may cause an EM energy wave (i.e., radar) to change directions; reflection (which makes radar possible), refraction, and diffraction or a combination of the three.

1.2.3.1 Reflection. When a radiated EM wave strikes a conducting surface, reflection of energy from that surface occurs. This reflection is in accordance with the law of reflection which states that the reflected and incident waves travel in directions which make equal angles with the normal to the reflecting surface and are in the same plane. The angles are called the angle of reflection and the angle of incidence respectively and are measured from the normal to the reflecting surface.

The law of reflection can be stated as follows: The angle of reflection equals the angle of incidence, and the reflected ray lies in the plane of incidence. In simple radar terms, radar energy is reflected from a target at the same angle at which it strikes it. It is important for the pilot to understand this basic concept because this has a direct effect on the amount of reflectivity exhibited by objects.

Reflection can be expressed in terms of the reflection coefficient of a surface, that is, the ratio of the intensities of the reflected field to the incident field. The most common measure of intensity is defined by the electric field strength. Often energy is lost from the incident wave because of the presence of natural obstacles such as dust, snow or water vapor. These will cause some degree of diffuse reflection resulting in a loss in beam power. The greatest loss in field strength, however, occurs from the diffusion caused by the roughness and irregularities in the conduction surfaces themselves.

1.2.3.2 Refraction. As an EM wave travels through the atmosphere it is also subject to the phenomenon of refraction. Refraction is defined as a bending or change of direction of a wave in passage from one medium to another of different refractive index. The refractive index of a medium is the ratio of the velocity of propagation in a vacuum to the velocity in the medium. Thus, when a wave strikes a boundary between two transparent media in which the velocity of light differs, the incident ray will generally divide into a reflected ray and refracted ray. For example, objects can be easily seen in clear water, the image in the water is shifted (refracted) from its expected position due to the different refractive indexes of the two media (i.e., water and air).

The law of refraction, commonly called Snell's Law, states that: The ratio of the sine of the angles of refraction to the sine of the angle of incidence is constant, and the refracted ray lies in the plane of incidence.

1.2.3.2.1 Atmospheric Refractivity. Refraction is not normally a factor for EM energy, however, a form of refraction occurs in the atmosphere which can be a factor under certain specific environmental conditions. While there are no clearly defined media boundaries in the earth's atmosphere, a radio wave can encounter several variations in air density. For air near the surface of the earth (sea level), the refractive index varies between approximately 1.000250 and 1.000450. For simplicity, these values are called N-units and are stated as 250 and 450 N-units.

Refractivity tends to decrease exponentially with altitude. Bending of radar waves by the atmosphere is determined by the changes or gradients in refractivity along a wave path and by the angle of penetration of the radar waves.

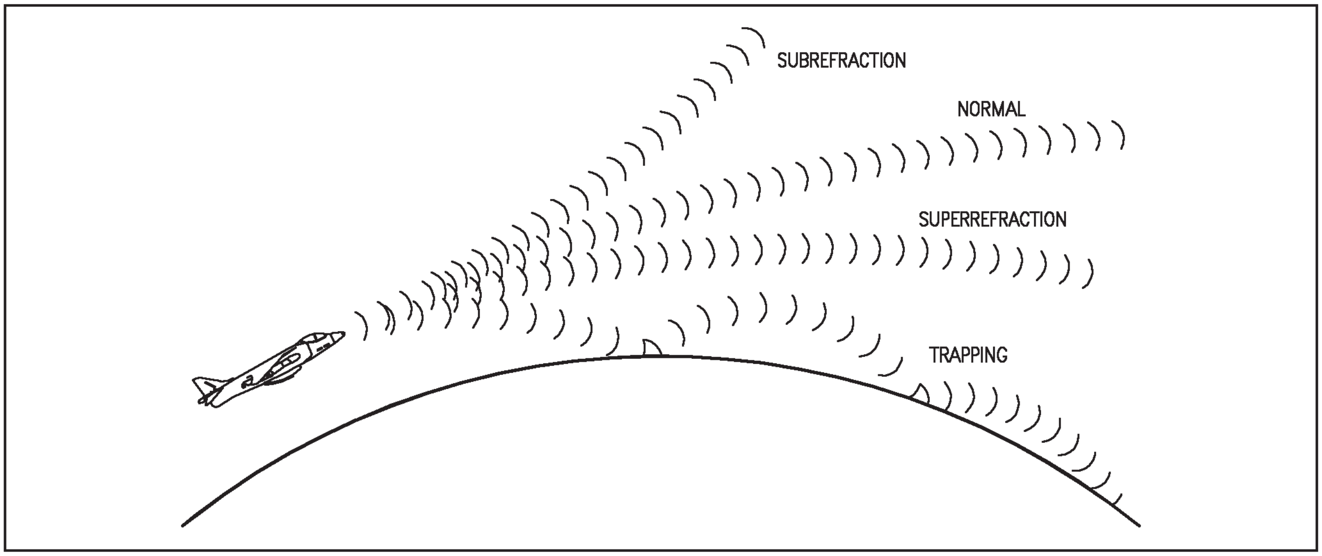

Figure 1-6. Refractive Bending

The atmosphere is generally assumed to be horizontally homogenous and only vertical refractivity changes are considered. Refractive bending effects are most pronounced at small angles to the horizontal; on the order of 1° or less. For a standard atmosphere, N-units decrease with height at a rate of approximately 12N per 1000 feet. In this instance, a radar wave will bend down toward the earth's surface, but with a curvature less than the earth's, which results in an apparent smooth, upward bending over a finite distance. With respect to the relationship of curvature less than the earth's, a refractive gradient of zero to −24N per 1000 feet maintains this degree of radar wave bending, and this is termed normal.

A refractive gradient which produces a greater than normal downward bending, but still less than the curvature of the earth's is from −24N to −48N per 1000 feet and is termed superrefractive. Either condition can enable a radar to see somewhat beyond the horizon. When the refractive gradient is −48N or greater per 1000 feet, the downward bending equals or exceeds the curvature of the earth's surface, and this is termed trapping. A refractive gradient which increases with height will produce less than normal bending or upward bending, and this is termed subrefractive. As a convenience in determining the occurrence of trapping, the modified refractivity (M) profile takes into account the curvature of the earth in such a way that the presence of trapping ducts can be determined from a simple inspection of M plotted versus height. When M decreases with height, a trapping duct is indicated. Figure 1-6 shows the relationship between the four types of refraction in terms of N and M gradients.

Atmospheric refraction is greatest in maritime tropical airmasses; intermediate in continental polar and maritime polar airmasses; and least in continental tropical airmasses. Subrefraction is most frequent in maritime polar and continental tropical airmasses. The southeast sector of a high pressure system favors the occurrence of refraction. Factors conducive for superrefraction and trapping are; subsidence and divergence; weak vertical velocities; warm, dry air overlying a moist layer of air; stability and stratification; and temperature inversions. Based on a variety of climatological references, 80 to 90 percent of all other-than-normal refractive layers will occur from the surface to 10,000 feet. This layer of the atmosphere has the greatest variability on moisture content and vertical distribution.

Two primary considerations resulting from nonstandard refractive conditions are known as ducting (or trapping) and radar holes. The existence of a duct may cause low-angle radar beams

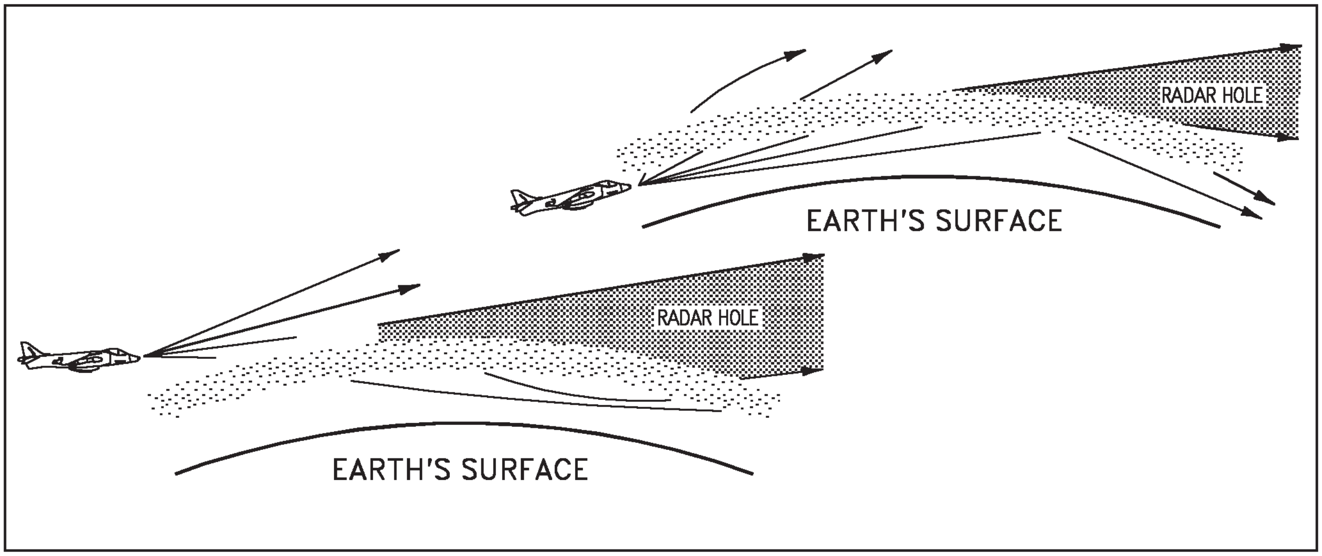

Figure 1-7. Radar Holes

(within about 1° of horizontal) to be trapped as if in a waveguide and thus be transmitted far beyond the normal radar horizon. Trapping or ducting is associated with distribution of temperature and relative humidity in a certain atmospheric layer near the surface of the earth. It is actually a case of superrefraction. When EM energy enters such a layer, it is bent downward sufficiently to continue its path some distance inside this layer around the curvature of the earth. In other words, the energy is trapped in the layer and prevented from reaching the ground. After a certain distance the EM wave may leave the layer and return to earth. This might be at a distance well beyond the horizon from the transmitter. Ducting and superrefraction should be suspected when a temperature inversion or a markedly smaller than normal temperature decreases (about −2 °C/1000 feet) occur.

A radar hole is an area rendered deficient in radar illumination because of refractive conditions that bend the radar energy away from it. The radar hole is a region which geometrically should be scanned by the radar signal, but in which refractivity (resulting from unique environmental conditions) has significantly reduced the radar signal in the affected area. See Figure 1-7.

The elevation boundaries of such a hole can be the layer, or the hole can be between two rays going through the layer. With a duct's greatly extended coverage, distant features that would not normally be detectable may actually be detected. A radar hole, however, may allow the virtually undetected approach of a rapidly closing threat. For example, approaching aircraft have been sighted visually before being detected by radar.

Still another phenomena attributable to atmospheric refractivity is the appearance of false radar targets. Sometimes known as ghosts or phantoms, such false targets are occasionally seen racing across the radar display at up to supersonic speed.

There are three basic types of ducts which can affect EM energy. They are surface-based ducts, elevated ducts, and evaporative ducts. If an elevated trapping layer is strong enough so that the M-value at the top of the trapping layer is less than the M-value at the ocean surface, a surface based duct will be formed. In this case the EM wave originating below the trapped layer is refracted downward by the trapping layer and

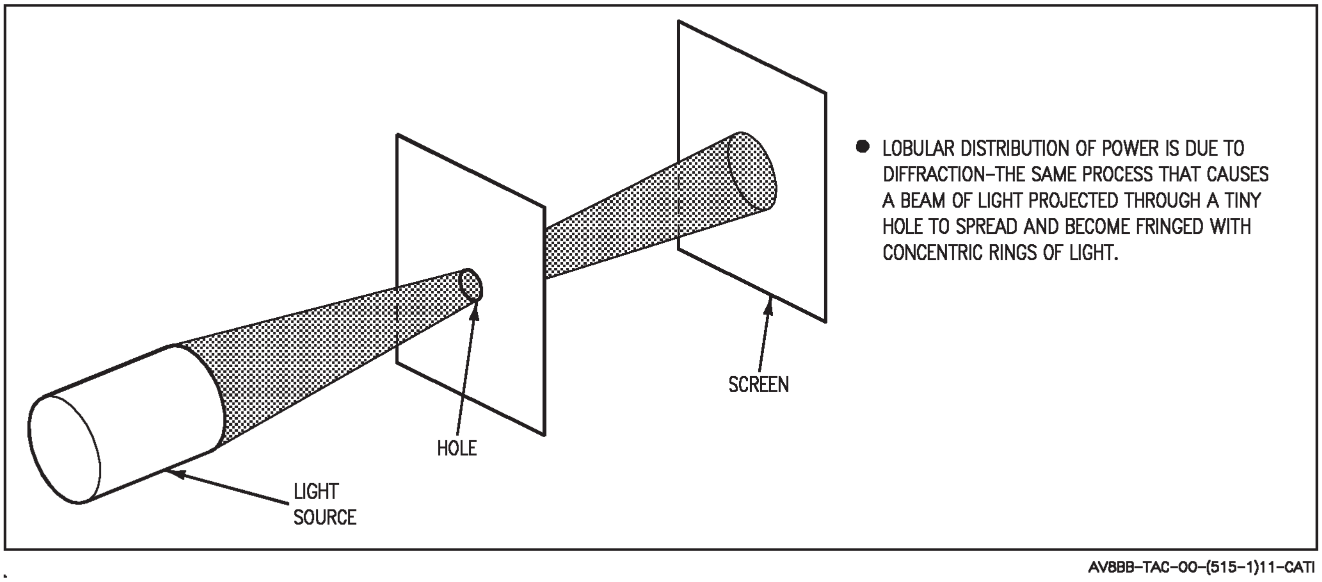

Figure 1-8. Lobular Radar Diffraction

reflected upwards by the ocean surface. Generally, surface based ducts give extended detection, intercept and comm ranges for all microwave frequencies above 100 MHz. Surface based ducts are usually less than 3000 feet thick, with 1000 feet the more common thickness. Elevated ducts primarily affect air-to-air, surveillance, comm, electronic warfare (EW), or weapons guidance systems. Elevated ducts may occur up to 20,000 feet, with maximum altitudes of 10,000 feet the most common.

A very persistent duct is created over certain ocean areas by the rapid decrease of moisture immediately above the ocean surface. Evaporative ducts are thinner and weaker than surface-based ducts. Generally, evaporative ducts will effect only surface-to-surface EM systems; however, low flying aircraft may also be affected. Usually, evaporative ducts are stronger and more common nearer the tropics during the summer season and during daylight hours. For example, significant evaporative ducts occur over 75 percent of the time in the Eastern Mediterranean during the summer days, but only 1 percent of the time in the Norwegian Sea during winter nights.

Present atmospheric refractivity conditions are generally not readily available to the pilot, however, it is useful for the pilot to understand that certain conditions can create anomalous propagation of the radar signal. Especially, under conditions of fair weather typified by clear skies, cool temperatures, and light winds, radar signals may become trapped in stable layers of the atmosphere. There are products describing EM propagation conditions from several different sources. Military weather services can provide pilots with forecast EM propagation conditions using a tool called IREPS.

1.2.3.3 Diffraction. If part of a beam of EM energy is interrupted by some kind of an opaque object, one would not expect, according to the theory of EM waves, to find any radiation in the geometrical shadow of this object. In reality, however, there is some energy observed in this shadow zone. The reason is that EM energy is a wave motion, and each point on the opaque object becomes a new source of radiation which radiates in all directions. A wave spreads around objects whose size is comparable to a wavelength and bends around the edges of larger obstructions. For a given size of obstruction, the longer the wavelength, the more significant the effect. This is why AM broadcast stations (operating at wavelengths of a few hundred meters) can be heard in the shadows of buildings and mountains, whereas TV stations operating at wavelengths of only a few meters cannot. See Figure 1-8.

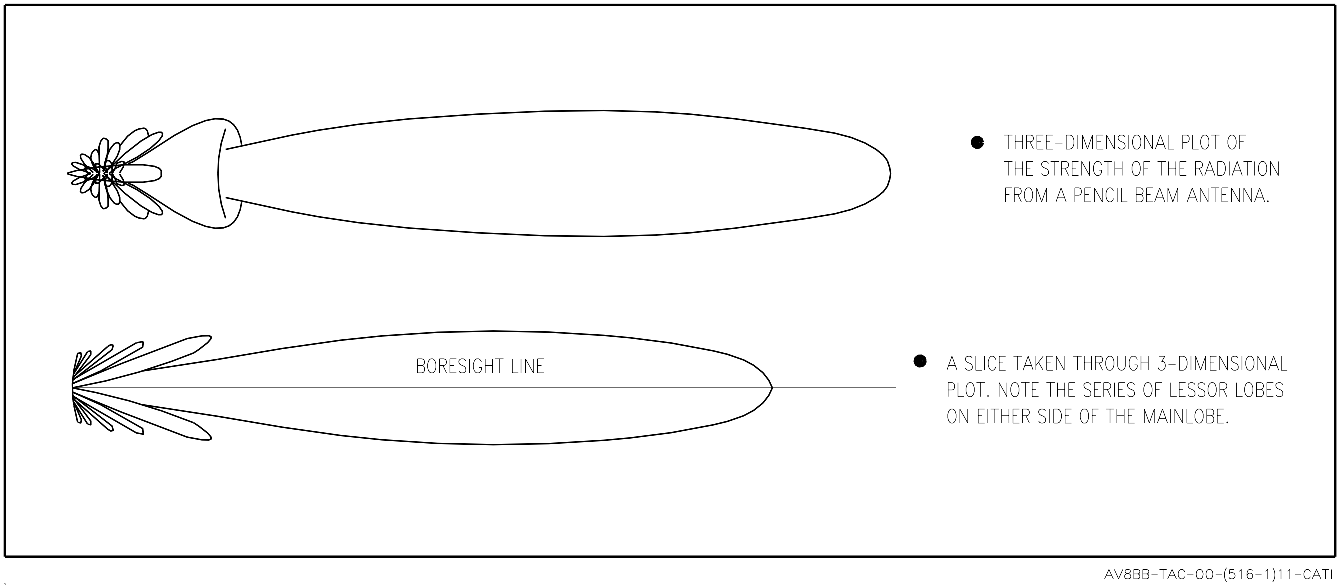

Figure 1-9. Sidelobes

This phenomenon, called diffraction, stems from the fact that the energy at each point in a wave is passed on just as if a radiator actually existed at that point. The wave as a whole propagates in a given direction only because the radiation from all points in every wavefront reinforces in that direction and cancels in others. If the wavefronts are broken by an obstruction, cancellation at the edge of the wave is incomplete.

The phenomenon of diffraction can also be used to explain the lobular structure of the radar beam. Most of the energy in the radar beam is concentrated in a more or less conical region surrounding the central axis, or boresight line, of the antenna. This region is called the mainlobe. As the distance from the antenna boresight increases to the edges of the antenna, a point is ultimately reached where the sum of the waves received from all of the radiators is zero. This creates a null in the total radiation from the antenna. As distance increases further, the waves no longer cancel exactly and the radiation from the waves increases to form another peak. However, portions of the radiated pattern still cancel, therefore, this new lobe does not have near the intensity of the mainlobe. This same general process repeats itself until the mainlobe is flanked on either side by a series of weaker lobes which are called sidelobes. See Figure 1-9.

Diffraction therefore is a major factor in determining the basic directivity (azimuth resolution) of the real radar beam. It is diffraction that dictates that the width of the mainlobe (beamwidth) is inversely proportional to the width of the antenna aperture in wavelengths.

1.2.4 Atmospheric Attenuation. In the real world, EM energy is not traveling through a vacuum therefore the energy (i.e., radio wave) is always attenuated by the atmosphere to some extent. Atmospheric attenuation can occur due to refraction, absorption, or scattering of the EM energy. The attenuating effects of the atmosphere and weather on EM energy is not constant across the EM spectrum. The most important factors that affect signal attenuation are the amount and type of material in the line of sight between the sensor and the scene, the distance between them, and the wavelength (frequency) of the signal. The severity of the atmosphere's attenuating effects is therefore different for the various electro-optic (EO) sensors (NVGs, NAVFLIR, radar, etc.).

As a rule of thumb, the shorter the wavelength an EO system operates at, the greater will be the degradation of system performance due to the occurrence of adverse weather. For example, the NVGs are significantly affected by any visibility obscurant while the NAVFLIR can provide a superior image in some limited visibility conditions (i.e., haze, light fog, some smokes) due to its lower frequency (longer wavelength). However, neither the NVGs nor the NAVFLIR is an all-weather sensor.

The level of atmospheric attenuation on radio waves is less than it is on either the NVGs or the NAVFLIR, however, the severity of its effects depends on the frequency band being utilized. Atmospheric attenuation is essentially negligible at the lower end of the radar frequency band (i.e., long range search, AWACS, etc.) but at the higher radar frequencies it can become quite significant. For example, short wave radars such as millimeter radars can be substantially affected by weather. The APG-65 radar offers somewhat of a compromise in that it can penetrate most clouds readily, however, moderate to heavy weather (rain, sleet, hail, etc.) does show up on the radar and very heavy weather essentially blocks the signal. This is not inherently bad since this means that the APG-65 serves as an excellent weather avoidance radar.

1.2.5 Atmospheric Transmissions. The atmosphere refracts, scatters, and absorbs IR radiation. The effect of refraction is almost negligible, except for orbital applications where the entire depth of the earth's atmosphere is of concern, and will therefore not be included in this text. The transmission of electromagnetic energy through the atmosphere is dependent on the concentration and distribution of the atmospheric constituents, which are, in turn, dependent on meteorological conditions. Therefore, the atmosphere itself is a limiting factor for transmission.

Scattering occurs due to the presence of molecules and particles of matter in the atmosphere (aerosols). Scattering causes attenuation of an incident beam of radiation because in the scattering process the energy is redistributed into all directions of propagation.

Another form of radiation attenuation is absorption due to the resonance-absorption bands of the molecules in the atmosphere. The periodic motions of a source of radiation results in the radiation of electromagnetic waves at these frequencies. The atmospheric molecules contain bound electrons with natural frequencies of vibration and rotation which depend on their structure. When these characteristic frequencies are matched by that of some propagating radiation, resonance absorption occurs. The molecule is excited and will likely return to its ground state, radiating in all directions, therefore attenuation in a given direction has taken place.

It is appropriate to point out that the severity of scattering and absorption is a function of radiation wavelength and particle size, and it is sometimes difficult to determine which is the primary attenuation mechanism. Since the radiated energy distribution is also wavelength dependent, there is an interest in selecting an operational spectrum, called a window, which maximizes the product of radiated energy and transmitted energy. Graphically, it can be shown that there are three specific windows where the atmospheric transmittance is consistently high, therefore EO systems are designed to operate in these areas.

Part of one window is in the visible region of the spectrum, which covers the small band from about 0.4 to 0.7 microns (400 to 700 nanometers). Although this is certainly the most familiar window, it is unfortunately the least useful for night time tactical purposes.

The NVG's and NAVFLIR allow the pilot to use the near and far IR regions of the spectrum. The NVG's sensitivity range (0.6 to 0.9 micron) extends from the deep red area of the visible range into the near IR region . The other two windows are both in the IR portion of the spectrum. One is the 3 to 5 micron band, which is located in the mid IR region. This band is associated mostly with missile seekerheads, and the radiation found in a jet plume. The other window is the 8 to 12 micron band, which lies in the far IR, and is normally used for surveillance purposes, such as the NAVFLIR. Figure 1-10 shows how modern EO sensors fit into these naturally occurring windows. Since the pilot can not *see* energy in either the near IR or the far IR region of the spectrum, the real purpose of the NVG's and the NAVFLIR is to create a visible image of these two windows for the pilot.

FREQUENCY BAND	WAVELENGTH	REMARKS
Ultraviolet	Below 0.40 microns (4.000 angstroms)	
Visible	0.40 to 0.70 microns	Operating range of photo camera.
Violet	0.40 to 0.46	
Blue	0.46 to 0.51	
Green	0.51 to 0.58	
Yellow	0.58 to 0.60	
Orange	0.60 to 0.63	
Red	0.63 to 0.70	
Infrared	0.70 to 1,000 microns	Operating range of infrared surveillance using infrared detectors.
Near IR	0.70 to 1.50	
Middle IR	1.50 to 5.60	
Far IR	5.60 to 1,000	
Radio Waves		
EHF	1 mm to 1 cm	High precision radar.
SHF	1 cm to 10 cm	High resolution radar.
UHF VHF HF MF	10 cm to 1 m 1 m to 10 m 10 m to 100 m 100 m to 1,000 m	Line-of-sight military and commercial communications (tacan), EW, GCI, FC DF stations, military communications, long distance commercial broadcast.
LF	1,000 m to 10,000 m	Polar communications, area coverage.
VLF	> 10,000 m	Navigational aids.

Figure 1-10. Electromagnetic Band/Wavelength

1.2.6 Sensors. That portion of the EM spectrum which is of most interest to the AV-8B pilot deals with the energy utilized by the EO sensors. Optical radiation, for the AV-8B, is generally defined as that energy between the wavelength limits of about 0.4 microns and 15 microns. Because the frequencies involved with optical radiation are so high, it is customary to refer to wavelength rather than frequency when referring to this energy. Although radars operate at wavelengths much longer than 15 microns, the APG-65 can be considered part of the EM sensor package. Most radars employ wavelengths (frequencies) somewhere between a millimeter (100

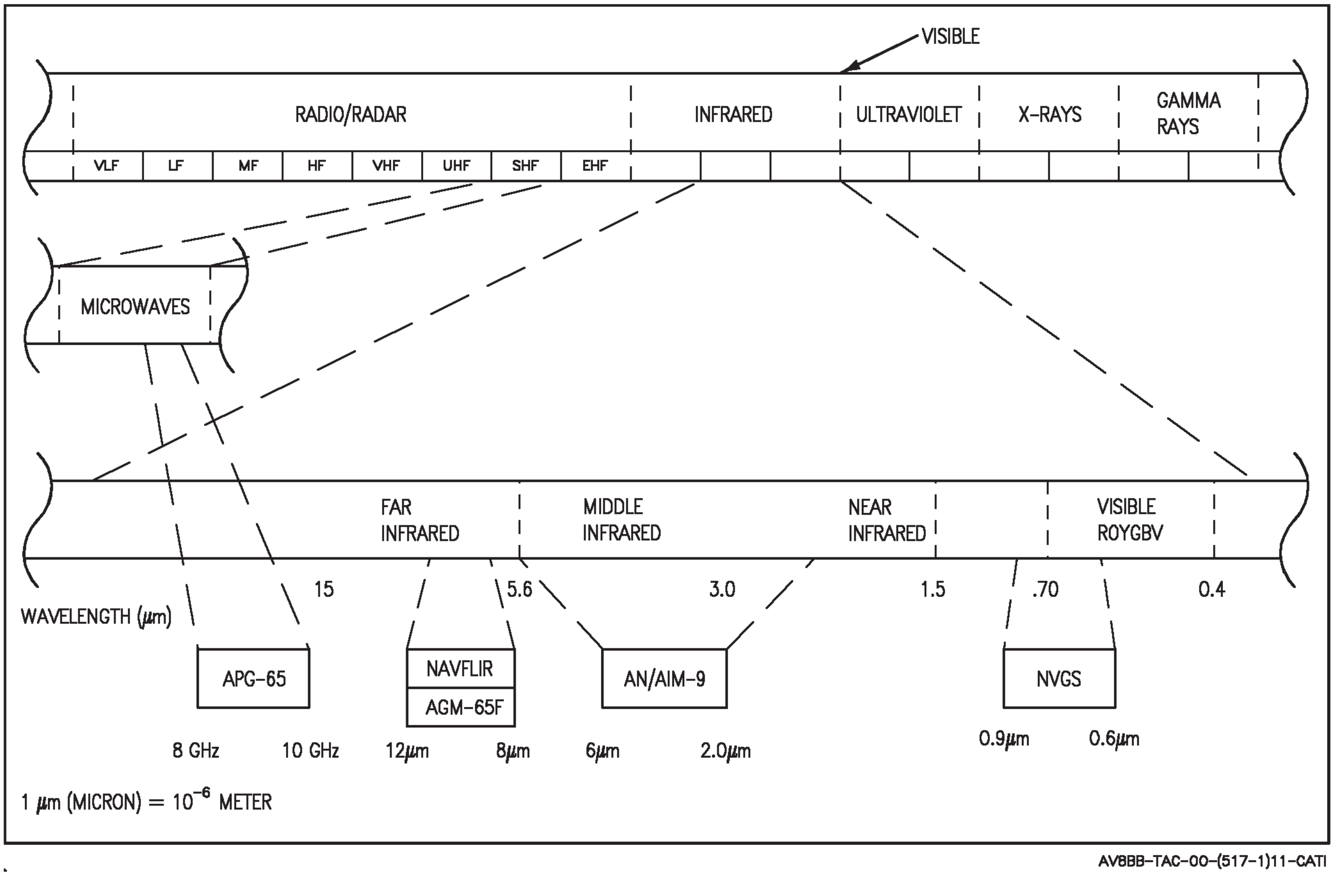

Figure 1-11. AV-8B Sensors

GHz) and about 10 meters (0.1 GHz) - the APG-65 operates at about 3 cm (10 GHz). When describing radars, it is as likely to be referred to by its frequency as well as its wavelength. See Figure 1-11.

All AV-8B sensors are sensitive to specific wavelength ranges just as radio receivers selectively tune within a broad spectrum of EM energy. Even our eyes are sensitive to a very specific band of energy in the EM spectrum. Visible light extends from about 0.4 microns to 0.76 microns (far red). The infrared (below red) region of the EM spectrum consists of that portion between the longest visible wavelengths and the shortest radio wavelengths (millimeter). The IR band is divided into the following sub regions:

Near IR - 0.70 to 1.50 microns
Mid IR - 1.50 to 5.60 microns
Far IR - 5.6 to 1,000 microns

The AV-8B has access to four IR sensors, however, each of these sensors operates in a different IR sub region. These consist of the following:

NVGs - 0.6 to 0.9 microns - Red/Near IR
AIM-9 - 2.0 to 6.0 microns - Mid IR
AGM-65F - 8.0 to 12.0 microns - Far IR
NAVFLIR - 8.0 to 12.0 microns - Far IR

Although all four sensors are IR devices, the nature of the different wavelengths/frequencies of the energy means that each sensor is affected differently by environmental factors as well as being designed for different mission requirements.

1.3 RADAR

1.3.1 Radar Fundamentals

1.3.1.1 Radar Frequencies . Radars of various kinds operate at frequencies ranging from as low as a few megahertz to as high as 300,000 gigahertz. At the low end are a few highly specialized radars: sounders that measure the height of the ionosphere, as well as radars that take advantage of ionospheric reflection to see over the horizon and detect targets thousands of miles away. At the high end are laser radars, which operate in the visible and near IR region of the spectrum and are used to provide the angular resolution needed for such tasks as measuring the ranges of individual targets on the battlefield. Most radars, however, employ frequencies lying somewhere between a few hundred megahertz and 100,000 megahertz. To make such large values more manageable, it is customary to express them in gigahertz. One gigahertz (giga - billion) equals 1000 megahertz (mega - million). A frequency of 100,000 megahertz, then, is 100 gigahertz. Radar operating frequencies are expressed in terms of wavelength - the speed of light divided by the frequency. A convenient rule of thumb for converting from frequency to wavelength is the following:

Wavelength in centimeters = 30 divided by frequency in GHz

Example: What is the wavelength of a 10 GHz radar?

30/10 = 3 cm

Besides being identified by discrete values of frequency and wavelength, radio waves are also broadly classified as falling within one or another of several arbitrarily established regions of the radio frequency spectrum - high frequency (HF), very high frequency (VHF), and so on. The frequencies commonly used by radars fall in the VHF, UHF, microwave (i.e., APG-65), and millimeter wave regions. During World War II, these regions were broken into comparatively narrow bands and assigned letter designations for purposes of military security: L-band, S-band, C-band, X-band, and K-band. To enhance security, the designations were deliberately put out of alphabetical sequence. Though long since declassified, these designations have persisted to this day. The K-band turned out to be very nearly centered on the resonant frequency of water vapor, where absorption of radio waves in the atmosphere is high. Consequently, the band was split up. The central portion retained the original designation. The lower portion was designated the Ku-band; the higher portion, the Ka-band. (An easy way to keep these designations straight is to think of the *u* in Ku as standing for under and the *a* in Ka as standing for above, the central band.)

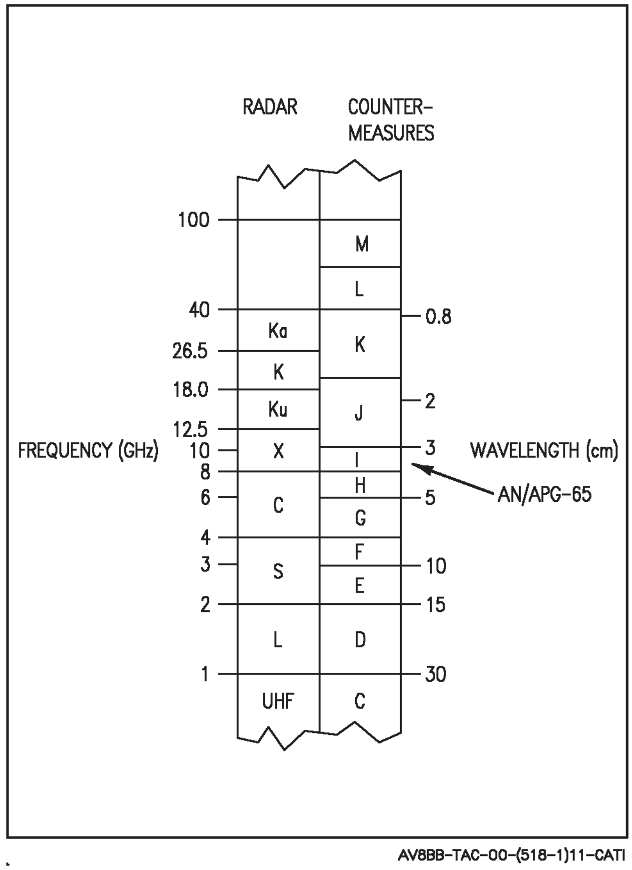

Figure 1-12. Frequency Band Designation

In the 1970’s, a complete new sequence of bands, assigned consecutive letter designations from A to M, was devised for electronic countermeasures (ECM) equipment. The new designations are normally used when referring to radars. However, it is not unusual to see both radar band letter designations used. As an example, the APG-65 operates in the I-band (new designation), however, it can also be stated that it operates in the X-band (old designation). See Figure 1-12.

1.3.1.1.1 Influence of Frequency on Radar Performance. The best frequency to use depends upon the job the radar is intended to do.

Like most other design decisions, the choice involves trade-offs among several factors; physical size, transmitted power, antenna beamwidth, atmospheric attenuation, and so on.

a. Physical Size. The dimensions of the hardware used to generate and transmit radio frequency power are in general proportional to wavelength. At the lower frequencies (longer wavelengths), the hardware is usually large and heavy. At the higher frequencies (shorter wavelengths), radars can be put in smaller packages and operate in more limited spaces, and they weigh correspondingly less.

b. Transmitted Power. Because of its impact on hardware size, the choice of wavelength indirectly influences the ability of a radar to transmit large amounts of power. The levels of power that can reasonably be handled by a radar transmitter are largely limited by voltage gradients (volts per unit of length) and heat dissipation requirements. The larger, heavier radars operating at wavelengths on the order of meters can transmit megawatts of average power, whereas millimeter-wave radars may be limited to only a few hundred watts of average power. Average power is a function of the wattage output of the radar and its duty cycle, which is the percentage of time that the radar is actually transmitting. Average power is discussed in more detail in Chapter 3. (Most often, the amount of power actually used is decided by size, weight, reliability, and cost considerations.)

c. Beamwidth. Basic physics dictates that the width of a radar's real beam is directly proportional to the ratio of the wavelength to the size (diameter) of the antenna. To achieve a given beamwidth, the longer the wavelength, the wider the antenna must be. At low frequencies, very large antennas must generally be used to achieve acceptably narrow beams. At high frequencies, comparatively small antennas will suffice. The narrower the beam, of course, the greater the amount of power that is concentrated in a particular direction at any one time, and the finer the angular resolution of the real radar beam. As an example, the airborne warning and control system (AWACS) radar operates in the S-band (10 cm). These radio waves are considerably longer than that used by the APG-65 (3 cm), however, AWACS utilizes an antenna which is about 24 feet wide. At the other extreme, an air-to-air missile which operates in the millimeter-wave region (94 GHz) can achieve the same angular resolution with a 3.8 inch antenna as an I-band radar would with a 36-inch antenna. The APG-65 operates in the I-band (3 cm) and has a 23.2 inch antenna, thus it offers a beamwidth of about 3.9°. In comparison, the A-6E operates in upper J-band and has a much larger antenna. These two factors combine to provide the A-6E with a very narrow beamwidth (about 1.4°). See Figure 1-13.

d. Atmospheric Attenuation. As noted before, all EM energy is attenuated by the atmosphere to some extent. In passing through the atmosphere, radio waves may be attenuated by two basic mechanisms: absorption and scattering. The absorption is mainly due to oxygen and water vapor. The scattering is almost always due to condensed water vapor (e.g. raindrops). Both absorption and scattering increase with frequency. Below about 0.1 GHz, atmospheric attenuation is negligible. Above about 10 GHz (APG-65 operates at 8 to 10 GHz), it becomes increasingly important. See Figure 1-14.

Above that frequency, the radar's performance is increasingly degraded by weather clutter competing with desired targets. Even when the attenuation is reasonably low, if enough transmitted energy is scattered back in the direction of the radar, it will be detected. In simple radars which do not employ moving target indications (MTI), this return (weather clutter) may obscure targets.

e. Ambient Noise. Electrical noise from sources outside the radar is high in the HF band. But it decreases with frequency, reaching a minimum somewhere between about 0.3 and 10 GHz, depending on the level of galactic noise, which varies with solar conditions. From there on, atmospheric noise predominates. It gradually becomes stronger and grows increasingly so at K-band and higher frequencies. In many radars internally generated noise predominates. But, when low-noise receivers are used to meet long

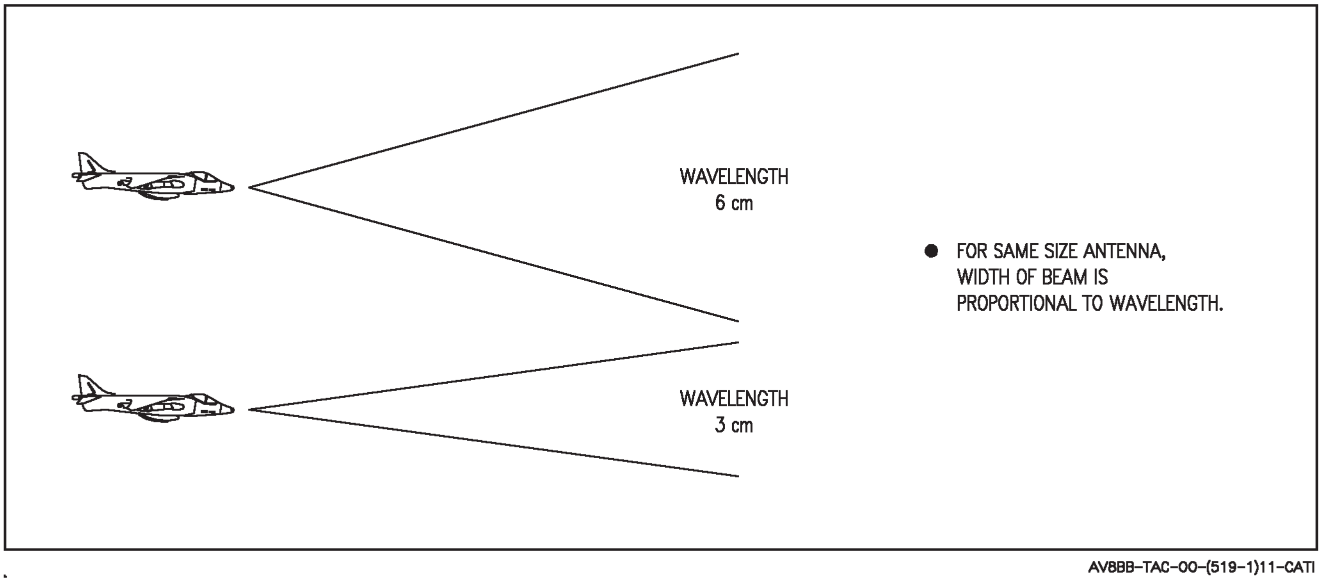

Figure 1-13. Width of Beam Propagation

range requirements, external noise can be an important consideration in the selection of frequency. See Figure 1-15.

f. Doppler Considerations. Doppler shifts are proportional not only to closing rate but to radio frequency. The higher the frequency, the greater the doppler shift a given closing rate will produce. Excessive doppler shift can cause problems while on the other hand, doppler sensitivity to small differences in closing rate can be increased by selecting reasonably high frequencies. See Figure 1-16.

1.3.1.1.2 Selecting the Optimum Frequency. The selection of the RF the radar utilizes is influenced by several factors: the functions the radar is intended to perform, the environment in which the radar will be used, the physical constraints of the platform on which it will operate, and cost.

a. Ground-based Applications. At one extreme are the long-range highpower surveillance radars. Unrestricted by size limitations, they can be made large enough to provide acceptably high angular resolution while operating at relatively low frequencies. Over-the-horizon radars operate in the HF-band where the ionosphere is suitably reflective. Space surveillance and early warning radars generally operate in the UHF and VHF bands, where ambient noise is minimal and atmospheric attenuation is negligible. These bands, however, are crowded with communications signals. So their use by radars (whose transmissions generally occupy a comparatively broad band of frequencies) is restricted to special applications and geographic areas. Where such long ranges are not required and some atmospheric attenuation is therefore tolerable, ground radars may be reduced in size by moving up to D through H-band frequencies or higher.

b. Shipboard Applications. Aboard ships, physical size becomes a limiting factor in many applications. At the same time, the requirement that ships be able to operate in the most adverse weather puts an upper limit on the frequencies that may be used. This limit is relaxed, however, where extremely long ranges are not required. Furthermore, higher frequencies must be used when operating against surface targets and targets at low elevation angles. At grazing angles approaching zero, the return received directly from a target is very nearly canceled by return from the same target, reflected off the water, a phenomenon called multipath propagation. Cancellation is due to a 180° phase reversal occurring when the return is reflected. As the grazing angle increases, a difference develops between the lengths of the direct and indirect paths, and

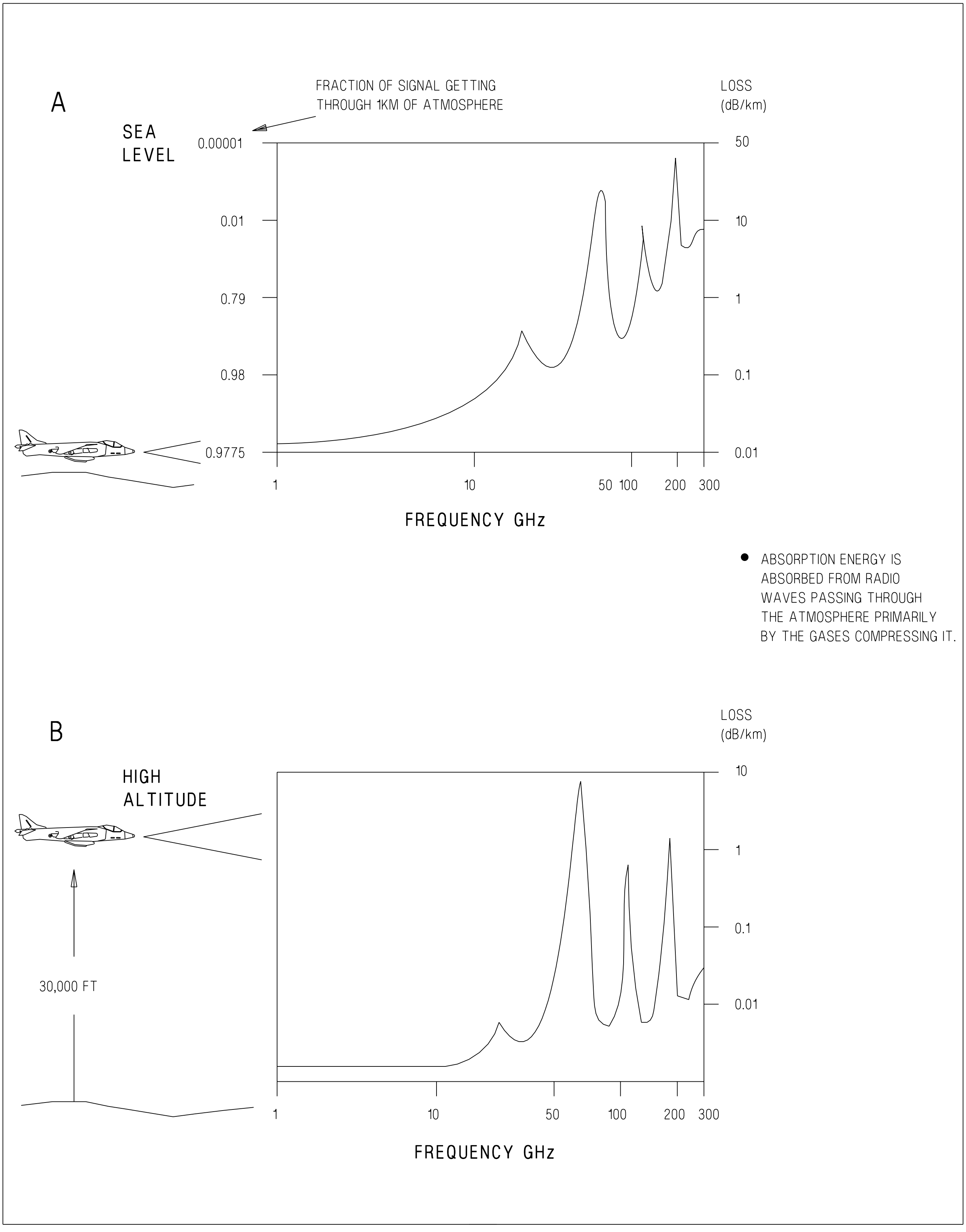

Figure 1-14. Atmospheric Attenuation

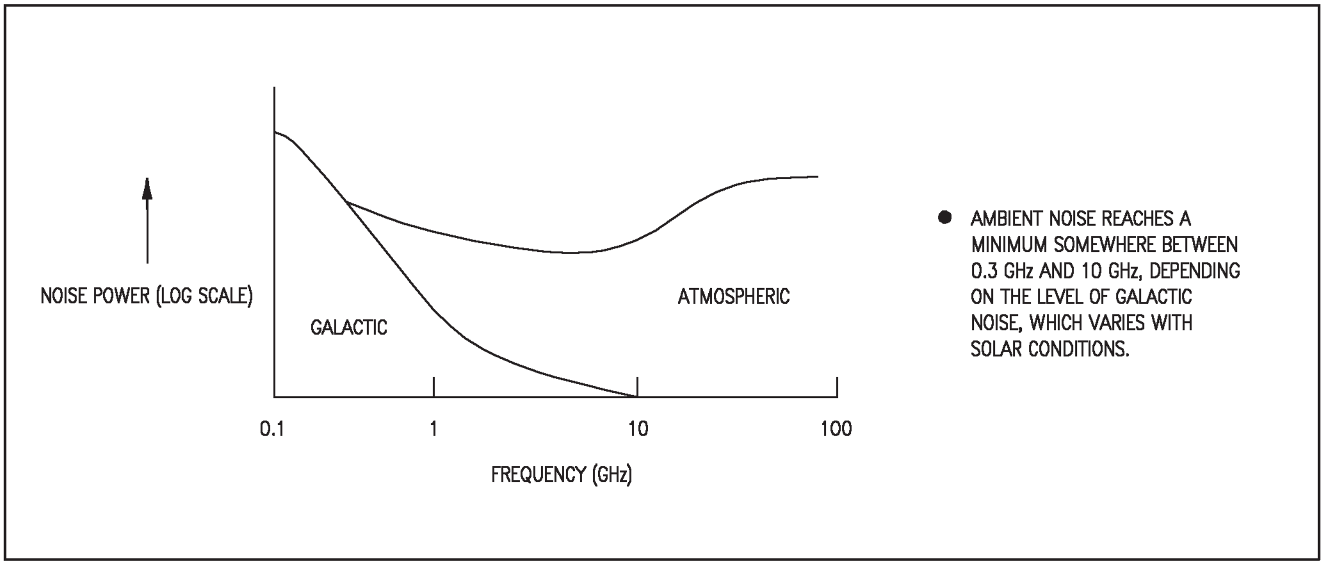

Figure 1-15. Sky Noise

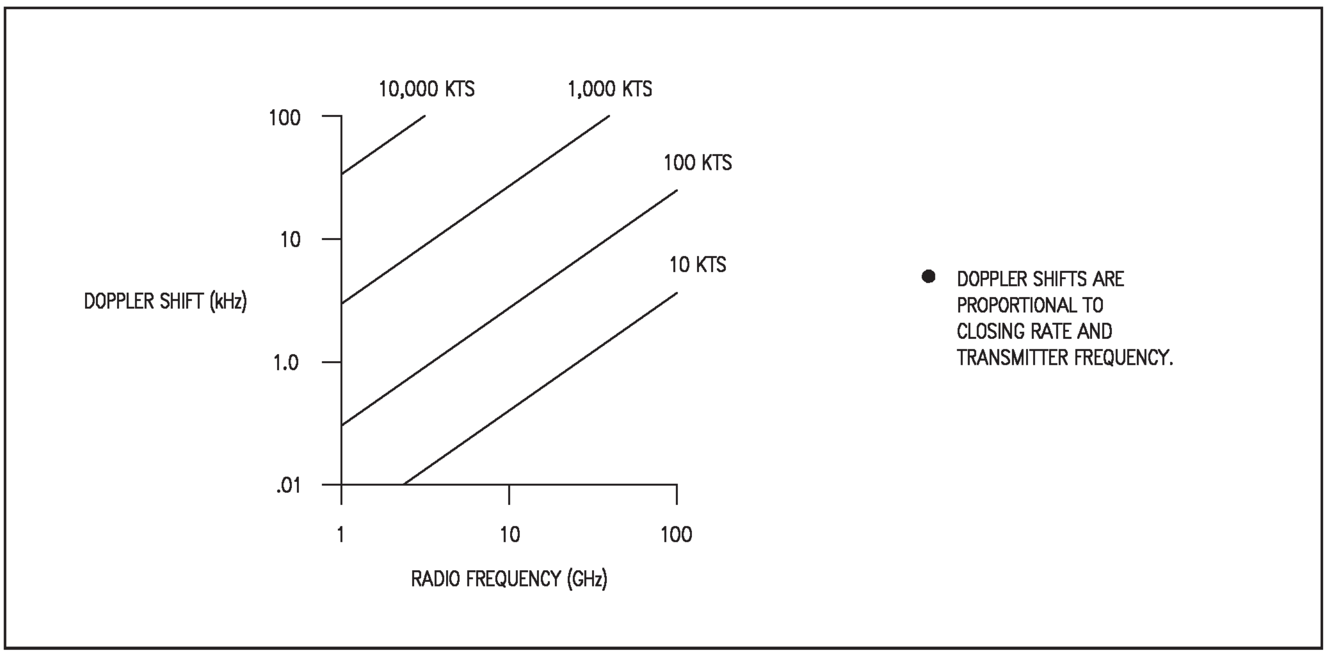

Figure 1-16. Doppler Shifts

cancellation decreases. The shorter the wavelength, the more rapidly the cancellation disappears. For this reason, the shorter wavelength E through I-band frequencies are widely used for surface search, detection of low flying targets, and piloting. (The same phenomenon is encountered on land when operating over a flat surface.)

c. Airborne Applications. In aircraft, the limitations on size are considerably more severe. The lowest frequencies generally used here are in the C and E-bands. They provide the long detection ranges needed for airborne early warning in the E2 and AWACS aircraft, respectively. One look at the large radomes of these aircraft and it is clear why higher frequencies are commonly used when narrow antenna beams are required in smaller aircraft, such as fighters.

The next lowest-frequency airborne applications are in the G and H-band. Radar altimeters operate here. These frequencies enable good cloud penetration. Because radar altimeters are simple, require only modest amounts of power, and do not need highly directive antennas, they can use these frequencies and still be made conveniently small.

Weather radars, which require greater directivity, operate in the G, H and I- bands. The choice between the bands reflects a dual trade-off. One is between storm penetration and scattering. If scattering is too severe, the radar will not penetrate deeply enough into a storm to see its full extent. Yet, if too little energy is scattered back to the radar, storms will not be visible at all. The other trade-off is between storm penetration and equipment size. G and H-band radars, providing better penetration, hence longer-range performance, are primarily used by commercial aircraft. I-band radars, providing adequate performance in smaller packages, are widely used by private aircraft.

Most fighter, attack, and reconnaissance radars operate in the I- and J-bands, with a great many operating in the 3 cm wavelength region of the I-band. The APG-65 operates in the I-band.

The attractiveness of the 3 cm region is threefold. First, atmospheric attenuation, though appreciable, is still reasonably low. Second, narrow beamwidths, providing high power densities and excellent angular resolution, can be achieved with antennas small enough to fit in the nose of relatively, small tactical aircraft. Third, because of their wide use, microwave components for 3 cm radars are readily available from a broad base of suppliers.

With the recent availability of suitable millimeter-wave power-generating components, radar designers are developing extremely small, albeit short-range, radars which take advantage of the atmospheric window at 94 GHz to provide radar capabilities in small packages (i.e., air-to-air missiles, AH-64 longbow).

1.3.1.1.3 Radar Summary. Radio frequencies employed by airborne radars range from a few hundred megahertz to 100 GHz, the optimum frequency for any one application being a trade-off among several factors.

In general, the lower the frequency, the greater the physical size and the higher the available maximum power. The higher the frequency, the narrower the beam that may be achieved with a given sized antenna. At frequencies above about 0.1 GHz, attenuation due to atmospheric absorption - mainly by water vapor and oxygen - becomes significant. At frequencies of 3 GHz and higher, scattering by condensed water vapor (i.e., rain, hail, and, to less extent, snow) produces weather clutter. It not only increases attenuation, but in radars not equipped with MTI may obscure targets. Above about 10 GHz, absorption and scattering become increasingly severe, and attenuation due to clouds becomes important.

Typically, early warning radars operate at C, E or F- bands; altimeters, at G or H-band; weather radars, at G, H or I- band; and fighter, attack, and reconnaissance radars, at the I and J-bands with the 3 cm region being particularly popular. The APG-65 radar operates in the I band (8 to 10 GHz or 3 cm).

1.3.1.2 Principles of Radar Operation. Radar is the application of radio principles to detect objects. All radars create radio waves, transmit them, and receive echoes from objects that reflect these waves. The reflected signal received by the radar is used to determine the range and direction of the objects. In addition, the doppler frequency can be extracted from the received signal in order to determine the range rate of detected targets or to create high resolution ground maps (i.e., expand modes).

Principles of Radar Operation:

1. Transmit RF signal
2. Receive reflected signal
3. Information extracted from received signal
   (a) range

(b) direction

(c) doppler

4. Display information

Most objects - aircraft, ships, vehicles, buildings, terrain features, etc. - reflect radio waves, much as they do light. Radio waves and light are, in fact, the same thing - electromagnetic (EM) energy. The main difference is that the frequencies of light are very much higher (shorter wavelengths). The reflected energy is scattered in many directions, but a detectable portion of it is generally scattered back in the direction from which it originally emanated.

At the longer radar wavelengths used by many shipboard and ground based radars, the atmosphere is almost completely transparent. And it is nearly so even at the shorter wavelengths used by the APG-65 (note: moderate to heavy weather is displayed, thus the APG-65 is an excellent weather avoidance radar). By detecting the reflected radio waves, therefore, it is possible to see objects not only at night, as well as in the daytime, but through haze, fog, clouds or many other visibility restrictions. Radar permits the rapid, convenient and accurate measurement of range. By extracting the doppler frequency of returns, it can also measure the relative velocity or range rate of objects.

1.3.1.2.1 Pulse Doppler Radar. The APG-65 is a pulse doppler radar. Radars are of two general types; continuous wave (CW) and pulsed. A CW radar transmits continuously and simultaneously listens for the reflected echoes. A pulsed radar, on the other hand, transmits its radio waves intermittently in short pulses, and listens for the echoes in the periods between transmissions. With the exception of the radar altimeter most airborne radars, including the APG-65, are pulsed. The chief reason is that with pulsed operation, one avoids the problem of the transmitter interfering with reception. Thus, if the transmission is pulsed, neither the transmitted signal nor transmitter noise is a problem; the radar does not transmit and receive at the same time. Pulsed operation has the further advantage of providing a simplified range measurement process.

a. Range Measurement. Radio waves travel at essentially a constant speed - the speed of light. A target's range, therefore, is simply half the round-trip transit time times the speed of light.

$$R = 1/2\,(t_r - t_t) \times c$$

where:

R = Range
t_r = time signal received
t_t = time signal transmitted
c = speed of light

If the pulses are adequately separated, a target's range can be precisely determined merely by measuring the elapsed time between the transmission of a pulse and the reception of the echo of that pulse. This method of range measurement is called pulse delay ranging and is used in all of the air-to-surface radar modes. In most air-to-air radar modes, the time interval between pulses can be so short that special methods of ranging must be utilized. One method is to systematically change the time between pulses in a set sequence. This method, known as pulse repetition frequency (PRF) switching, provides the accuracy of pulse delay ranging for long range targets while operating at higher energy outputs. An alternate method of ranging employed in some air radar modes (high PRF) is to vary the frequency of the transmitted wave and observe the lag in time between this modulation and the corresponding modulation of the received echoes. This type of ranging, referred to as frequency modulation (FM) ranging, is used when there is simply insufficient time between pulses to measure range. Although not as accurate as pulse delay ranging, FM ranging provides an alternative when the pulses are simply coming and going too rapidly to use pulse delay ranging. PRF switching and FM ranging are introduced here for your information, however, neither ranging method is used in the air-to-surface radar system. Both modes of ranging will be discussed in greater detail in the air radar system.

b. Doppler Effect. The doppler effect is defined as a shift in the frequency of a wave radiated, reflected, or received by an object in motion. The classic example of the doppler effect is the change in pitch of a locomotive's whistle as it passes by. The whistle pitch (frequency) is high as the train approaches and lowers as the train passes.

A radio wave radiated from a radar behaves in a similar manner in that it is compressed in the direction of motion and is spread out in the opposite direction. In both cases, the greater the object's speed, the greater the effect will be. Only at right angles to the motion is the wave unaffected. Since frequency is inversely proportional to wavelength, the more compressed the wave is, the higher its frequency is, and vice versa. Therefore, the frequency of the wave is shifted in direct proportion to the object's velocity.

Because of the doppler effect, the RF (radio frequency) of the echoes the radar receives is generally shifted slightly relative to the frequency of the transmitted wave. Consequently, by sensing a return's doppler shift, or doppler frequency as it is often called, a radar not only can measure range rates, but also can separate target echoes from clutter, or produce high resolution ground maps (i.e., Expand modes).

Doppler shifts are produced by the relative motion of the radar (i.e., ownship velocity) and the objects from which the radar's radio waves are reflected. If the distance between the radar and the reflecting object is decreasing, the waves are compressed. Their wavelength is shortened and their frequency is increased. If the distance is increasing, the effect is just the opposite. The doppler effect disappears completely in the pure beam aspect. In this case, the RF energy waves are not compressed or stretched when they are bounced back to the radar since it is not moving towards or away from the aircraft.

With ground-based radars, any relative motion is due entirely to movement of the radar's targets. Return from the ground has no doppler shift. Differentiating between ground clutter and the echoes of moving targets, therefore, is comparatively easy. With airborne radars, on the other hand, the relative motion may be due to the motion of either the radar or the targets, or both. Consequently, both airborne target echoes and ground returns have doppler shifts. This complicates the task for the radar in that the ground return has a doppler shift due to the ownship velocity in addition to any other target's motion.

1.3.1.2.2 Summary of Pulse Doppler Radar. The function of a pulse doppler radar is defined by its name. A pulse doppler radar is a pulsed radar which has the capability to generate coherent pulse transmissions and thereby measure doppler frequencies. Pulsed operation prevents the transmitted signal from interfering with the receiver and provides the capability for simple pulse delay ranging. By sensing a return's doppler shift, or doppler frequency, the radar not only can measure range rates, but also can separate target echoes from clutter, or produce high resolution ground maps (i.e., Expand modes). Thus, a pulse doppler radar can take advantage of both its pulsed operation as well as its ability to measure doppler frequencies to extract the desired data from received returns.

1.3.2 Basic Radar Terminology and Definitions. This section introduces the pilot to basic radar terminology and definitions so he may become familiar with the language and abbreviations that will become commonplace to the experienced radar operator. See Figure 1-17.

1.3.2.1 Carrier Frequency. The carrier frequency is the RF on which the radar transmits. Frequency is the number of complete oscillations an energy wave exhibits in one second. Carrier frequency should not be confused with PRF (pulse repetition frequency) which is the number of pulses transmitted each second. See Figure 1-18.

The APG-65 operates in the I- band (8 to 10 GHz), however, it does not always transmit on the same exact carrier frequency. The carrier frequency can be varied within a limited operating band to transmit on any number of different frequencies, called channels, to satisfy specific system or operational requirements. For example, the ability to transmit on various channels serves to reduce mutual interference from

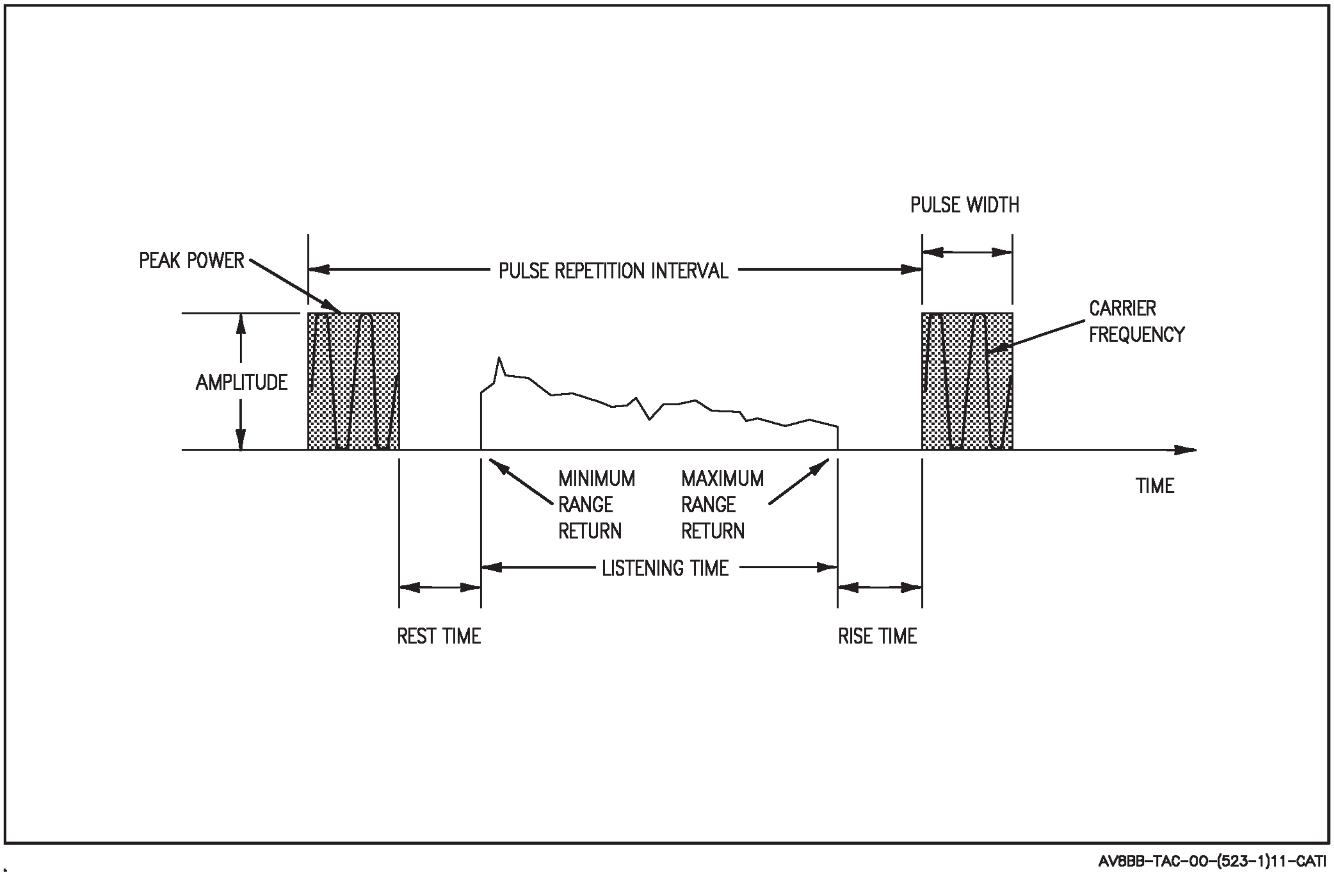

Figure 1-17. Anatomy of a Radar Pulse

nearby aircraft and allows some small scale frequency agility for ECCM. When the pilot selects a manual channel number via the CHAN option, he is actually selecting a specific carrier frequency.

1.3.2.2 Pulse Width (PW). Pulse width is the length of time that the radar is on for each pulse transmitted, normally expressed in microseconds. Pulse width may also be expressed in terms of physical length. That is, the distance, at any one instant, between the leading and trailing edge of a pulse as it travels through space. Pulse width is of keen interest because it normally determines the ability of a radar to resolve (separate) closely spaced targets in range.

1.3.2.3 Pulse Repetition Frequency (PRF). PRF is the number of radar pulses transmitted each second. The PRFs of airborne I-band radars are generally categorized as low (about 250 hertz to 4 kHz), medium (about 10 to 20 kHz) and high (100 to 300 kHz). PRF frequencies are extremely small compared to an I-band carrier frequency (8 to 10 GHz). The PRF used by the radar varies depending on the mode, range, and pilot selection.

There are several other measures associated with PRF which the pilot should be familiar with. One is the period of time between the start of one pulse and the start of the next pulse. This is called the interpulse period or the pulse repetition interval (PRI). See Figure 1-19.

Another measure is the time between pulses when the radar receiver is actually receiving echoes. This is referred to as the listening time and defines the minimum and maximum ranges which can be measured by pulse delay ranging.

The choice of PRF is crucial because it determines whether and to what extent the ranges and doppler frequencies observed by the radar will be ambiguous, that is, capable of being misinterpreted.

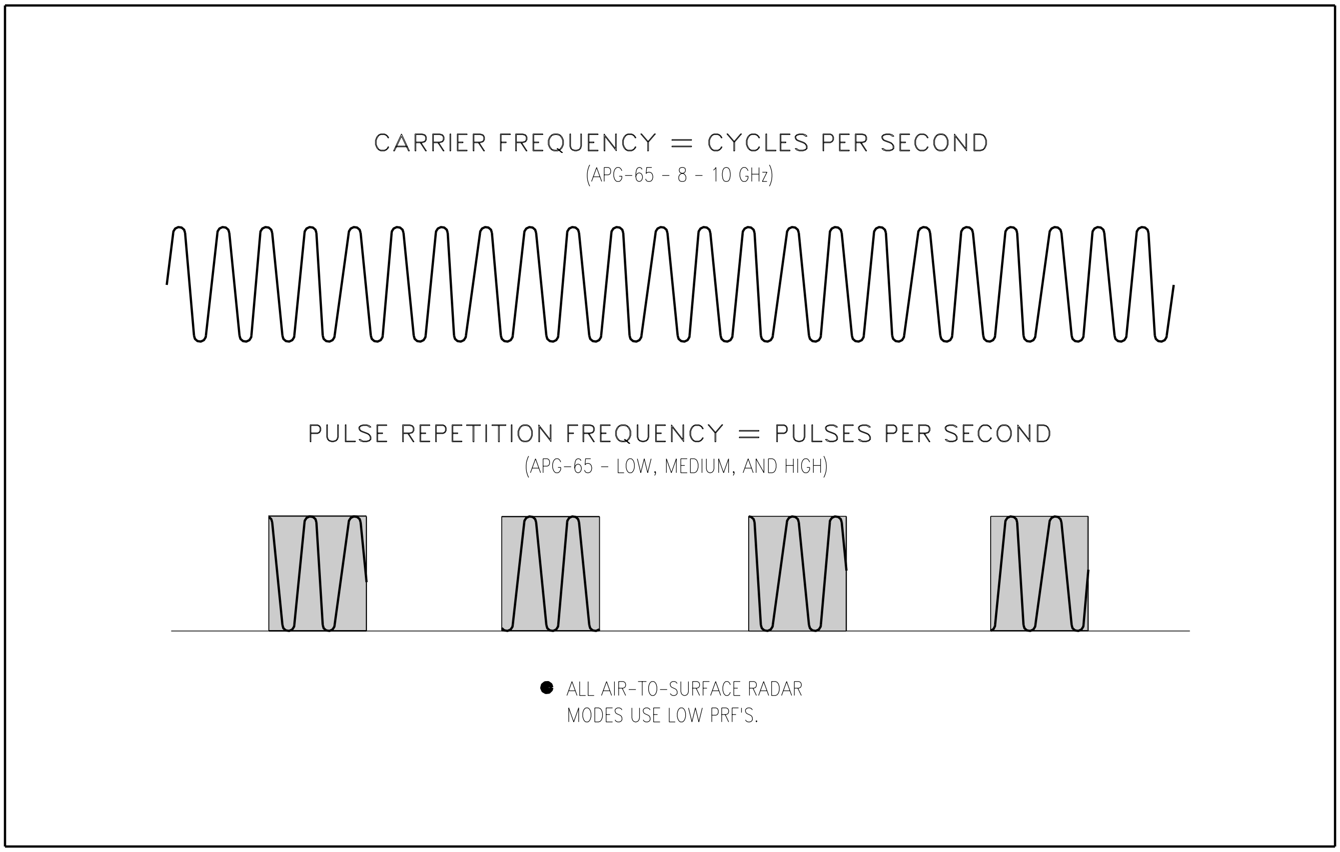

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Figure 1-18. Carrier Frequency/PRF Frequency

1.3.2.3.1 Range Ambiguities. A radar has no direct way of telling which pulse a particular echo belongs to. If the listening time is long enough for all echoes of one pulse to be received before the next pulse is transmitted, this doesn't matter: any echo can be assumed to belong to the immediately preceding pulse. But, if the listening time is shorter than this, depending on how much shorter it is, an echo may belong to any one of a number of preceding pulses. Thus, the ranges observed by the radar may be ambiguous. If a target echo reaches the antenna at the exact moment the radar begins transmitting another pulse of RF energy the echo is not detected because the receiver is disabled during transmit time. This is referred to as target eclipsing. If the target echo arrives at the antenna slightly before or slightly after initiation of the pulse, only partial eclipsing occurs. This causes what is known as a target fade in the receiver processing circuits. The higher the PRF, the shorter the listening time, hence, the more severe the ambiguities will be and the greater the chances of target eclipsing and target fades.

All of the air-to-surface radar modes use low PRFs. All air-to-surface PRFs are automatically selected by the radar and vary depending on the mode and range selected. In each case the listening time is large compared to the pulse width which enables simple pulse delay ranging. All target echoes are detected by the receiver before the next pulse of energy is transmitted, thus the listening time is sufficiently long to prevent range ambiguities. On the other hand, the air radar modes utilize PRFs in the low, medium and high categories, therefore, as noted earlier special techniques (multiple PRF switching and FM ranging) must be used to avoid the problems

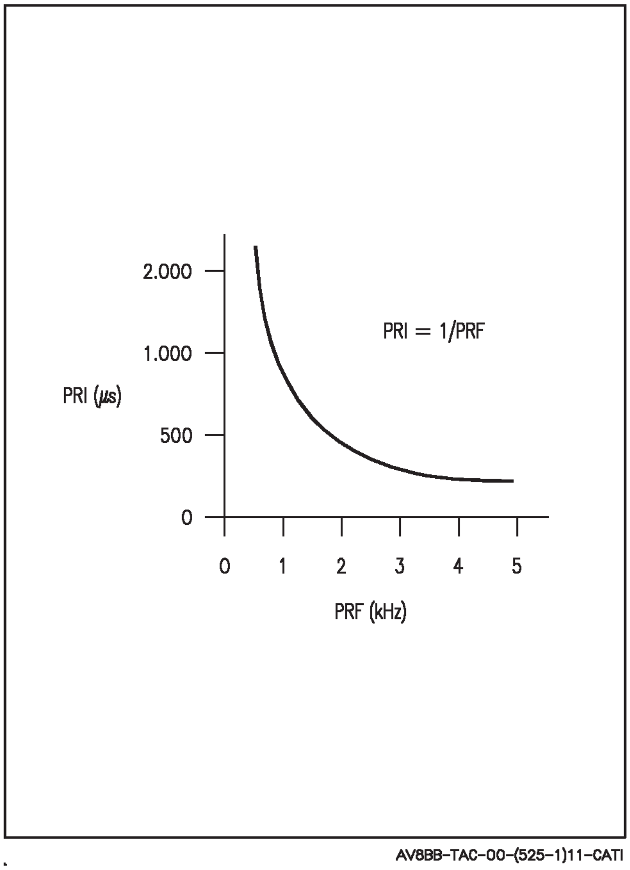

Figure 1-19. Pulse Repetition Interval

associated with the inevitable range ambiguities, target eclipsing and target fades. This will be discussed in greater detail in the air radar system.

1.3.2.3.2 Doppler Ambiguities. Doppler ambiguities arise because of the discontinuous nature of a pulsed signal. As with observed ranges, depending on the PRF, the observed doppler frequencies may be ambiguous. In the case of doppler frequency, though, the relationship is reversed: the higher the PRF, the less severe the ambiguities will be. Indeed, the definition of a high PRF is one for which the observed doppler frequencies of all significant targets are unambiguous. On the other hand, in the air-to-surface radar modes where low PRFs are used exclusively doppler ambiguities are quite severe.

1.3.2.3.3 Summary of PRF. Three categories of PRF are used in the APG-65: low, medium and high. See Figure 1-20. A low PRF is one for which the maximum required operating range falls within the first range zone or listening time. Simple pulse delay ranging can therefore be used to determine range. However, in many radar applications, knowing a target's angle and range relative to the radar is not enough. Often one must be able to predict the target's position at some future time. For that, we must know the target's angular rate and its range rate.

Range rate can be indirectly determined using low PRFs by measuring the target position rate of change from a series of echoes - a method referred to as range differentiation. In another and generally superior method, the radar measures the target's doppler frequency since it is directly proportional to the range rate. However, determining range rate by virtue of doppler frequency is not practical for low PRFs because of severe doppler ambiguities. In contrast, a high PRF is one for which doppler frequencies of all significant targets are unambiguous, therefore using a high PRF eliminates this problem. However, simple ranging techniques such as pulse delay ranging are impractical for high PRFs since the receiver listening time is cut to a minimum. Thus, both low and high PRFs have their distinct advantages and distinct disadvantages.

Medium PRFs were conceived as a compromise to handle the limitations of low and high PRFs. A medium PRF is one for which both range and doppler frequency are ambiguous. At first glance, this doesn't seem like a solution to the problem, however, if the value of the PRF is judiciously selected, the ambiguities inherent to medium PRFs are comparatively easy to resolve. As noted above, all of the air-to-surface radar modes use low PRFs and they are automatically selected based on mode and range.

ADVANTAGES	LIMITATIONS
LOW PRF	
1. Good for air-to-air look-up and ground mapping.	1. Poor for air-to-air lookdown - much target return may be rejected along with mainlobe clutter.
2. Good for precise range measurement and fine range resolution.	2. Ground moving targets can be a problem.
3. Simple pulse delay ranging possible.	3. Doppler ambiguities generally too severe to be resolved.
4. Normal sidelobe return can be rejected.	
MEDIUM PRF	
1. Good all aspect capability - copes satisfactorily with both mainlobe and sidelobe clutter.	1. Detection range against both low and high closing rate targets can be limited by sidelobe clutter.
2. Ground moving targets readily eliminated.	2. Must resolve both range and doppler ambiguities.
3. Pulse delay ranging possible.	3. Special measures needed to reject sidelobe return from strong ground targets.
HIGH PRF	
1. Good nose-aspect capability - high closing rate targets appear in clutter free region of spectrum.	1. Detection range against low closing targets may be degraded by sidelobe clutter.
2. High average power associated with high PRF increases detection range.	2. Precludes use of simple, accurate pulse delay ranging.
3. Mainlobe clutter can be rejected without also rejecting target echoes.	3. Targets in or near the beam aspect may be rejected.
	4. Tail aspect targets will not be detected.

Figure 1-20. PRF Considerations

1.3.2.4 Radar Power - (Peak Power and Average Power). When discussing radar power, two different measures are commonly used to describe the power of a pulsed radar's output: peak power and average power. Peak power refers to the greatest power level achieved by a single radar pulse. Peak power must be fairly high in order to pack enough energy into each pulse to travel great distances, encounter atmospheric attenuation, and still be strong enough to be detected on its return. However, high peak power generates a great deal of heat which could cause real problems if it were sustained for very long. Fortunately it isn't, since each radar pulse is of such short duration. However, even though the radar transmits in pulses, there are upper limits on the acceptable level of peak power due to hardware and cooling requirements. Together, peak power and pulse width determine the amount of energy conveyed by the transmitted pulses. The energy in each pulse equals the peak power times the pulse width.

Since the radar transmits in discrete pulses, the energy in a train of pulses is what is important. This is related to average output power. A radar's average transmitted power is the power of the transmitted pulses averaged over the interpulse period, that is, the PRI. Average power equals the peak power times the ratio of the pulse width to the PRI. This ratio of pulse width to PRI is called the duty factor of the radar. Duty factor represents the fraction of the time the radar is actually transmitting. Average output power is important primarily because it is a key factor in determining the radar's potential detection range. See Figure 1-21.

Quite simply, high average output power results in more target returns (reflections) over a given period of time and thus a greater probability of detection. The total amount of energy transmitted in a given period equals the average power times the length of the PRI. In the interest of maximizing detection range, average power may be increased in any of three ways: by increasing the PRF, by increasing the pulse width, or by increasing the peak power. Thus, there are always tradeoffs in maximizing radar capabilities against operational requirements, and size and hardware limitations.

1.3.2.5 Coherency. In order for a radar to determine the doppler frequency of a return, it must have a reference with which to measure the doppler shift of the return. In this case, the reference is the transmitted signal. Coherence is a continuity, or consistency, in the radio frequency phases of successive radar pulses. Coherent transmissions are achieved in the APG-65 by, in effect, the transmitter (GTWT) chopping the pulses from a continuous wave of highly stable frequency. The APG-65 can operate in either a coherent mode with/without frequency agility or a non-coherent mode with frequency agility depending on the operational requirement. Coherent or non-coherent transmission is automatically selected by the radar based on the mode selected. See Figure 1-22.

1.3.2.6 Scan Volume. In order for the radar to achieve good azimuth resolution, as well as detect targets at greater ranges, the antenna concentrates the radiated energy into a narrow beam (3.9° diameter). For this reason, the beam must be scanned back and forth in azimuth and elevation in order to cover a large area.

In the air radar modes, the beam is systematically swept through the region in which targets are expected to appear. The path of the beam is called the search scan pattern and the region covered by the scan is called the scan volume or frame; the length of time the beam takes to scan the complete frame, the frame time. The scan pattern is a raster type scan with pilot selectable azimuth and elevation coverage. The elevation coverage is determined by the number of elevation scans, which is referred to as elevation bars. The number of elevation bars which can be selected range from 1 to 6 bars. Increasing the number of elevation bars increases the angular coverage of the antenna in elevation.

The surface radar modes operate in a similar manner, however, all surface radar modes which scan an area use a 1 bar scan pattern. When necessary, the antenna beam pattern can be changed to illuminate a larger portion of the scan volume. The mission computer (MC) commands either pencil beam, fan beam, or auto. When auto is commanded, the radar selects either the pencil or fan beam to provide target illumination

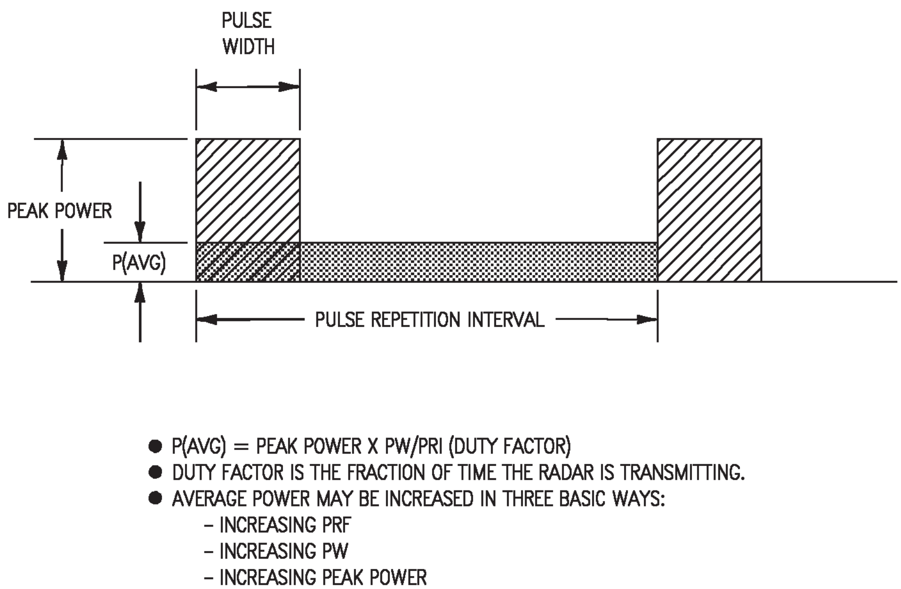

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Figure 1-21. Average Output Power - P(AVG)

out to the maximum display range and to maximize the signal-to-noise ratio. The pencil beam is a narrow (3.9°) beam centered about the antenna boresight. The fan beam is also 3.9° in azimuth but is 10° in elevation, hence it illuminates a larger area than the pencil beam.

1.3.2.7 Scan Rate. Scan rate is the rate at which the radar antenna sweeps, expressed as degrees/second. Scan rate will determine how often the radar paints a particular target. All of the surface radar modes use a fixed scan rate of 65° per second except for the expand modes which have a variable scan rate.

1.3.2.8 Summary of Principles of Radar Operation. By transmitting radio waves and listening for their echoes, the radar can detect objects day or night in just about any condition except heavy weather. By concentrating the RF pulses into a narrow beam, it can determine direction and by measuring the transit time of the pulses, it can measure range (pulse-delay ranging). Because of the doppler effect, the RF of the echoes the radar receives are shifted in proportion to the reflecting object's range rates. By sensing these shifts, the radar can measure target closing rates, reject clutter, and differentiate between ground return and moving vehicles on the ground. In addition, these doppler shifts can be used to create high resolution ground maps. The radar can even measure its own ground velocity (i.e., PVU) with precision (± 2 knots).

Because of its narrow beamwidth, the radar beam must be repeatedly swept through a search scan (scan volume) to cover a large area. Since radio waves are scattered and reflected in different amounts by different features of the terrain, the radar is capable of providing good quality ground mapping.

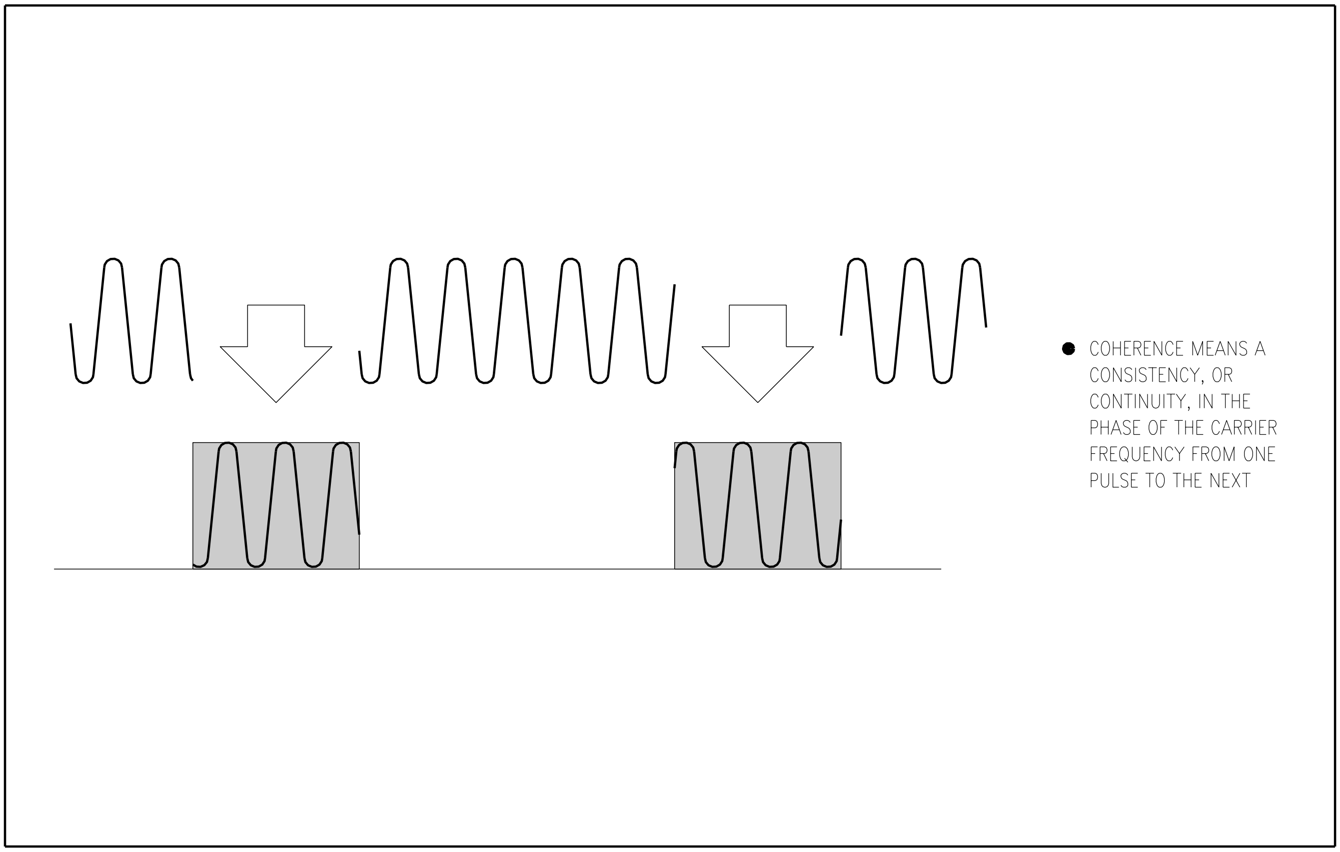

Figure 1-22. Coherent Pulse Transmission

1.3.3 Radar Set Component Description.

The AN/APG-65 radar set is a multiple mode, search and track radar. One of the major benefits of computer technology and the modern multimode pulse doppler radar is the degree of automation provided. In most cases, the pilot simply selects the desired operating mode and the optimum operating parameters are automatically selected and controlled by the radar. For example, the operating PRF for each air-to-surface radar mode is selected automatically and varies depending on the range and mode selected.

Since most of the operating parameters are controlled by the radar, pilot workload (i.e., radar switchology) is reduced significantly. Normally, a pushbutton actuation or a HOTAS selection is all that is required to enter the desired operating mode. This allows the pilot to concentrate more on the tactical arena and maintain good situational awareness. From a practical standpoint, it is important the pilot thoroughly understands all of the operating modes and their tactical features, however, it can be helpful to have a basic understanding of how the radar operates. This chapter is designed to provide a more technical look at the radar components and operation. This information is most useful after the pilot has already developed a good working knowledge of the radar's programs and operating modes.

The AV-8B radar is basically the same radar set used in the F/A-18. However, some modifications have been made in order to integrate the radar into the AV-8B aircraft. These modifications include the following:

1. Radar electronics have been distributed throughout the airframe in order to maintain critical cg (center-of-gravity) location.

2. New forward equipment rack.

3. Modified (smaller) antenna.

4. Modified Radar Target Data Processor - new timing and control circuit card for WRA separation.

5. Modified Computer-Power Supply - software update for smaller antenna and increased WRA separation.

6. The AV-8B radar uses a modified version of the F/A-18's *87X* software program.

7. Radar display formats are basically the same as those used in the F/A-18, however, pushbutton options have been relocated as necessary to retain AV-8B locations/logic.

8. HOTAS radar controls are designed to integrate into existing AV-8B Night Attack aircraft HOTAS format/philosophy.

1.3.3.1 Radar Set Equipment. The major radar set components include the computer-power supply (CPS), radar target data processor (RTDP), receiver-exciter (R/E), radar transmitter, and antenna. The antenna, radar transmitter and receiver-exciter make up the microwave part of the radar set, while the RTDP and CPS make up the processing and low voltage power supply part of the radar set.

1.3.3.1.1 Radar Computer-Power Supply. The radar computer-power supply (CPS) is a stored program digital processor and a low voltage power supply (LVPS). The CPS is located on the aft main equipment shelf. The CPS provides radar management control, selected data processing, performance monitoring and measurement, and low voltages required by the radar set (with the exception of the RTDP). The CPS controls the radar set components though commands over the radar multiplex bus and functions as the interface for signal handling and conditioning between the radar set and the MC.

The CPS has three program overlays (air-to-air, air-to-surface, and BIT) which it retrieves from memory depending on the mode commanded by the MC. This information is processed and used to load the RTDP, and commands the other radar set components to the correct mode of operation. The CPS sets the fault indicators for failed radar set components and supplies the MC with BIT status.

1.3.3.1.2 Radar Target Data Processor. The radar target data processor (RTDP) is a high speed, software controlled programmable signal processor. The RTDP is located on the aft main equipment shelf. With the CPS providing primary control, the RTDP provides radar timing, mode control, and target data interpretation functions. Timing and control outputs include analog-to-digital sampling, PRF generation, transmit/receiver keying, pulse compression, and receiver gain controls. The RTDP is software programmed by the CPS for its individual modes of operation. Once programmed, the RTDP operates independently from the CPS until reprogrammed. The main inputs to the RTDP are digitized radar video from the receiver-exciter and command and program data from the CPS. The main RTDP outputs are target parameters such as target hit/miss data, target range and frequency data, and tracking discriminant data to the CPS in the air-to-air mode, and composite video to the display computer in the air-to-surface mode.

1.3.3.1.3 Radar Receiver-Exciter. The receiver - exciter provides the radar set's receiver function (i.e., target echo processing), and provides the low level RF drive signal for amplifications by the radar transmitter. The receiver-exciter is located in the radar equipment rack in the nose cone.

As a receiver, the receiver-exciter provides low noise amplification of the received RF pulses (echoes), then down-converts them to a digital signal for use by the RDTP. The receiver has two parallel channels for target return processing; main/sum and guard/differences. The main/sum channel receiver target returns for the main antenna array via the radar transmitter. The main/sum channel processes main array targets retained in search modes and sum pattern returns in tracking modes (i.e. monopulse track). The guard/difference channel receives target returns directly from the antenna. The guard/difference channels receive guard horn returns in search modes and difference pattern returns in the track modes. The two receive channels will operate independently or be combined at the receiver output depending on the mode.

The exciter has three sections: the references oscillator (RO), the local oscillator (LO) and the transmitter driver. The RO is an oven-controlled crystal oscillator which serves as the primary reference frequency for the exciter. The exciter uses the LO to generate stable low level drive signals for the transmitter. Signal modulation (pulse comparison, FM ranging, frequency agility) may be performed before the low-power pulsed waveform is supplied to the transmitter for amplification. The LO can operate in either a coherent mode with/without frequency agility or a non-coherent mode with frequency agility. Coherence allows comparison of the target return signal with a reference signal for frequency (doppler) shift evaluation.

1.3.3.1.4 Radar Transmitter. The radar transmitter is a liquid cooled, high power RF amplifier that amplifies RF signals for transmission through the antenna. Other functions include duplexing of main/sum channel RF echoes and receiver protection. The transmitter is located in the radar equipment rack in the nose cone.

The transmitter accepts the low level RF drive signal from the receiver-exciter and amplifies it using a gridded traveling wave tube to produce a high power RF output. The high power RF pulses are routed through a duplexer to a waveguide switch which routes the RF pulses to either a dummy load (weight-on-wheels) or the main antenna. In a weight-on-wheels condition, RF energy is routed to the dummy load to prevent the accidental radiation of ground personnel. Receiver protection is provided by a multipactor. The multipactor operates as a high speed microwave switch to protect the receiver from any excessive transmitter leakage or direct transmission from other radars.

1.3.3.1.5 Radar Antenna. The radar antenna radiates RF pulses from the transmitter and receives target return echoes for processing by the receiver. The main antenna is a 23.2 inch planar (flat) array in the nose of the aircraft. The antenna is driven by direct coupled electric motors on a two axis gimbal assembly. The antenna gimbal limits are $\pm 70^\circ$ azimuth and $\pm 60^\circ$ elevation. See Figure 1-23.

The planar array antenna consists of an array of hundreds of individual radiators distributed over a flat surface. The radiators are slots cut in the walls of a complex of waveguides that forms the face of the antenna. The RF feed network is set up so that the array is broken into quadrants of radiating slots to allow monopulse tracking to be achieved. The antenna also contains guard, null filling, and flood horn antennas for specialized functions.

The main planar array antenna radiates the high power RF pulses from the radar transmitter through either a pencil or fan shaped beam. When the transmitter is periodically shut off during the interpulse periods, the antenna receives target return echoes. During the receive time, the RF echoes are processed into a main/guard signal during search mode or a sum/difference signal during track modes.

In search modes, guard horn receptions are routed along with the main array target echo returns to the radar receiver-exciter. The guard horn input is used in some modes to suppress signals from the main antenna array side lobes.

1.3.3.1.6 Radar Interface with Display System. In order to integrate the radar into the AV-8B avionic system, a number of additions and modifications are required. The aircraft uses the same basic MC (XN-6 variant of the AYK-14) as the AV-8B Night Attack aircraft. However, the MC software is modified to delete the ARBS software and add control of the radar. In addition, a third input/output (I/O) channel is added to connect the MC and the display computer. See Figure 1-24.

The AV-8B radar aircraft uses a modified display computer (DC). The DC has been repackaged for installation in the aft fuselage and uses modified software. In addition to its' other functions, the DC receives the radar video signal and performs radar video scan conversion for display purposes. The DC also performs radar serial interface and control. A high speed, serial digital mux bus (D Bus) connects the DC

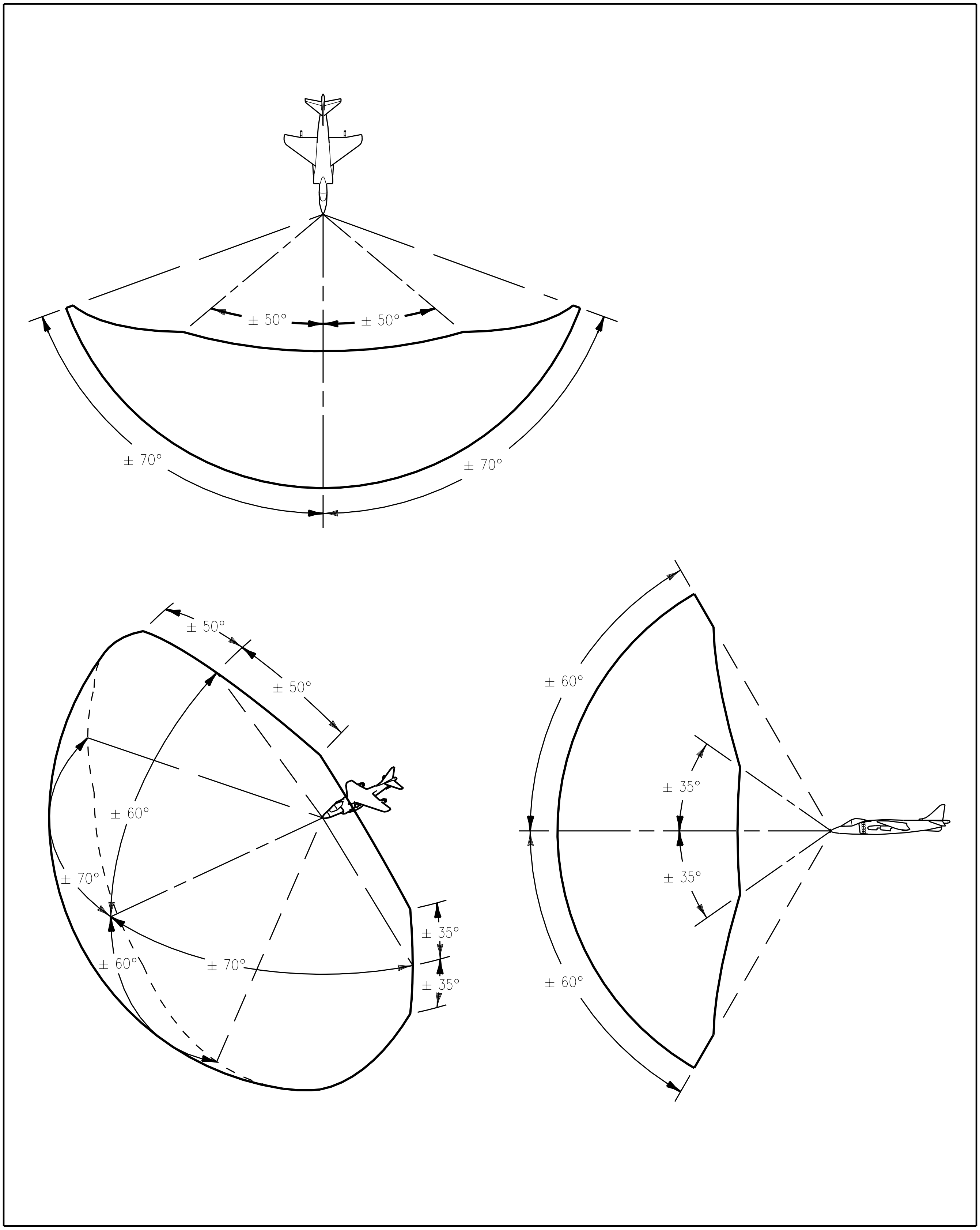

Figure 1-23. Radar Field of Regard

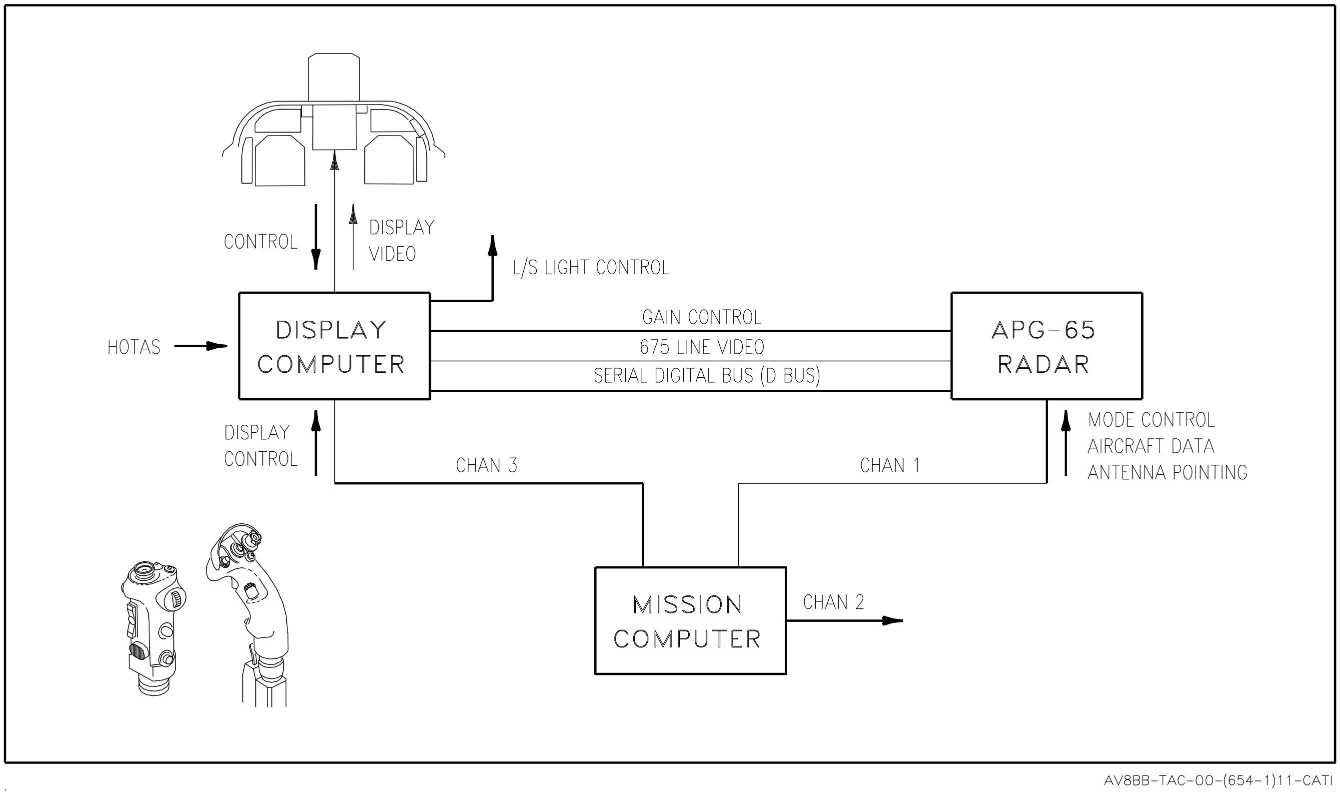

Figure 1-24. Radar Interface Display

and the radar. Since the radar is directly connected to the display computer via a serial digital mux bus, backup radar operation is available with a MC failure. For more information on backup radar operation and displays, refer to Chapter 2.

1.3.4 Radar Controls and Indicators

1.3.4.1 Radar Switch. The RADAR switch is on the miscellaneous switch panel, directly above the INS controls. See Figure 1-25. The switch has four positions:

1. OFF - Removes all radar set power

2. STBY (Standby) - All radar functions are operational except the radar transmitter and RF transmission circuits. Allows radar set to warmup before application of high voltage.

3. OPR (Operate) - The radar is placed in the normal mode of operation. Commands radar to full operation if all safety interlocks have been satisfied and initial warmup and ORT (operational readiness test) is complete.

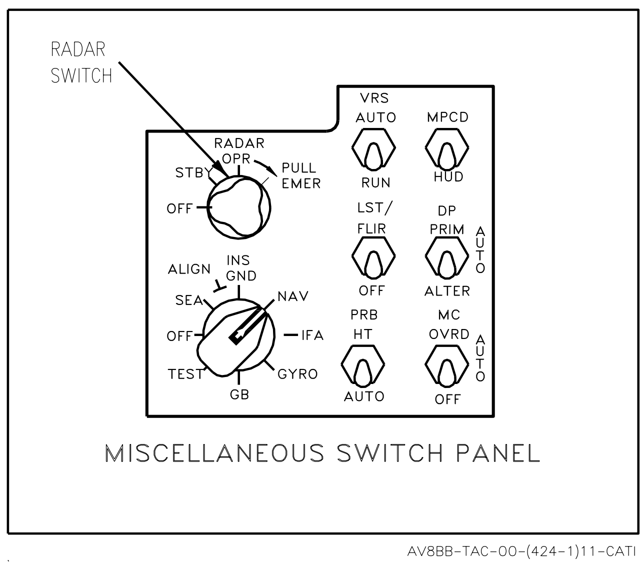

Figure 1-25. Radar Switch

4. EMER (Emergency) - With weight-off-wheels, bypasses temperature and pressure interlocks and allows full radar operation. The radar is prevented from shutting down due to an overheat condition. If the radar overheats, it will automatically shut down 30 seconds

after the overheat (OVHT) indication appears unless EMER is selected. Selection of EMER with weight-on-wheels will turn the radar off.

1.3.4.2 UFC Emission Control Button (EMCON). All onboard emitters except the radios and the RALT during a WOF and TOO, are disabled when the EMCON button is selected. When EMCON is selected with the air-to-surface radar display format enabled, the SIL (Silent) and FRZ (Freeze) options are selected, the ACTIVE option is displayed at the upper right pushbutton position, and the Maltese cross is displayed in the lower left corner of the radar display. The ACTIVE option, although displayed, is not functional with EMCON selected. When EMCON is selected with the air-to-air radar display format enabled, the SIL option is selected and the Maltese cross is displayed in the lower left corner of the radar display. Reactuation of the EMCON button enables radar transmissions, unboxes the SIL and FRZ options, and removes the ACTIVE and Maltese cross from the radar display.

1.3.4.3 Radar HOTAS Controls

1.3.4.3.1 Target Designator Control (TDC). The TDC provides slewing control for various functions depending on sensor/mode selection. The pushbutton switch is used to enable slewing control and/or command designation. The TDC provides acquisition cursor slew, EXP1, EXP2, or EXP3 display corral slew, or in-video cursor slew for the radar depending on the radar mode of operation. The TDC is also used in conjunction with the acquisition cursor to select radar parameters from the non-tactical portion (perimeter) of the radar display via HOTAS. The TDC, in conjunction with the acquisition cursor, can also be used to indicate antenna scan coverage with respect to altitude versus range. See Figure 1-26.

1.3.4.3.2 Antenna Elevation Control. The radar antenna elevation control is a three position rocker switch spring loaded to a neutral center position with momentary up and down positions. Depressing and holding the top or bottom of the switch commands the antenna in the respective up or down direction at a 5.8° per second rate. Releasing the control allows the control to return to a neutral position and stops antenna elevation movement. Full range is ± 60° in elevation about the aircraft waterline. The antenna elevation angle is denoted on the radar display by an elevation scale and caret. See Figure 1-26.

1.3.4.3.3 Air Program Select (APS) Button. The APS button on the throttle has two separate functions; one for the A/A master mode and one for the A/G, NAV, and VSTOL master modes. Alternate depressions of the APS button in A/G, NAV, or VSTOL master mode selects and deselects the air-to-air program of the APG-65 and boxes/unboxes the AIR option.

Selecting the AIR option initially selects the default RWS (range while search) mode display: 40 nm range, 140° azimuth scan, 4 bar elevation scan, 8 sec target aging, interleaved PRF.

Deselecting the AIR option switches the radar back to the default air-to-surface radar display: MAP mode, 40 nm (AUTO) range, 120° azimuth scan, auto beam selection.

The AIR option provides the pilot with an A/A search and track capability while remaining in the selected master mode. Air program functionality depends on whether the aircraft is in the A/G, NAV or VSTOL master mode (refer to the AIR option in this chapter for further information on this feature). Depressing the button again switches the radar back to the default air-to-surface radar display: MAP mode, 40 nm range, 120° azimuth scan, auto beam selection.

In the A/A master mode, depressing the APS button provides a HOTAS method of decrementing the radar range scale in RWS/TWS or to cycle the velocity scale (2400 or 800 knots) in VS.

In the A/A mode, with track while scan (TWS) or range while search (RWS) selected, depressing the APS button allows selected decrementing of the range scale. It is mechanized to decrement from the currently selected range and then wraparound to the max range available for the

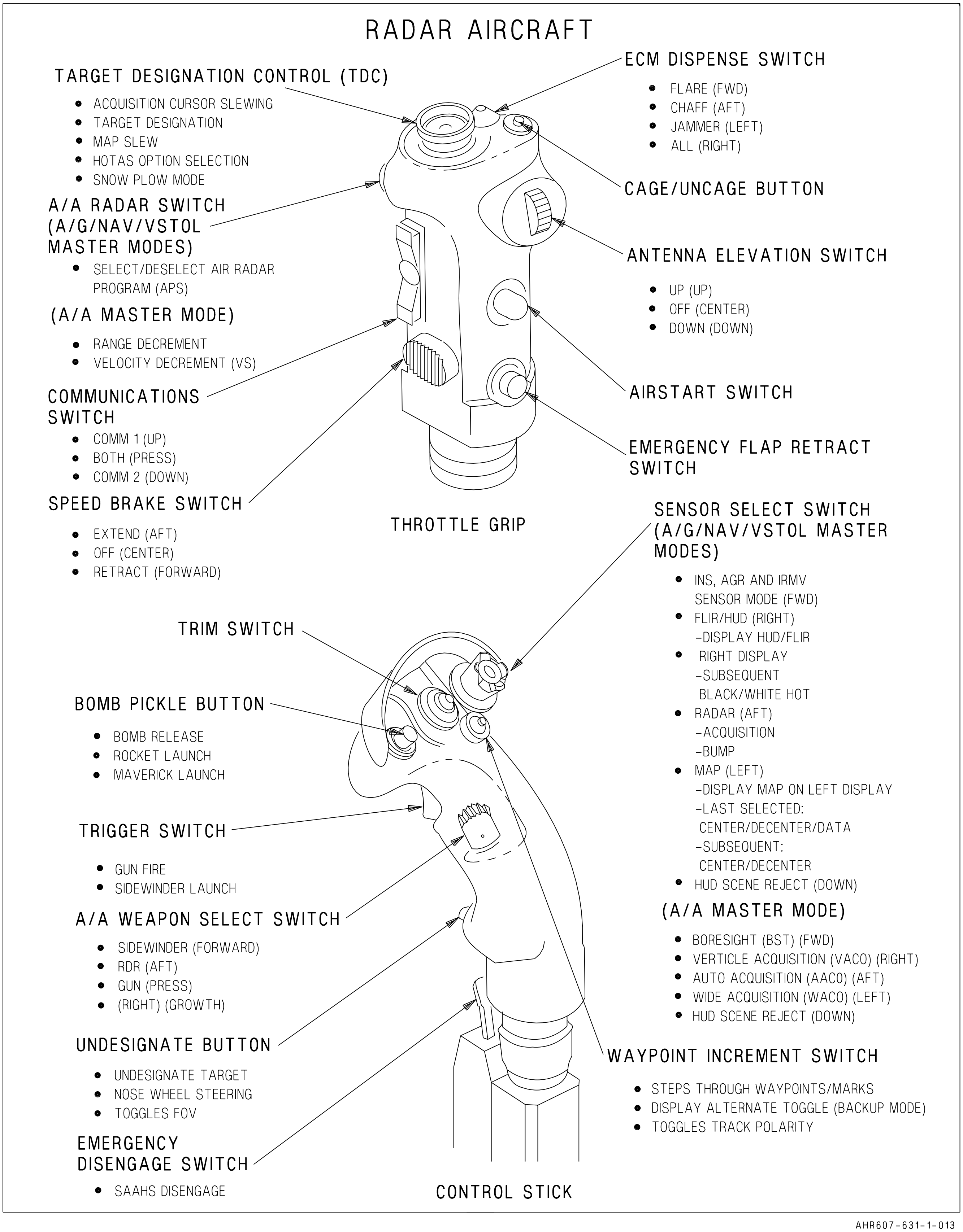

Figure 1-26. Radar HOTAS Controls

selected mode. For example, in RWS, if the selected range is 40 nm, successive depressions would result in 20, 10, 5, 160, 80, 40, ...etc.

In the A/A master mode with VS selected, successive depressions alternate between the 2400 (power -up default selection) and 800 knots velocity scales.

1.3.4.3.4 Cage/Uncage Switch

a. Gun mode. Radar not tracking (or LCOS option selected) - alternately selects long/short range LCOS (Lead Computing Optical Sight) gun reticle. Radar tracking (LCOS not selected on stores page) - switch is not functional.

b. Sidewinder (AIM-9) selected. The cage/uncage switch is used to command missile track/break track. Sidewinder seeker head operation depends on the missile selection (Boresight or SEAM) and radar operation.

c. Summary. When the Sidewinder is selected, the cage/uncage button is assigned to the Sidewinders. Actuating the cage/uncage button uncages the selected Sidewinder missile seeker and commands it to track the target. The missile, however, will only track if sufficient IR return is present. Reactuation of the cage/uncage button commands the missile to break track and return to boresight. It is not required that a Sidewinder be uncaged and tracking a target before launch. When the missile is launched, it is automatically uncaged and enabled for target track.

When the gun is selected in the A/A master mode, the cage/uncage button is assigned to the gun. The HUD initializes to the long range gun reticle to provide computation for a 2,400 foot firing range. Actuating the cage/uncage button switches the HUD to the short range gun reticle to provide computation for a 1,200 foot firing range. A subsequent actuation of the cage/uncage button reselects the long range gun reticle. Regardless of which reticle is selected, the tip of the straight line extending from beneath both reticle indicates the bullet flightpath at a 4,800 firing range.

1.3.4.3.5 Air-to-Air Weapon Select Switch. A/A weapon selection automatically commands the A/A master mode, initializes the radar display to the selected weapon, and assigns the TDC to the radar. Sidewinder and gun mechanization with the radar off is basically the same as the Day and Night Attack aircraft except for SEAM symbology on the HUD. (Note: the outer circle has been removed.) Associated with each A/A weapon selection (Sidewinder Boresight, SEAM, Gun) is a set of radar mode initialization parameters. When power is first applied (WOW), a default set of parameters is initialized. Gun initialization parameters are fixed. If the radar is not in STT or an ACM mode, selecting gun commands the GACQ mode. For Sidewinder Boresight and SEAM, the pilot can change PRF, azimuth, elevation bars, aging, and range initialization parameters using the SET option on the RWS display (SET is covered later).

A new inboard position has been added to the A/A Weapon Select Switch. This position is not functional with the current radar aircraft configuration but provides growth capability.

1.3.4.3.6 Trigger Switch. The trigger is used to command firing of all A/A weapons; Sidewinder and gun. In addition, when the trigger is pressed (second detent), the event marker is enabled. The event marker is superimposed on the HUD camera video and appears as a small black box in the upper left corner of the screen during playback. When the trigger is released, the event marker is removed.

1.3.4.3.7 Sensor Select Switch. The sensor select switch on the control stick has two separate sets of functions; one for the A/A master mode and one for the A/G, NAV, and VSTOL master modes. The sensor select switch has five tactical positions (six counting neutral) : FORWARD, LEFT, RIGHT, AFT, and DEPRESSED. All five positions are momentary and the switch returns to the center position when it is released. The same mechanization used in the Night Attack aircraft is used whenever practical on the Radar aircraft. The major differences deal with the deletion of the ARBS and the addition of the radar set. When operating in the A/A master mode (i.e., Sidewinder or

A/A gun selected), the sensor select switch, in conjunction with the A/A weapon select switch, provides a HOTAS method of commanding the automatic target acquisition modes (AACQ and ACM modes). This provides a fast and easy way to command track on a target and allows the pilot to remain heads-up when trying to get a VID or maintain *padlock* on a target. The sensor select switch functions are as follows:

1. FORWARD - In A/G, NAV, or VSTOL master mode, sliding the sensor select switch forward selects the INS sensor mode and assigns the TDC to the HUD. In order to provide a cue to the pilot, a dot is displayed in the middle of the velocity vector whenever the TDC is assigned to the HUD. In addition, initial actuation commands the radar to the air-to-ground ranging (AGR) mode.

   In air-to-air (A/A) master mode, sliding the sensor select switch forward selects the BST (Boresight) ACM mode. In the BST mode, the radar antenna positions to aircraft boresight (no scan) and remains pointed dead ahead. In order to give the pilot a radar coverage cue, the radar beam (3.9°) is depicted on the HUD by a dashed circle. The radar will automatically acquire the nearest target in the radar beam within a range of 10 nm.

2. LEFT - In A/G, NAV, or VSTOL master mode, if no EHSD is displayed headsdown, initial actuation selects the EHSD on the left MPCD. Subsequent actuation alternates the EHSD between the center and decenter modes (Same as the Night Attack aircraft).

   In A/A master mode, sliding the sensor select switch to the left selects the WACQ (Wide Acquisition) mode. When WACQ is selected, the radar is initialized to the RWS mode, 20 nm range scale, medium PRF, and 6 bar elevation scan pattern. Scan coverage is 140° in azimuth and encompasses 13.8° in elevation centered 1.5° below A/C waterline. The scan center is body stabilized in pitch while the azimuth sweeps of the antenna always remain parallel to the horizon.

3. RIGHT - In A/G , NAV, or VSTOL master mode, if no FLIR display is displayed heads-down, initial actuation selects a FLIR display on the right MPCD. Subsequent actuation alternately selects FLIR white hot/black hot polarity (Same as the Night Attack aircraft).

   In A/A master mode, sliding the sensor select switch to the right selects the VACQ (Vertical Acquisition) mode. In the VACQ mode, the radar scans a vertical sector (+5° to +55° above the waterline) aligned with the aircraft centerline. The general scan coverage area is denoted on the HUD by two vertical dashed lines spaced 5.2° apart. VACQ is aircraft referenced and offset vertically to ensure optimum chance for lock on in a tail chase.

4. AFT - In A/G, NAV, or VSTOL master mode, if no radar display is displayed (other than AGR), initial actuation selects the previously selected radar display on the right MPCD and assigns the TDC to the radar. Subsequent actuation commands radar acquisition/track. Releasing the switch commands the radar to track (FTT, GMTT). Subsequent actuation, after the radar is in track, commands the radar to break track. If the AIR option is selected (boxed) in the NAV or VSTOL master mode, sliding the sensor select switch aft commands the air radar's auto acquisition mode (AACQ).

   In A/A master mode, this switch has a dual function depending on whether the radar is tracking or not tracking a target and which radar mode is currently operating. If the radar is in RWS, VS, or TWS, momentary aft selection commands the radar to the auto-acquisition (AACQ) mode using existing search parameters. If the radar is in RWS or VS, the radar will initiate acquisition to command STT on the detection under the cursor, provided one exists. This feature is known as FAST ACQ. If the acquisition cursor has not been placed over a target, selecting AACQ commands track on the closest target in RWS or the highest closing velocity detection in VS. If no detections are present, the radar enters STT on the first detection. In TWS, the same logic is followed by commanding STT if an

L&S target or an unfiled target is under the cursor. However, if a non-L & S track file is under cursor, AACQ selection will reassign that track file as the L & S target. Similar to the RWS and VS mode of operation. If there is no target under the acquisition cursor, selecting AACQ in TWS will command STT on the L & S target or on the closest unfiled target if an L & S target is not established. If there are no target detections, the radar will command STT on the first detection. Once the radar is in STT, the pilot can *bump* the acquisition by reselecting the AACQ position. This establishes a range/azimuth exclusionary window about the current STT target to preclude immediate reacquisition, and commands the radar to search the scan volume and attempt lock on of the first detected target outside the exclusionary window. If no new targets are found after searching one frame (two if INTL PRF), the radar will command STT on the previously selected target.

5. DEPRESSED - Also known as the HUD scene reject feature, depressing the sensor select switch alternately displays/rejects the HUD FLIR display when the HUD brightness selector switch is in the NIGHT position (Same as the Night Attack aircraft).

1.3.4.3.8 Undesignate Button. Actuating the undesignate button undesignates a designated target (WYPT, O/S, radar designation, etc.). If the radar is tracking a target (surface or air), pressing the undesignate button breaks track in addition to undesignating the target.

The undesignate button has a number of functions in the A/A master mode, depending on the selected mode. Actuating the undesignate button while in STT commands the radar to return to search if it is tracking a target and commands the radar to return to the search mode commanded by the MC. If the radar is in STT, an ACM mode, AACQ, or manual acquisition, it will exit that mode and return to RWS, VS, TWS, or GACQ, depending on which was last used. The undesignate switch has no effect when the radar is in RWS, VS, or GACQ. If no other track file exists, the current L&S target remains unchanged.

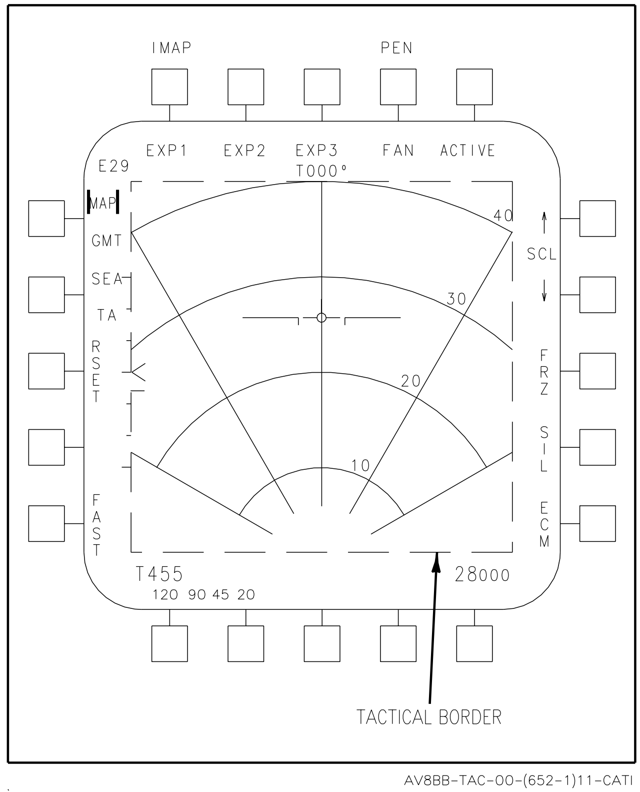

Figure 1-27. Air-to-Surface HOTAS Options

1.3.4.4 MPCD Indicators. Most radar controls are part of the radar display and are optimized for the mode in which the radar is currently operating. Actual radar data are displayed in the center 4″ × 4″ area referred to as the tactical region of the display. See Figure 1-27.

Most radar modes/parameters can be selected either by the MPCD pushbuttons or by HOTAS control. Generally with pushbutton control, the button is successively actuated to step through the available options until the desired option is indicated. The system makes extensive use of HOTAS operation of many radar options and parameters.

When the acquisition cursor is moved across the tactical border into a HOTAS region, the control functions/parameters available in that region are displayed. The desired function/ parameter is selected by positioning the cursor over it and actuating the TDC action switch. After the selection is made, the cursor either moves to its stowed position inside the upper left corner of the display border or, if applicable, it

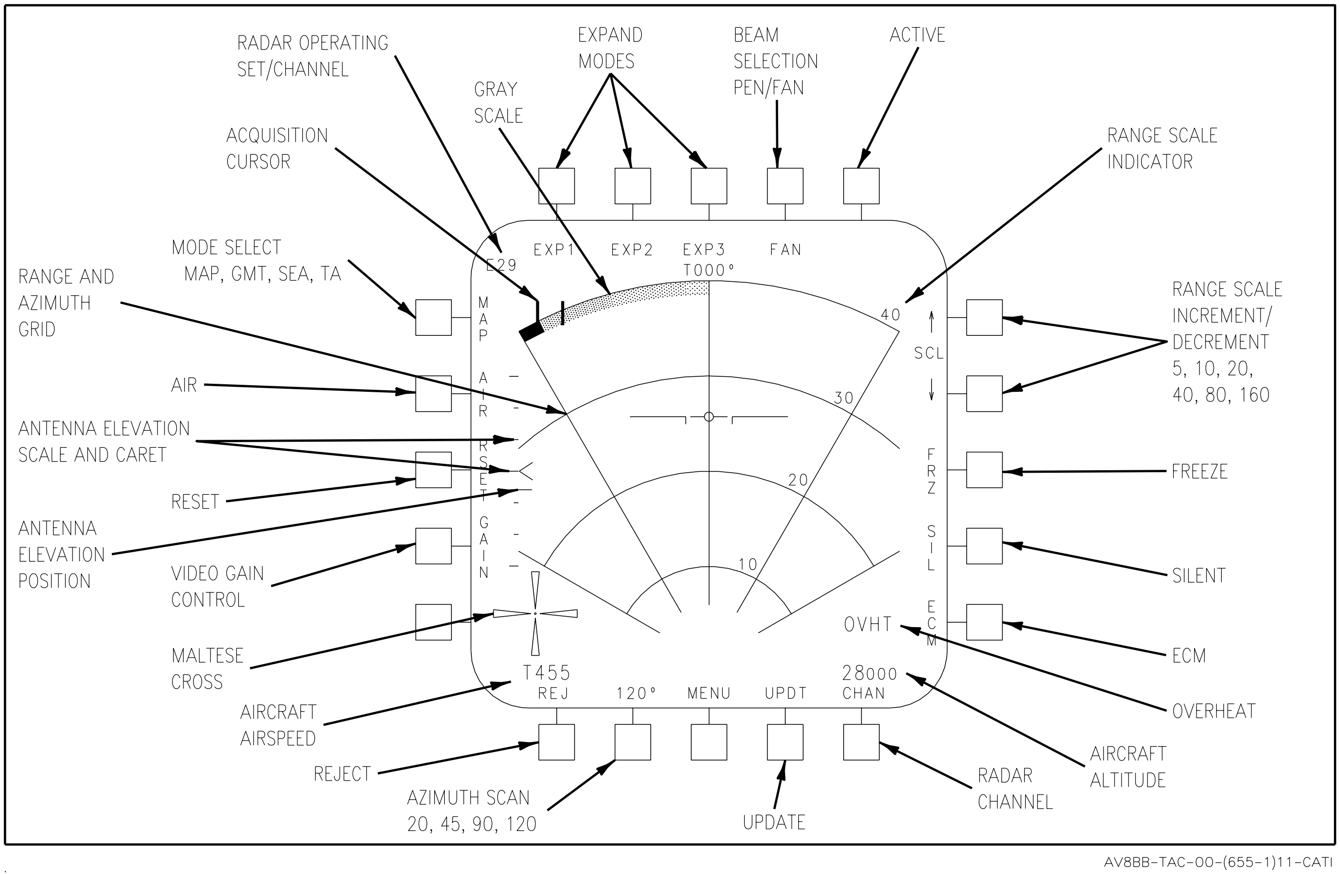

Figure 1-28. Radar Display Options/Parameters

remains over the option for further selection. The REJ, MENU, UPDT and CHAN options can not be selected via HOTAS.

The MAP mode is the basic air-to-surface radar mode. It uses the real radar beam to display the terrain in front of the aircraft. Many of the MPCD options are the same for all surface radar modes. For this reason, the basic MAP mode radar format is used to describe the radar options and parameters. Typical MAP mode displays are provided to more readily understand the following options (starting from the top left side and moving counter clockwise):

1.3.4.4.1 RF Channel Indication. The RF channel legend indicates the RF channel (i.e., carrier frequency) on which the radar set is operating. If the MC is commanding auto channel control, the commanded channel set will also be displayed to the left of the operating channel. When in auto channel control, the radar will operate in an automatic frequency agility mode utilizing the unique channels of the selected set. When in manual channel control the radar will operate only on the selected channel. Manual channel control is not selectable in the terrain avoidance (TA) mode. If manual was previously selected, it will be deselected when TA mode is entered. See Figure 1-28.

NOTE

If the radar detects a failure in the operating channel, a CH FAIL legend will be displayed to the right of the channel indication. The RF channel indication is applicable in all radar modes (surface and air). RF channel and channel control is covered in more detail under the CHAN option.

1.3.4.4.2 Acquisition Cursor. Two small vertical lines are positioned by the radar set in response to TDC slewing and MC commands. The cursor is used in conjunction with the TDC for target designation or HOTAS radar options selection. It is displayed only when the TDC is assigned to the radar, and only when target designation or HOTAS selections can be performed. The acquisition cursor is not available when operating in AGR, PVU, FTT, GMTT, STT, VACQ, GACQ, BST, and WACQ mode.

In the A/A master mode, when the cursor is in the tactical region, antenna beam altitude coverage at the cursor range is digitally displayed above and below the cursor. The lower number represents the lower altitude limit of the scan pattern in thousands of feet MSL and the upper number represents the upper altitude in thousands of feet MSL. This coverage is computed by the MC and is based on the number of elevation bars selected, antenna elevation angle, aircraft altitude, and the present acquisition cursor range.

When the cursor is moved across the radar border into a HOTAS region, the altitude coverage numerics are removed and the control functions/parameters available in that region are displayed. The desired function/parameter is selected by positioning the cursor over it and actuating the TDC action switch. After the selection is made, the cursor moves to its stowed position inside the upper left corner of the radar border except when selecting the range scale increment/decrement arrows and azimuth scan (until TDC is released).

1.3.4.4.3 Mode Option. In air-to-surface radar mode, the mode select option allows the pilot to select MAP/GMT/SEA or TA. When operating in the MAP, GMT, SEA, or TA modes, successive selections of the mode pushbutton will cause the MC to command the radar from MAP to GMT, to SEA, to TA and back to the MAP mode, in that order. The desired mode may also be selected by HOTAS. In this case, the pilot selects the mode by slewing the acquisition cursor over the desired option legend and depressing and releasing the TDC. In the EXP1, EXP2 or EXP3 modes, MAP is displayed at the mode select position. However, in order to return to the MAP mode the pilot must unbox the selected expand mode option vice boxing the MAP mode option or HOTAS select the MAP option. The radar will initialize to the default Surface mode: MAP, 40 nm AUTO range scale, 120° azimuth scan, auto beam selected.

A MODE FAIL legend will be displayed in the upper left corner of the display if P-BIT (Periodic BIT) detects a failure in the mode selected. The legend will be removed if P-BIT finds the failure cleared.

1.3.4.4.4 Air Option. Selection of the AIR option, by pushbutton or HOTAS, loads the air-to-air radar program without requiring the pilot to switch to the A/A master mode. The radar will initialize to the default air-to-air mode; RWS, 40 nm range scale, 140° azimuth scan, etc.. The availability of other air radar modes will depend on the current master mode. Pressing the AIR button a second time will return the radar to the air-to-surface program. The radar will initialize to the default surface mode: 40 nm AUTO range scale, 120° azimuth scan, auto beam selected.

1.3.4.4.5 Range and Azimuth Grid. The azimuth lines are displayed at 0°, ± 30°, and ± 60° (0°, ± 35°, ± 60° for TA). The 0° azimuth line is referenced to the aircraft ground track and is corrected for a maximum aircraft drift of 10°. The four range arcs are separated to divide the selected range scale into four equal segments, with the range arcs at one-fourth, one-half, three-fourths and maximum range of the selected range scale. All range and azimuth grid lines are displayed in the MAP, SEA, GMT, TA, and track modes.

1.3.4.4.6 Reset (RSET) Option. In the air-to-surface radar mode, selection of the RSET option, by either pushbutton or HOTAS selection, commands the radar to reinitialize the selected mode; the video gain, auto (PEN or FAN) beam selection, and the antenna elevation angle to provide optimum coverage for the selected range scale and present aircraft altitude. The antenna elevation angle will be reinitialized only when the antenna is not being positioned by the MC. The RSET option is a momentary option and will not be boxed when selected. This function is performed automatically by the radar in each mode when the mode is first selected, provided the MC is not slaving the radar antenna as the result of a radar track.

The reset (RSET) option is not provided in the AGR, PVU, or TA modes, when designated, or when the radar is tracking a target.

1.3.4.4.7 Antenna Elevation Scale and Caret. The antenna elevation scale indicates ±60° of antenna elevation, referenced to the local horizontal. The scale is graduated in 10° increments in the range of ±30° of antenna elevation, with the full ±60° range being displayed over the 4″ tactical display region of the radar display. The elevation caret moves on the scale to indicate the antenna elevation. Normally, the antenna elevation is automatically positioned by the radar to optimize radar coverage for the range, beam selection and altitude, however, the pilot has the option of manually positioning the antenna via the antenna elevation control on the throttle.

1.3.4.4.8 Video Gain (GAIN) Option. In the air-to-surface radar mode, target and clutter levels vary as a function of range because of the antenna elevation beam shape, grazing angle, and attenuation. Sensitivity time control (STC) is used to attain a nearly uniform target and clutter power level for all ranges by setting receiver gain (system sensitivity) as a function of range (Automatic Gain Control - AGC). When using AGC, the optimum gain setting is internally determined based on radar operating mode, radar range, antenna beam, aircraft altitude, and antenna elevation angle. The radar (RTDP) samples radar returns, both targets and clutter, and continuously updates the receiver gain to present the optimum picture for current conditions.

In the MAP and expand modes, the radar determines the optimum setting for the current conditions and uses that setting as the initial map gain control setting. The pilot may then adjust the gain from that initial setting via the GAIN option. In addition to the MAP and expand modes, when IMAP (Interleaved MAP) is selected in the SEA or GMT mode, the GAIN option is displayed so that the pilot may manually adjust the gain of the interleaved MAP video.

a. Operation. When the GAIN option is selected, it is replaced by up and down increment/decrement arrows with the selected gain displayed as a number between the arrows. This number, ranging from 1 to 9, indicates the relative video gain (system RF sensitivity) used by the radar. A value of 1 indicates the lowest possible gain setting (low system sensitivity), while a value of 9 indicates the highest gain setting (high system sensitivity). The GAIN option will reappear automatically when no action is taken for 10 seconds.

1.3.4.4.9 Optimum Antenna Elevation Position. This symbol indicates the antenna elevation angle which the radar has computed to achieve the optimum radar coverage for the range scale and operating beam selected, and for present aircraft altitude. The radar initializes the antenna elevation to this value when a mode is initially selected and the antenna is not slaved by the MC.

1.3.4.4.10 Maltese Cross (Iron Cross). A steady Maltese cross is displayed in the lower left corner of the radar display when the radar is not transmitting per normal operation. This includes the following situations:

1. Weight-on-Wheels
2. The radar power switch in STBY
3. The radar power switch in OPR with either EMCON or radar silent (SIL) selected.

In addition to the WOW feature which inhibits RF transmission on the deck, a Not In-Flight bit mechanization assures that the radar will not transmit while airborne during VSTOL operations. The Not In-Flight bit secures the radar transmitter if indicated airspeed is below 70 knots for more than 15 seconds.

A flashing Maltese cross is displayed if radar transmitter power is degraded or off as a result of an avionics or radar failure.

1.3.4.4.11 Airspeed and Altitude. Airspeed and altitude, which is identical to that displayed on the HUD, is displayed to provide a head-down reference. These readouts are provided by the MC and displayed in all radar modes except AGR, provided the data is valid.

1.3.4.4.12 Reject (REJ) Option. In air-to-surface radar mode, selecting the REJ option removes the horizon line and the appropriate flight reference symbol (i.e., velocity vector), and the intermediate range numerics from the display range arcs and boxes the REJ legend. REJ is applicable in all radar modes. HOTAS selection of the REJ option is not available.

1.3.4.4.13 Azimuth Scan Selection Option. The selected antenna azimuth scan width is numerically displayed above the second button from the left on the bottom row of the MPCD in the MAP, SEA, and GMT modes. This option is used to manually select the desired radar azimuth scan. In the MAP mode, repeated depressions of the pushbutton commands azimuth scans of 120°, 20°, 45°, 90°, 120° etc. The scan selections in MAP, SEA and GMT are identical, except that 120° azimuth scan is not available in the GMT mode.

Radar azimuth scans may also be selected using HOTAS. When the TDC is assigned to the radar and the acquisition cursor is slewed to the HOTAS azimuth scan region, the azimuth scan options are displayed. In order to change the azimuth scan, the pilot positions the cursor to bracket the desired azimuth scan and depresses the TDC to the action position.

If the TDC action switch is held pressed after making a HOTAS selection of less than 120°, the acquisition cursor repositions to the center of the display and is replaced by the in-video cursor. While the TDC is held depressed, scan centering control is available through left-right forces on the TDC. As the pilot slews the in-video cursor, the MC commands the radar to maintain the selected scan centered, within the 140° scan limits of the radar, on the cursor. After the TDC is released, the in-video cursor disappears, the acquisition cursor returns to the stowed position, and the antenna scan remains centered at the last cursor position. The pilot may recenter the scan pattern in the same manner. In addition, if a limited azimuth scan is selected while designated, the radar will attempt to center the azimuth scan about the designation (stab cue) within the gimbal limits of the radar.

1.3.4.4.14 Update Option. The UPDT option allows immediate access to the available update options on the ODU. Only the TCN and OVFY methods are available in the A/A master mode. The designate (DESG) and velocity (VEL) update methods are available in the NAV, VSTOL, and A/G master mode.

1.3.4.4.15 Channel (CHAN) Option. The CHAN option is used to select either the RF channel (Manual) or the RF channel set (Auto) in which the radar will transmit.

The RF channelization scheme of the radar is structured to reduce mutual interference between the radar sets of closely spaced equivalently equipped radar aircraft while at the same time allowing for small scale frequency agility to be performed. To achieve this, all of the available radar channels have been divided into small sets or banks of channels. These sets are labeled as A, B, C, D, E, F, G and *, where the * set is a unique set which contains nearly all of the radar channels. Each set allows the radar to transmit on a number of slightly different frequencies (channels) within the operating region (I band) of the radar. Refer to NWP 3-22.5-AV8B, Vol. III, Chapter 1 for channel set deconfliction recommendations.

When in manual channel control, the pilot will be able to select any of 26 individual channels on which to operate (29E, 30F, 31G, 4D, 5E, 6F, 7G, 8C, 9A, 10B, 11C, 12D, 13E, 14F, 15G, 17A, 18B, 19C, 20D, 21E, 22F, 23B, 25A, 26B, 27C, 28D, Repeat). Depending on whether or not the radar is operating in a Surface radar mode or an Air radar mode, the radar and MC will only allocate certain channels on which to operate.

When the CHAN option is selected, the CHAN option is replaced with the corresponding radar channel or channel set and the UPDT option is replaced by the MCHN option. Either automatic (MCHN unboxed) or manual (MCHN boxed) will be selected depending on the radar's current channel mode. At power up with weight-on-wheels or whenever the radar transitions between Air and Surface radar modes, automatic channel control is initially selected; otherwise, the last selected channel control is selected. If neither of the pushbuttons are selected for 10 seconds, the channel control options will be removed and the CHAN and UPDT options will reappear. See Figure 1-29.

When MCHN is unboxed, automatic control is selected and the MC will display the auto channel set as one of the eight auto channel sets (A, B, C, D, E, F, G, or *). When the aircraft powers up with weight-on-wheels, the radar will initialize to the * channel set. Subsequent depressions of the channel set option will scroll through and wraparound the channel sets in the order A, B, C, D, E, F, G, *, repeat. If automatic control is selected while the radar is operating in manual control the MC will command the radar to the channel set which corresponds to the previously selected manual channel.

Each set has a group of channels associated with it in which the radar will operate. As noted, in auto control the radar is free to perform small scale coherent frequency agility (CFA) within the commanded channel set. There is a unique CFA set for each auto channel, however, it is not pilot selectable.

When MCHN is boxed, manual channel control is selected, CFA is deselected, and the radar is limited to transmit only on the commanded channel. When manual control is selected, the manual channel number along with the channel set to which it has been assigned is displayed. When initially selected, the MC will command the radar to the channel on which the radar was last operating in the auto mode. If the previous auto mode channel is not selectable in manual, the MC commands the radar to the next higher available channel. Subsequent depressions of the channel number pushbutton will scroll through and wraparound the available channel numbers. The number of available channels depends on whether the radar is operating in a Surface radar mode or an Air radar mode. There are 26 available channels for the Surface radar modes. The available numbers range from 4 thru 31 with some channel numbers missing to account for the compatibility with all other modes.

The commanded channel set (auto) or number (manual) is blanked if it is not the same as the channel set/number the radar is currently operating in. This condition momentarily occurs when a new channel set or number is selected, or the pilot rapidly sequences (boxes and unboxes) the MCHN option between the auto and manual channel control selections.

When the TA (Terrain Avoidance) mode is selected, the radar is required to operate in a non-coherent frequency agility type mode. Therefore, whenever TA mode is selected, the radar will automatically default to auto channel control. If manual control is selected while the radar is operating in the TA mode, the MC will blank the channel number and the radar will continue to operate in auto control.

1.3.4.4.16 Overheat (OVHT) Indication. An overheat condition is indicated by the legend OVHT in the lower right corner of the currently active radar display. The OVHT indication appears when temperature sensors in the various radar WRAs exceed threshold limits. If the overheat condition continues for more than 30 seconds the radar system will shut down. If the pilot selects EMER with the RADAR switch within 30 seconds of the start of the overheat condition, the system will continue to operate until it fails. The exception to this is when a liquid coolant low flow fail is present along with an overheat condition. This is a fire hazard and the radar system will shut down for safety of flight reasons. The pilot can go to the BIT page from the main MENU to determine if a liquid coolant low flow condition exists (radar fault code 7).

Once an OVHT condition is sensed and the radar shuts down, it will remain shutdown until the system OVHT 30 second clock is reset. The pilot can reset the 30 second OVHT clock by switching the radar to OFF and then back to OPR or STBY on the radar switch. This will

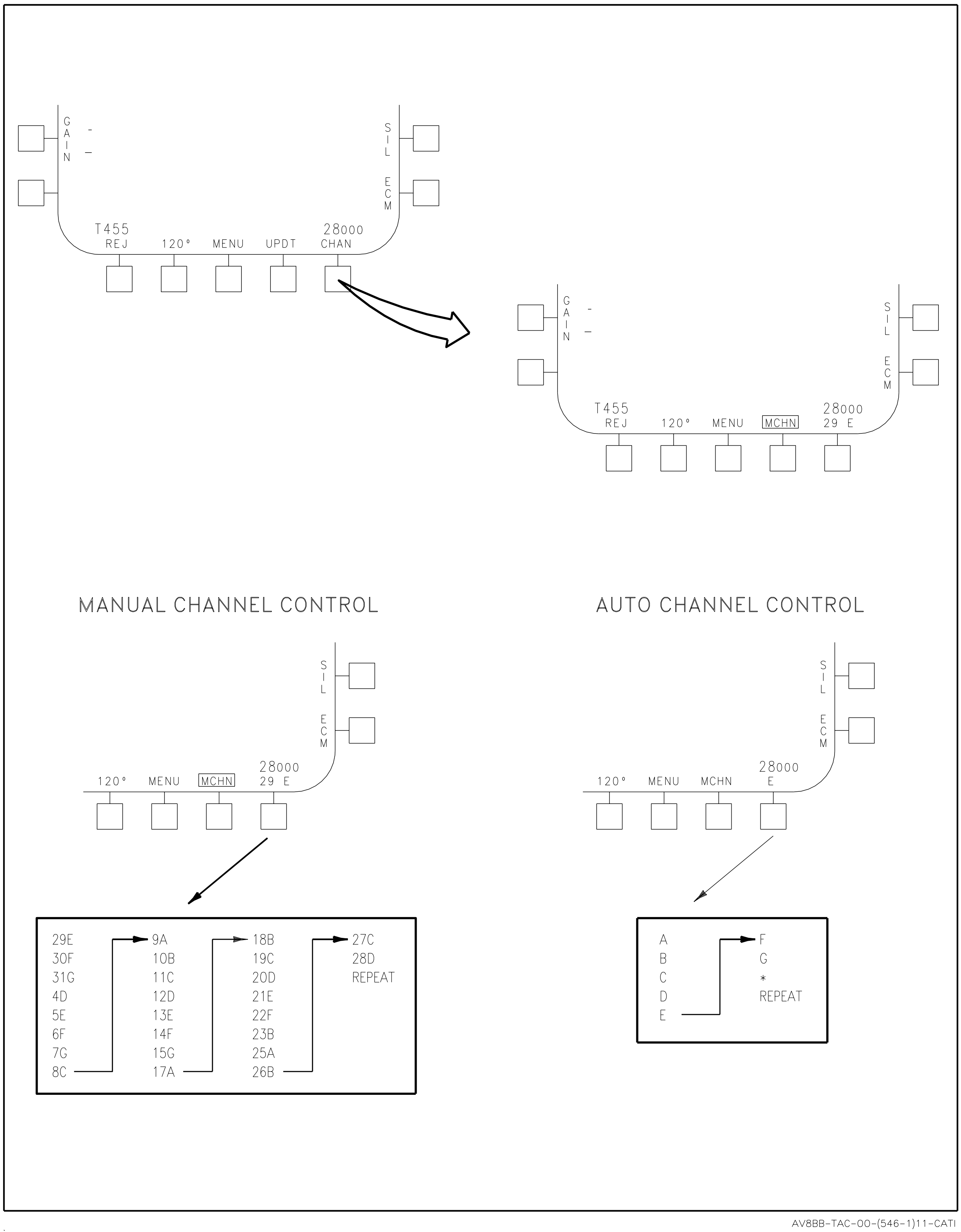

Figure 1-29. Channel Option

reset all OVHT conditions except liquid coolant low flow which is reported by a separate sensor and cannot be reset.

The radar system is cooled by both ECS cooling air and liquid cooling systems (LCS). Failure of either system could lead to an OVHT condition indication on the radar display. Cooling air failures are signaled by the MASTER CAUTION light, voice warning, and either the FWD BAY or AFT BAY caution lights. A failure in the LCS will produce a failure code (7) on the BIT page and lead to an OVHT condition in the transmitter. Selecting the EMER position on the radar switch with weight-on-wheels will shut the radar down.

CAUTION

Operating the radar with the RADAR switch in EMER, while the radar is in an overheat (OVHT) condition, can cause damage to the radar. The pilot should not operate the radar under these conditions unless it is mandatory.

1.3.4.4.17 ECM and ECCM Option. The APG-65 radar ECCM modes provide the capability to determine the presence and location of active ECM sources, and to automatically adapt the radar for search and acquisition performance against noise and deception type jammers. The pilot is alerted to the presence of a jamming environment by ECCM cues that are provided on the radar and HUD displays. The radar automatically changes its functional operation to a configuration that is best suited to counter the specific jamming detected. Selecting the ECM option, either via pushbutton or HOTAS, selects the ECM display. The ECCM (Electronic Counter Countermeasures) option on the ECM display deals only with the radar set. The ECCM option is displayed in all radar modes (Surface and Air) and is used to enable/disable radar ECCM processing. When disabled, the radar will not perform any active ECCM processing nor will it display most of the passive ECCM cuing. When ECCM is enabled, the option is boxed and the radar processes with full ECCM capability. ECCM is default selected (boxed) on power up with weight-on-wheels.

When ECCM is selected (boxed), the Surface radar provides the pilot with passive visual ECCM cuing. For more information on ECCM, and the radar display when jamming is detected, refer to NWP 3-22.5-AV8B, Vol. III, Chapter 6.

1.3.4.4.18 Silent (SIL) and Active (ACTIVE) Options. The SIL option is displayed directly above the ECM option and is applicable in all modes except AGR, PVU and TA. Selection of the SIL option commands the radar to terminate radar transmissions, however, the radar will continue to passively process received in-band signals for ECCM purposes. SIL is selected and deselected by alternate depressions of the pushbutton or it may be selected via HOTAS.

When SIL is selected, the radar freezes the video display, the Maltese cross is displayed in the lower left of the display, the FRZ (Freeze) option, directly above the SIL option, is boxed and the ACTIVE option appears under the top right pushbutton on the display. HOTAS or pushbutton selection of the ACTIVE option commands the radar to transmit for 1 frame which results in an updated video display. The FRZ legend will be unboxed and the Maltese cross will be removed during the ACTIVE frame and returned at the completion of the frame. At the completion of the scan, the radar returns to silent operation and the display is again frozen. When the ACTIVE option is selected via HOTAS, the acquisition cursor remains in its current position and is not stowed. This allows the pilot to command an additional active scan when required.

Changing radar modes while the SIL option is selected blanks the video. The radar video will not be displayed until either an active scan is performed, via selection of the ACTIVE option, or until the silent mode is deselected. When SIL is deselected, normal radar transmissions resume, the ACTIVE option is blanked, the FRZ option is unboxed, the Maltese cross is removed, and the video display is again updated with each radar scan.

1.3.4.5 Freeze (FRZ) Option. Either HOTAS or pushbutton selection of the FRZ option boxes the FRZ option and freezes the video display. In this case, the radar continues transmitting but does not update the video display. Upon deselection of the FRZ option (when silent operation has not been selected), the video is again updated by the radar scanning and the FRZ option is unboxed.

As noted above, the FRZ option is automatically selected when the SIL option is selected. Radar video will not be updated until either an active scan is performed via selection of the ACTIVE option or SIL is deselected. Selection of the FRZ option when SIL is selected unboxes the FRZ legend and causes the radar to blank the video within the tactical display region. Changing modes with SIL selected also blanks the video. The radar video will not be displayed until either an active scan is initiated via selection of the ACTIVE option, or until SIL is deselected. When the SIL option is deselected, the FRZ option is automatically deselected.

The FRZ option is not available in the AGR, PVU, and TA modes.

1.3.4.5.1 Range Scale Selection. The pilot utilizes the range decrement/increment pushbuttons adjacent to the upper and lower arrows to select the desired range. Depressing the range decrement pushbutton commands the radar to decrement to the next lower range. If the last selected range was 160 nm, then successive depressions will command the radar to 80, 40, 20, 10, and 5 nm. To decrement the range using HOTAS, the TDC is depressed and released while the acquisition cursor is positioned to bracket the decrement arrow. In this case the cursor does not automatically return to the stowed position after the range decrements. This permits the range to be decremented from 160 nm to 5 nm without having to reposition the cursor. When the 5 nm range is selected, further range decrements have no effect. The range increment function operates in the same manner.

The range increment/decrement arrows are applicable in the MAP, SEA, TA, and GMT modes. The range selection is limited to a maximum of 80 nm in the SEA mode unless interleaved (IMAP) operation with the MAP mode selected. The maximum range for the SEA/MAP interleaved mode is 160 nm. The GMT mode is limited to a maximum range of 40 nm. In TA mode, range scale selection is limited to 5 or 10 nm.

The range increment/decrement arrows are not displayed when a radar track or radar designation exists. In this case, the MC will automatically command range scale changes to maintain the stab cue or tracked target between 45 percent and 93 percent of the display.

1.3.4.5.2 Pencil/Fan (PEN/FAN) Beam Selection. The pencil (PEN) beam is a narrow (3.9° diameter) beam centered about the antenna boresight. The fan (FAN) beam is spread out in a vertical direction (10°) to cover a larger area at one time, but it retains the pen beam azimuth. The pilot can choose manual control of radar beam selection or it may be selected automatically by the MC. When auto beam selection is used, the radar automatically selects either pencil (PEN) or fan (FAN) to provide target illumination out to the maximum display range and to maximize signal-to-noise ratio.

Selection of the alternate action PEN/FAN option, either via pushbutton or HOTAS, disables auto beam selection and allows the pilot to manually select either the pencil beam or fan beam via a beam override command issued by the MC. When PEN is displayed (selected) and the button is pressed or a HOTAS selection is made by the pilot, the radar selects the fan beam and the FAN legend is displayed. The operation is identical in going from FAN to PEN. The pilot can reselect auto beam selection by selecting the reset (RSET) option.

Beam selection is only available in MAP, SEA and GMT radar modes.

1.3.4.5.3 Expand Mode Options (EXP1, EXP2 AND EXP3). The EXP1, EXP2 and EXP3 options command high resolution radar maps

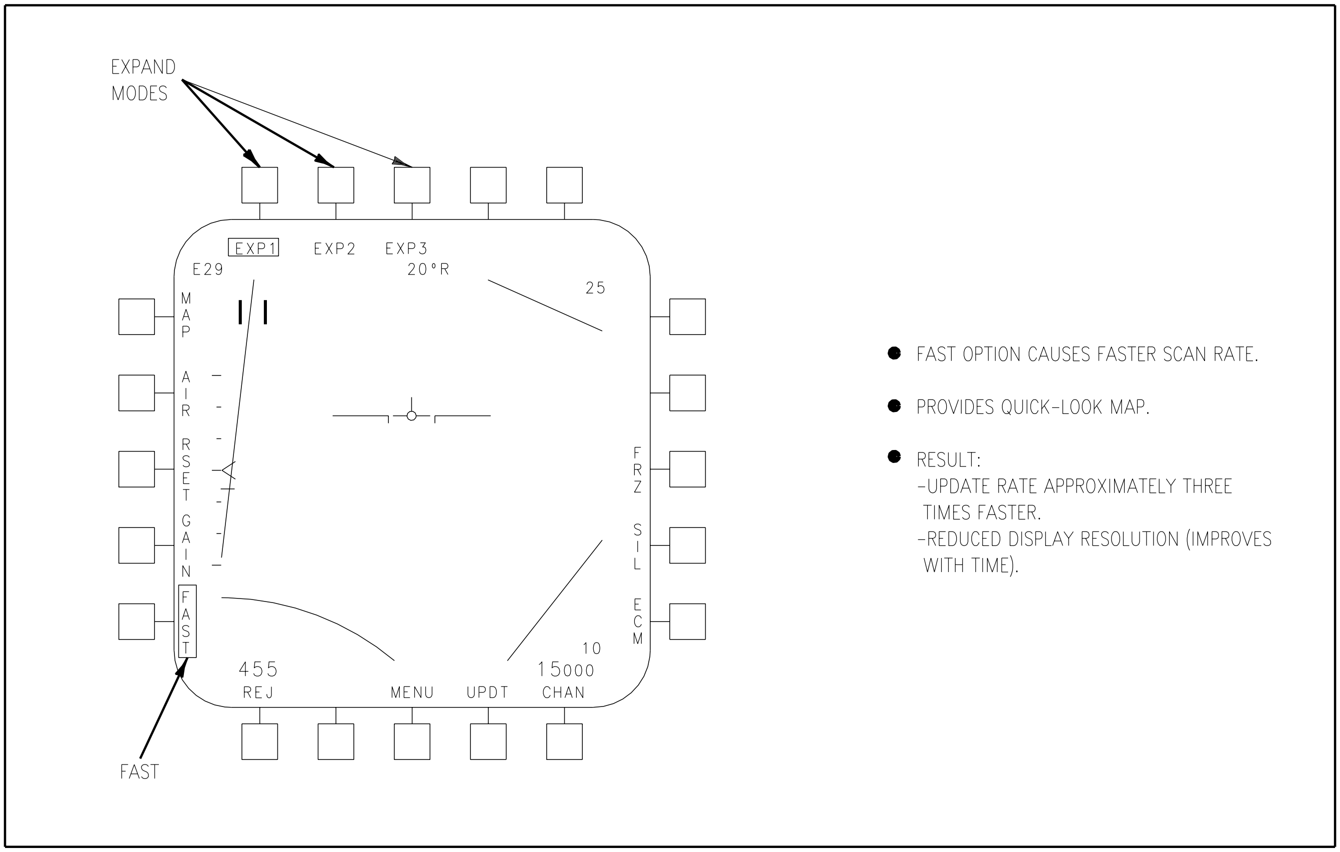

Figure 1-30. Expand Modes Fast Option

which use synthetic processing techniques such as DBS (Doppler Beam Sharpened) to improve ground mapping. The Expand modes can provide the pilot with improved detail of selected areas for improved area search and accurate target designation for navigation, update, or weapon delivery purposes.

The expand modes can be selected by either selecting the mode directly from the MAP mode or from another expand mode. The expand modes may be selected by depressing the appropriate pushbutton or via HOTAS.

1.3.4.5.4 Gray Scale. The top approximately 1/8 inch of the raster display of the MAP video consists of a gray scale. The gray scale is used as a reference to adjust the MPCD brightness and contrast. The gray scale has 8 levels of brightness from no return (black) to full return. In order to ensure that the full dynamic range of radar intensities is available, the pilot should adjust the MPCD controls so that all seven intensities on the gray scale are distinguishable and black is indeed black.

1.3.4.5.5 Fast (FAST) Option. When the EXP1, EXP2 or EXP3 mode is selected, a FAST option appears directly under the GAIN option on the left side of the display. Selecting the FAST option, either via pushbutton or HOTAS, will reduce the video processing time to about 1/3 of the normal processing time. When FAST is selected (boxed), the radar performs a faster scan with reduced processing of the selected area. This results in a display which initially has reduced quality but which is updated at approximately three times the rate at which it is updated when FAST is not selected. Display resolution will improve the longer the area is scanned. See Figure 1-30.

When the FAST option is not selected, the radar performs its full processing at a reduced scan rate, resulting in a high resolution display which has an update rate on the order of every 3

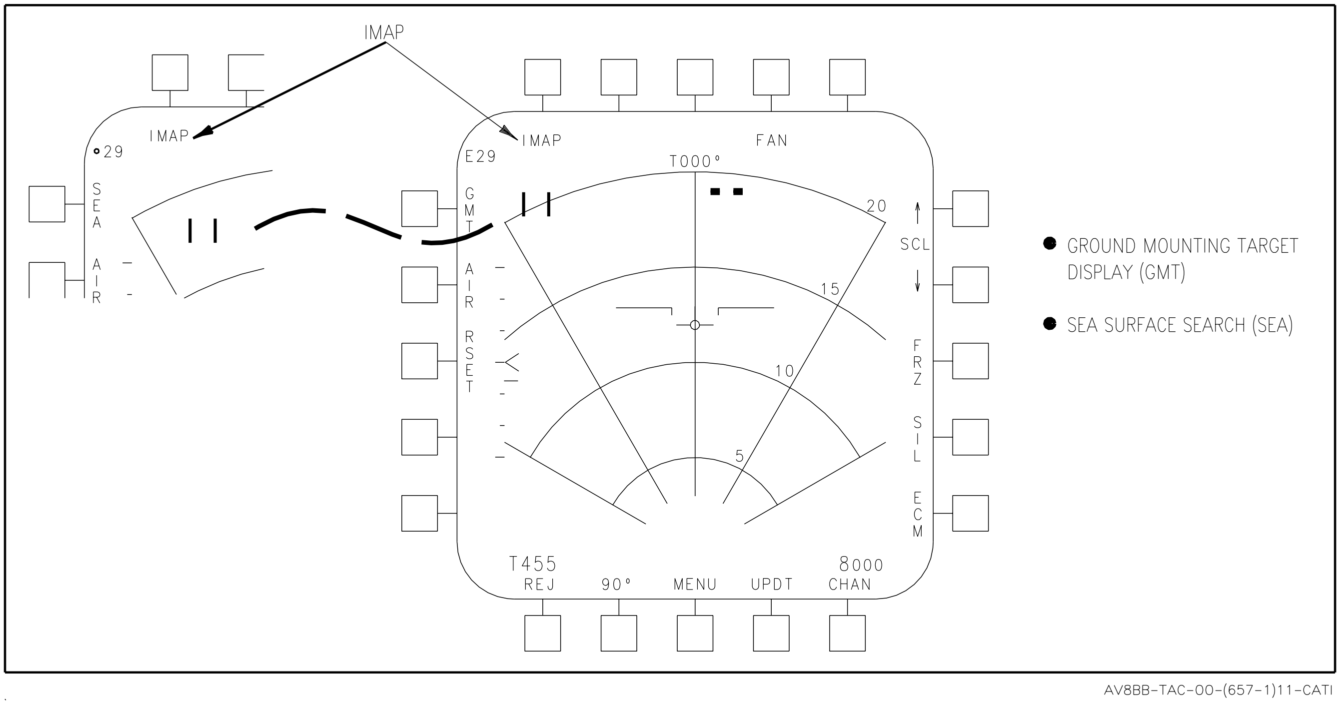

Figure 1-31. Interleaved MAP (IMAP) Option

to 8 seconds, depending on the angle off track; the greater the angle off track, the quicker the frame will build.

1.3.4.5.6 Interleaved Map (IMAP) Option. In the GMT mode and SEA mode, an IMAP option is displayed beneath the far left pushbutton on the top row of the MPCD. When the pilot selects the IMAP option, either via pushbutton or HOTAS, the radar is commanded to interleaved operations in which the radar scans in the MAP mode on a periodic basis in addition to scanning in the GMT or SEA modes. The resultant tactical video contains synthetic GMT or SEA mode target symbols superimposed over MAP mode video. When interleaved operation is selected, IMAP is boxed and the GAIN option is displayed and adjustable as described for the MAP mode. It may be necessary to adjust the gain setting to prevent the map video from washing out/occluding the synthetic target blips associated with the GMT and SEA modes. See Figure 1-31.

IMAP is a useful option since interleaved operation allows orientation of the synthetic targets (GMT or SEA) to the surrounding terrain. Once the IMAP option is selected for SEA or GMT mode, it remains selected for that mode until deselected by the pilot. Changing radar mode, or master mode, or cycling the radar transmitter off and on does not deselect IMAP.

NOTE

Selection of IMAP decreases search time and ultimately probability of detection in GMT and SEA modes. Processing is time shared between presenting interleaved mapping and searching for GMT/SEA targets. IMAP should be temporarily selected for geographical referencing.

1.3.4.5.7 Failure Legends. Failure indications can be displayed in the upper left hand corner of the radar display. All three failure legends appear in the same place and cannot be displayed at the same time. The priority for the display of the failures is as follows:

1. WPN FAIL

This legend appears flashing when an SMS function failure is reported in the A/G and A/A master mode. When practical, the pilot should select the SMSFF option on the BIT display to review the specific failure.

2. MODE FAIL

This legend will be displayed on the radar display when P-BIT detects a failure in the selected mode. The legend will be removed if P-BIT finds the failure cleared.

3. CH FAIL

This legend will be displayed on the radar display with the failed channel selected. Normally, if Auto channel is selected the radar will simply use another channel in the channel set. However, if Manual channel selection is being used this would cue the pilot to select another manual radar channel or switch to Auto channel control.

1.4 AIR-TO-SURFACE RADAR MODES AND OPERATION

The air-to-surface radar program performs four basic functions: mapping, search, track, and special use measurements. These functions are executed by eleven different modes within the surface program. The APG-65 air-to-surface program consists of the following modes.

1.4.1 Air-to-Surface Radar Modes. Air-to-surface radar modes are as follows:

1. Mapping:

   (a) Real Beam Ground Map (RBGM) - MAP

   (b) Doppler Beam Sharpened (DBS) Sector - EXP1

   (c) Doppler Beam Sharpened (DBS) Patch - EXP2

   (d) Medium Resolution Synthetic Aperture Radar (MRSAR) - EXP3

2. Search:

   (a) Sea Surface Search - SEA

   (b) Ground Moving Target - GMT

3. Track:

   (a) Fixed Target Track - FTT

   (b) Ground Moving Target Track - GMTT

4. Special Use:

   (a) Terrain Avoidance - TA

   (b) Air-to-Ground Ranging - AGR

   (c) Precision Velocity Update - PVU

1.4.2 Mapping Modes. The MAP and expand (EXP1, EXP2, EXP3) modes are generally used for navigation and to detect ground targets. The MAP mode uses the radar real beam to display a large sector of the terrain in front of the aircraft. The MAP mode is useful for the *big picture* and finding the approximate location of selected targets, however, resolution is fairly poor when compared to the Expand modes. The Expand modes can be thought of as submodes of the MAP mode which provide high resolution patch maps of selected areas. In addition to displaying a magnified view of selected areas, they offer improved scene detail for more accurate area search, and precise target designation.

1.4.3 Search Modes. The SEA and GMT modes are special modes which provide a synthetic display of target returns (solid rectangles). Both modes allow the pilot to detect, designate and track targets. The SEA mode is optimized for detecting targets (ships or small islands) on large bodies of water and can be used as a substitute for the MAP mode at sea. The GMT mode also provides a synthetic display of target returns similar to the SEA mode display. The only target returns displayed in the GMT mode, however, are from moving targets (trucks or tanks moving down a road). Ground and fixed returns are not displayed. Both the SEA and GMT modes may be interleaved (IMAP selected) with the MAP mode in order to display the synthetic targets overlayed over MAP video. IMAP is a useful feature in that it allows the pilot to orient the synthetic targets to their surroundings.

1.4.4 Track Modes. There are two types of radar track: Fixed Target Track (FTT) and Ground Moving Target Track (GMTT). When track is established, the radar antenna remains pointed at the target and the radar automatically maintains target position. Both types of radar track are essentially the same, the difference dealing from which mode the radar track is established. A radar track from the MAP, Expand, or SEA modes is known as FTT while a radar track from the GMT mode is known as a GMTT.

1.4.5 Special Use Modes. In the TA mode, the radar searches the area ahead of the aircraft and displays detected obstructions on the radar display. This mode can be used to confirm what the pilot sees (either unaided or sensor visual) but is *not* designed to provide an all-weather terrain avoidance capability.

The AGR and PVU modes are special use modes that work in conjunction with other MC and INS functions. The AGR mode provides accurate slant range measurements along the commanded LOS. Valid AGR is the priority source for ranging data and determining height above target for weapon delivery computations. The PVU mode provides accurate radar-derived velocities of aircraft ground speed which can be used to improve weapon delivery computations or for in-flight alignment (IFA) purposes.

1.4.6 Radar Power Up. The radar is turned on by selecting either STBY or OPR with the RADAR switch. Selection of either of these switch positions will initiate the radar warm-up sequence and the operational readiness test (ORT) sequence. It takes 3.5 to 4.0 minutes for the radar to perform warm-up and ORT. The ORT is performed concurrent with the warm-up process and begins after 30 seconds. During ORT, the pilot can select the radar display to monitor test status. During certain tests a radar video test display will be presented in the box. The legend TEST (see Figure 1-32) will appear in the upper left corner of the display followed by the number identifying the test being conducted. The test numbers range from 0.0 to 9.0. The first set of numbers 0.0 to 0.29 reflect the warm-up period prior to the first radar test. Test categories represented by the remaining numbers are as follows:

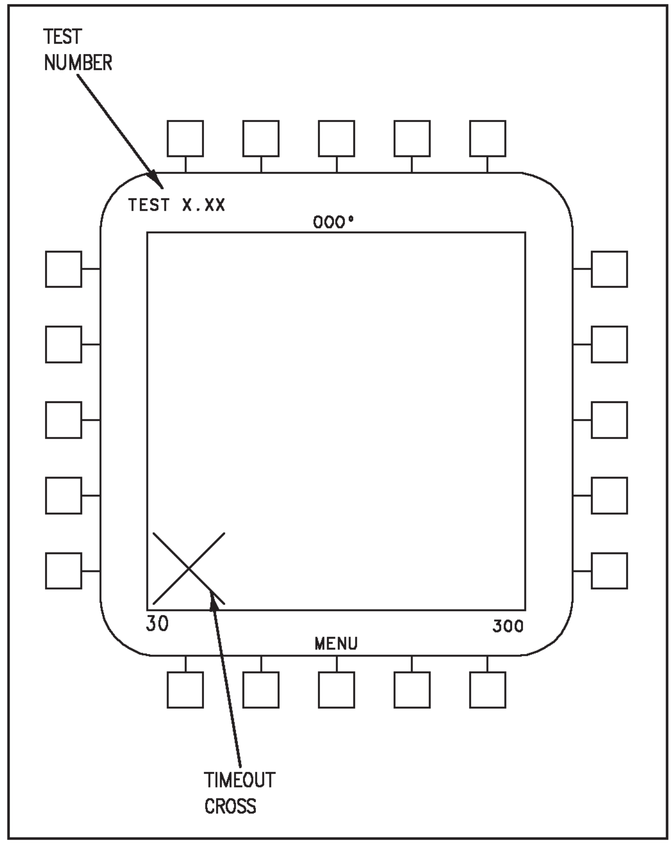

Figure 1-32. Radar Warm-up Display (ORT)

1.0 - Computer Power Supply Tests
2.0 - Computer Power Supply Tests
3.0 - Computer Power Supply Tests
4.0 - Computer Power Supply Tests
5.0 - Radar Target Data Processor Tests
6.0 - Antenna Servo Tests
7.0 - Receiver Exciter Tests
8.0 - Transmitter IBIT
9.0 - Fault Isolation Tests

After 1 minute, a time-out cross is displayed in the lower left corner of the MPCD to indicate the transmitter is not ready. After three minutes (+10 seconds), a Maltese cross replaces the time-out cross indicating that RF power transmission is inhibited and that the system is ready for the transmitter tests.

In order to protect ground personnel from radiation hazard, normal radar transmission is inhibited on the ground. During the ORT (and IBIT with weight-on-wheels), the transmitter tests are performed by transmitting into a dummy load. The transmitter test should take about 30 to 45 seconds to complete and can only be performed if the radar switch is in OPR and the aircraft is not in EMCON. Selecting STBY will inhibit transmission tests until OPR is selected. The radar will not function until these tests are completed and, if not completed on the ground, they will be completed in the air as soon as the radar is turned to OPR.

While on the ground, radar cooling is limited below 110 °F OAT. No time limit exists for ground operation above 110 °F. If the radar is operated in STBY or OPR for more than 10 minutes, RDR BIT failures may be observed that will clear when airborne. No permanent damage should occure.

If EMCON is selected prior to turning the radar on, transmitter tests will be deferred until EMCON is deselected. This will result in a 30 to 45 second delay in radar operation after EMCON is deselected to allow for the completion of the transmitter tests. The pilot does not have any indication of this 30 to 45 second delay prior to radar operation until EMCON is deselected.

If a test can not be performed, the system skips over the test and reinitiates it when it can be performed. Once all tests have been attempted, the radar format initializes as described later in this chapter.

In addition to the WOW feature which inhibits RF transmission on the deck, a *Not In-Flight BIT* mechanization assures that the radar will not transmit while airborne during VSTOL operations. The *Not In-Flight BIT* secures the radar transmitter if indicated airspeed is below 70 knots for more than 15 seconds. The radar will resume transmission when indicated airspeed exceeds 75 knots while weight off wheels. This mechanization serves as a backup for a WOW switch failure and assures the radar will not transmit on the ground. If the WOW switch and the in-flight bit do not agree for more than 150 seconds the radar software will declare a *WOW/In-Flight BIT disagree* BIT failure. This particular BIT failure is displayed as a number 9 beside the RDR legend on the BIT display. This indication will likely occur after performing hover checks. If so, an AUTO BIT is recommended.

1.4.7 Radar BIT. BIT provides the pilot and maintenance with detailed information regarding system failures down to the WRA (i.e., black box) level. There are two types of BIT; Periodic BIT (PBIT) and Initiated BIT (IBIT). The warm-up BIT (ORT) is generally considered an IBIT since it is initiated by the pilot during power-up. In addition to an initial system checkout, the pilot typically records and reports to maintenance the results of BIT tests performed during the mission. This includes PBIT and the ORT and can include IBIT tests performed using AUTO during pre and post flight, and any system IBITs selected during flight.

1.4.7.1 Periodic BIT. Periodic BIT (PBIT) executes automatically during radar operation and provides fail status information on the radar display for immediate use by the pilot. It also stores failure codes on the top level BIT page for inflight or postflight review and retains a count of failed tests on a separate MPCD maintenance data page. Operation of PBIT is transparent to the pilot as tests are scheduled on a non-interference basis within the software program.

PBIT is designed to identify 90 percent of all failures that occur in the radar operating mode. It tests the system between 1 and 20 times a second to ensure the pilot has current system status. In order to maintain test sensitivity while minimizing false alarms, the software must sense at least one PBIT failure of a specific test per minute for seven consecutive minutes before a failure indication will appear on the top-level BIT page, or before a hardware degrade will occur. A single minute with no failures resets the count. In addition to the fault codes presented on the top level BIT page, the results of PBIT tests include a cumulative count of the times a test was failed even if no fault code was sent to the top level BIT page. This information is provided on the BIT-MAINT-RDR page when

″A″ is selected (see paragraph 1.4.7.5). and is used to assist in troubleshooting the radar.

1.4.7.2 Initiated BIT. The initiated BIT (IBIT) is primarily used by maintenance for fault isolation to failed WRAs, and by the pilot prior to flight to ensure the avionic systems are working properly. IBIT is designed to be conducted with all radar WRAs in place and connected. The system is designed to detect at least 98 percent of all radar failures and isolate at least 99 percent of detected failures to the faulty WRA.

IBIT is accessed by selecting BIT from the main MENU page. IBIT can be initiated by pressing either the AUTO or the RDR option select pushbuttons. AUTO initiates BIT for radar and all other systems except the INS and the SAAHS. Pressing the RDR option initiates BIT for the radar system while on the ground or inflight. AUTO, however, is not available with weight-off-wheels.

As covered above, the radar self-test or ORT is initiated automatically when the system is powered up. The ORT is nearly identical to an IBIT, however, the results are stored on a separate MPCD maintenance data page to keep track of failures during system warm-up. Another difference between selected IBIT and ORT is that IBIT can be terminated at the end of any major test by selecting the STOP or MENU option pushbutton, while ORT will run until conclusion. The ORT is automatically initiated whenever the radar has been off for more than 7 seconds and is then powered up. It is this interval which defines the difference between a quick start and a cold start.

1.4.7.3 BIT Display. Selecting BIT on the main MENU display brings up the BIT 1 page which contains a list of acronyms of all the systems which are tested by BIT. Messages are provided next to each affected system showing the type of failure, test progress, and a fault code indicating which WRA within the system has failed. See Figure 1-33. The following messages are displayed to indicate equipment status:

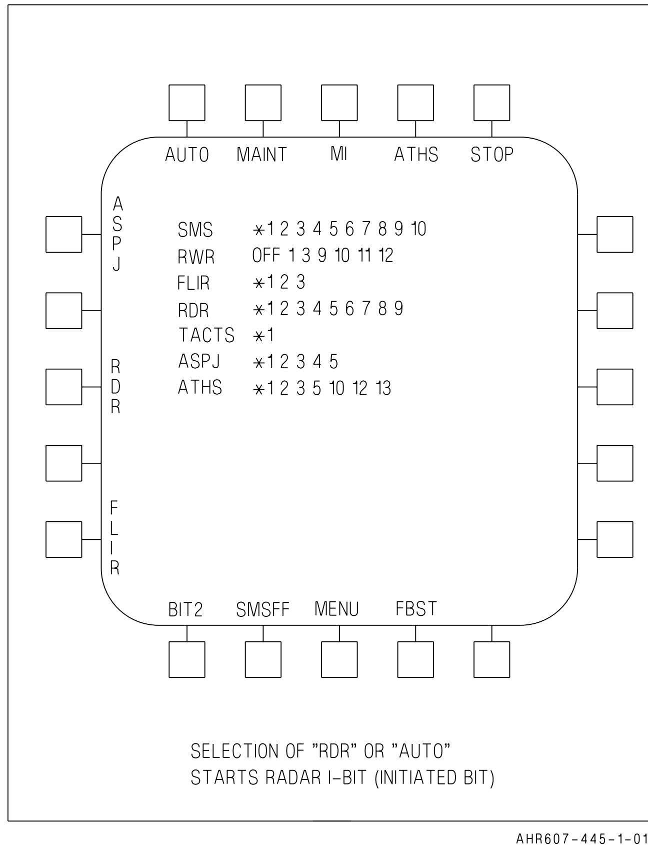

Figure 1-33. Radar Failure Reporting

1. OFF - Indicates no multiplex response and no equipment ready signal (equipment not turned on or not installed, power supply failure, etc.).

2. * - Indicates a single mux bus failure on the ground or a dual mux bus failure in the air.

3. TEST - Indicates that IBIT has been initiated for the system but has not yet been completed.

4. Numerals 1 to 9 - WRA fault codes range from 1 through 9 for the radar system.

5. Blank indicates that system status is OK.

Numerical failure codes for the radar system identify the WRAs which have failed. These codes provide the pilot with specific failed equipment information for possible correlation with functional failures, and the maintainer with information for determining his troubleshooting (i.e., R&R) decisions. The radar fault codes are as follows:

1 - Radar Target Data Processor failure
2 - Transmitter failure
3 - Receiver-Exciter failure
4 - Computer Power Supply failure
5 - Antenna failure
6 - Antenna Electronics failure
7 - Tx Flow Low (Indicates low liquid coolant)
8 - Waveguide Pressure Low
9 - Weight-on-Wheels/Inflight Disagree

In addition to the top level BIT page, there are a number of maintenance data displays available.

1.4.7.4 Maintenance Page. The Maintenance page is accessed by selecting the MAINT option select pushbutton on the BIT page. This option is only available with weight-on-wheels. Selecting MAINT brings up the maintenance data selection menu for the individual avionic systems. See Figure 1-34. It also identifies the software version of the radar installed in the aircraft. Selecting the RDR option select pushbutton will step the display to the radar detailed maintenance pages which provide access to the data from the individual tests performed during the three categories of BIT: IBIT (run by selecting AUTO or RDR), ORT (run automatically on all radar cold starts) and PBIT (run automatically during radar operation).

1.4.7.5 Radar Maintenance Data Displays. Selecting RDR on the MAINT page displays the first of the BIT maintenance data displays, the IBIT relay selection menu. This is referred to as the relay mode because it directly relays the BIT information from the BIT system to the AV-8B displays. This page comes up with the B, O, and A option select pushbuttons available. The B, O, and A option select pushbuttons select the IBIT, ORT, and PBIT test results respectively. The options select pushbuttons are boxed when a particular display page is selected. MENU and BIT pushbuttons allow the operator to exit to the indicated display pages. To return to the MAINT page, the operator must step through

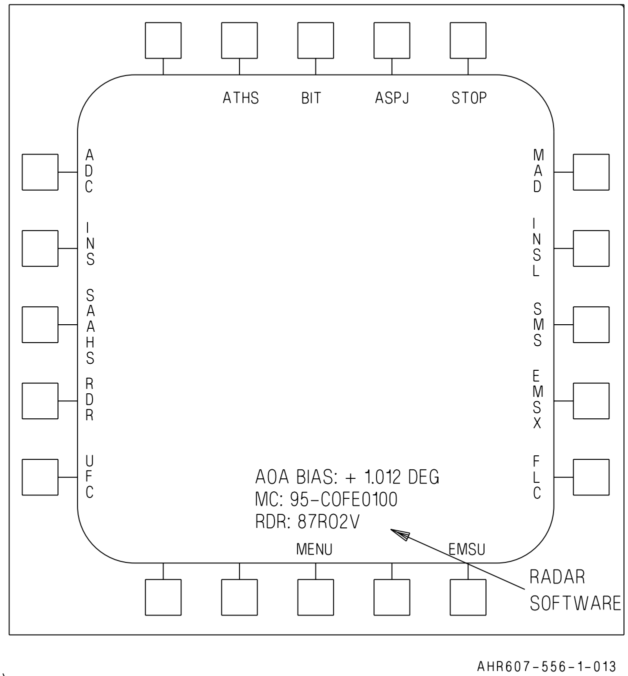

Figure 1-34. BIT Maintenance Page

the top level BIT page. This mechanization was selected since the MAINT option is not required for obtaining additional radar system data. See Figure 1-35.

The first line of data on the IBIT display, B selected and boxed, provides a list of failed WRAs. These are represented by the following abbreviations:

WRAs	Abbreviation
Radar Target Data Processor	RTDP
Transmitter	XMTR
Receiver-Exciter	RE
Computer Power Supply	CPS
Antenna	ANT
Antenna Servo	SERV
Run IBIT	RBIT

The second line of data lists the fault codes of the failed tests. If more than 10 failures have occurred the legend FULL appears in the bottom right portion of the display. Selecting the boxed option select pushbutton (B, O, or A) will present the next 10 fault codes until all codes have been presented and the FULL legend disappears.

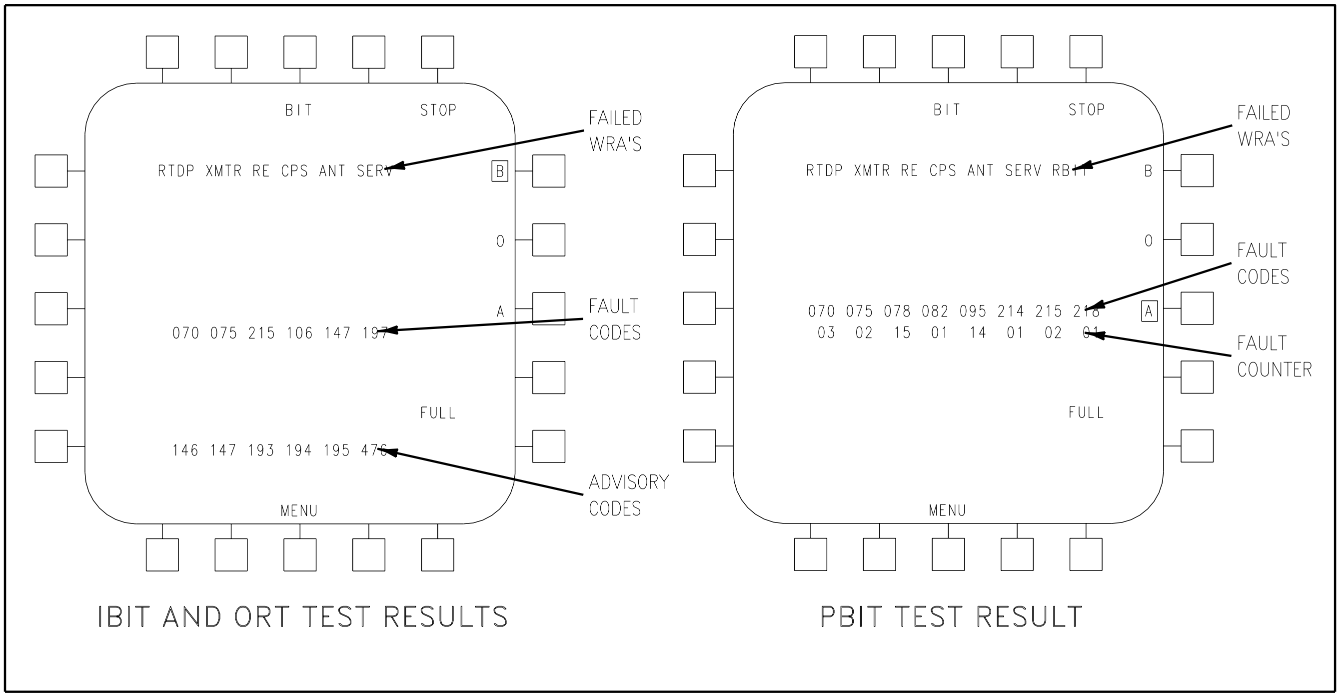

Figure 1-35. Radar Relay Mode Displays

The third line of data are codes for advisory messages to facilitate troubleshooting the failed system. The advisory numbers and the associated messages are as follows:

Advisory	Code
Equipment NO GO	146
IBIT Complete	147
IBIT Manually Terminated	148
Transmitter Test Skipped	193
Antenna Motion Sensitive Test Skipped	194
Excessive RF Interference Detected	195
ORT/IBIT Incomplete	197
PPM Not Present	465
Weight-on-Wheels Set	476

Although unlikely, it is possible to exceed the advisory display capability of six codes. If this occurs, FULL will be displayed in the same manner as more than 10 fault codes. Selecting the boxed option pushbutton again will advance the advisories to the remaining codes. Selecting the boxed option pushbutton advances both advisories and fail codes at the same time.

Selecting O will provide the same data format but the data will be for ORT tests run during the radar initialization. The O option will become boxed.

Selecting the A option pushbutton will provide the data obtained during PBIT. This display includes a line below the fault codes which indicates the number of times that a specific failure has occured. For instance, if fault code 070 occurs at least once a minute for three minutes then goes away, the numerals 03 will appear beneath fault code 070 on the A page. A PBIT failure must be present at least once a minute for seven consecutive minutes before a top level BIT page indication or hardware degraded will occur. This information on the number of times a failure has occured is only provided on the A page.

1.4.7.6 Resetting BIT Maintenance Data. The MPCD maintenance data pages contain histories of BIT test failures that have occurred since the last time the radar completed the ORT with the weight-on-wheels. Completely cycling through ORT under these conditions (the test must include the transmitter tests) clears the IBIT (B) and ORT (O) MPCD maintenance data pages and updates the B and O pages with the just completed ORT and the current PBIT. The A page will remain until ORT is completed and weight-off-wheels is sensed by the system. It will then reset and begin to accumulate data in the current flight. A cold start in the air will initiate ORT, but it will not reset the MPCD maintenance data pages. This mechanization allows the maintainer to obtain the BIT maintenance data from the last flight by powering up the aircraft and selecting STBY on the RADAR select switch.

1.4.8 Radar Display Selection and Initialization. The radar can be displayed on either MPCD, however, it is normally displayed on the right MPCD. The radar can be selected by depressing the RDR pushbutton on the main MENU of either MPCD (RDR replaces DMT option), or it may be selected via HOTAS. The radar mode initialized on power-up (given the warm-up ORT is complete) depends on the aircraft master mode selected. If the A/G, NAV or VSTOL master mode is selected, sliding the sensor select switch aft initially selects the default Surface radar display on the right MPCD and assigns the TDC to the radar if the radar display is not already present. The default Air-to-Surface radar display is the MAP mode, 40 nm range scale, 120° azimuth scan, auto beam selection. The pilot may then change the operating parameters or select another mode, as desired. If the radar is in the A/A master mode with gun selected, the radar will initialize in the Gun Acquisition (GACQ) mode. If the radar is in the A/A master mode with Sidewinder or SEAM selected, the radar will initialize to the Range While Search (RWS) mode. Since the transmitter is inhibited with weight-on-wheels, the radar format will not include any radar return, whichever radar format is initialized.

1.4.9 TDC Assignment. The pilot should remain aware of TDC assignment because slewing rates for the radar, HUD, and digital map are significantly different. For example, if the TDC is assigned to the radar and the pilot attempts to slew a designation via the TD diamond on the HUD he will note that slewing response is extremely sensitive (fast). When the aircraft first powers up, the TDC is automatically assigned to the radar. Assignment through the rest of the flight depends on pilot selection. When commanding the surface radar via HOTAS, the radar display initializes on the right MPCD and the TDC is automatically assigned to the radar. Radar TDC assignment is indicated by the presence of the acquisition cursor on the radar display. Selecting the radar format using the RDR option on the main MENU does not command TDC assignment; however, if the last assignment was to the radar, it will be indicated by the presence of the acquisition cursor.

Generally speaking, assigning the TDC to the radar requires HOTAS action, however, it should be noted that deselecting the digital map sensor mode will return the TDC to the last selected sensor mode (i.e., INS or RDR) which could also result in TDC assignment to the radar without HOTAS selection. In addition to the acquisition cursor, a RDR legend is displayed in the upper left corner of the EHSD and FLIR display to cue the pilot when the TDC is assigned to the radar (otherwise INS or MAP is displayed). Also, a dot is displayed in the middle of the velocity vector when the TDC is assigned to the HUD (i.e., INS sensor mode).

1.4.10 General Radar Considerations. The pilot should remember that all radar modes have equal priority. That is, the current operating mode will be overridden if the radar is commanded to a different mode. As an example, if the radar is in the MAP mode, the MC automatically bumps the radar into the AGR or PVU mode when AGR or a PVU is commanded. When in the AGR mode, sliding the sensor select switch aft commands the radar back to the mode it was in prior to AGR selection (in this case, the MAP mode). When in PVU mode, the MC commands the radar back to the mode it was in prior to commanding PVU once the update (VEL) is accepted or rejected.

When the MAP, EXP1, EXP2, EXP3, SEA or GMT mode is selected, the video gain (if applicable), operating beam, and antenna elevation are optimized for the display and surface coverage based on the range scale selection and aircraft altitude. The operating parameters can then be changed by the pilot as desired. If the pilot wishes to return to the automatic settings, he simply selects the reset (RSET) option. Otherwise, the automatic settings are initially selected anytime the pilot switches radar modes or master modes.

When a radar mode change is made, the radar retains the same range scale and azimuth scan selections if possible. For example, if the radar is operating in the MAP mode with an 80 nm range scale and 120° azimuth scan and the pilot selects the SEA mode, the same range scale and azimuth scan are retained in the SEA mode. However, if the GMT mode is selected, the range scale is changed to 40 nm and the azimuth scan is changed to 90° since these are the maximum range and azimuth scan widths available in the GMT mode.

1.4.11 Option/Parameter Selection. Most radar modes/parameters can be selected either by the MPCD pushbuttons or by HOTAS control. Generally with pushbutton control, the button is successively actuated to step through the available options until the desired option is indicated. HOTAS provides the pilot with control of the radar in all tactical situations without requiring him to remove his hands from the throttle or stick. This serves to lessen pilot workload and keep the pilot head-up in the tactical arena.

HOTAS option selection is accomplished with the TDC and the acquisition cursor. In order to utilize HOTAS control, the pilot must first assign the TDC to the radar. The radar display is divided into two distinct regions; the tactical region and the non-tactical region which consists of the outside 1/2 inch of the display. When the acquisition cursor is within the tactical region, depression and release of the TDC will command radar designation. The non-tactical data region is subdivided into HOTAS regions reserved for specific sets of selectable radar parameters. These regions will be displayed when the cursor enters the region. The pilot selects an option by slewing the cursor over the desired option legend and depressing and releasing the TDC. All HOTAS options except azimuth scan are selected when the TDC is released. The azimuth scan is selected upon TDC depression.

The REJ, MENU, UPDT, and CHAN options can not be selected via HOTAS.

1.4.12 Radar Modes

1.4.12.1 Map Mode. The MAP mode is the basic air-to-surface radar mode. It uses the real radar beam to display a large sector of the terrain in front of the aircraft. The MAP mode provides a long-range mapping capability which assists in navigation and helps to locate and acquire targets. By interpreting the various shadings and shapes of returns, the nature of the terrain ahead can be determined. Comparing the MAP display against the digital map (EHSD) on radar significant features such as land/water contrast can provide a cross-check of *real world* radar video to the INS driven digital map and its overlays. This cross-check increases system confidence and enhances SA.

Major features of the real beam ground map include the ability to display large cultural areas, prominent targets, water/land contrast and mountains. Although isolated, reflective targets and prominent land/water points can be detected, resolution in the MAP mode is limited when compared to the expand modes. The ability to locate point targets such as a specific building in a dense cultural area would be quite limited even with a good INS. As a result, while the MAP mode is useful for general navigation, maintaining the *big picture* and finding the approximate location of a selected target or navigation point, the expand modes are much more useful for detailed search of a small area and the most accurate target designation.

Although the expand modes can provide more detail, the MAP mode offers a full range of operating parameters and it can be used when the expand modes are unavailable (i.e., operating in the doppler *notch*: ±6 degrees of aircraft ground track).

1.4.12.1.1 Radar Display Format. The radar scans the surface of the terrain ahead of the aircraft and presents the return echoes as a video

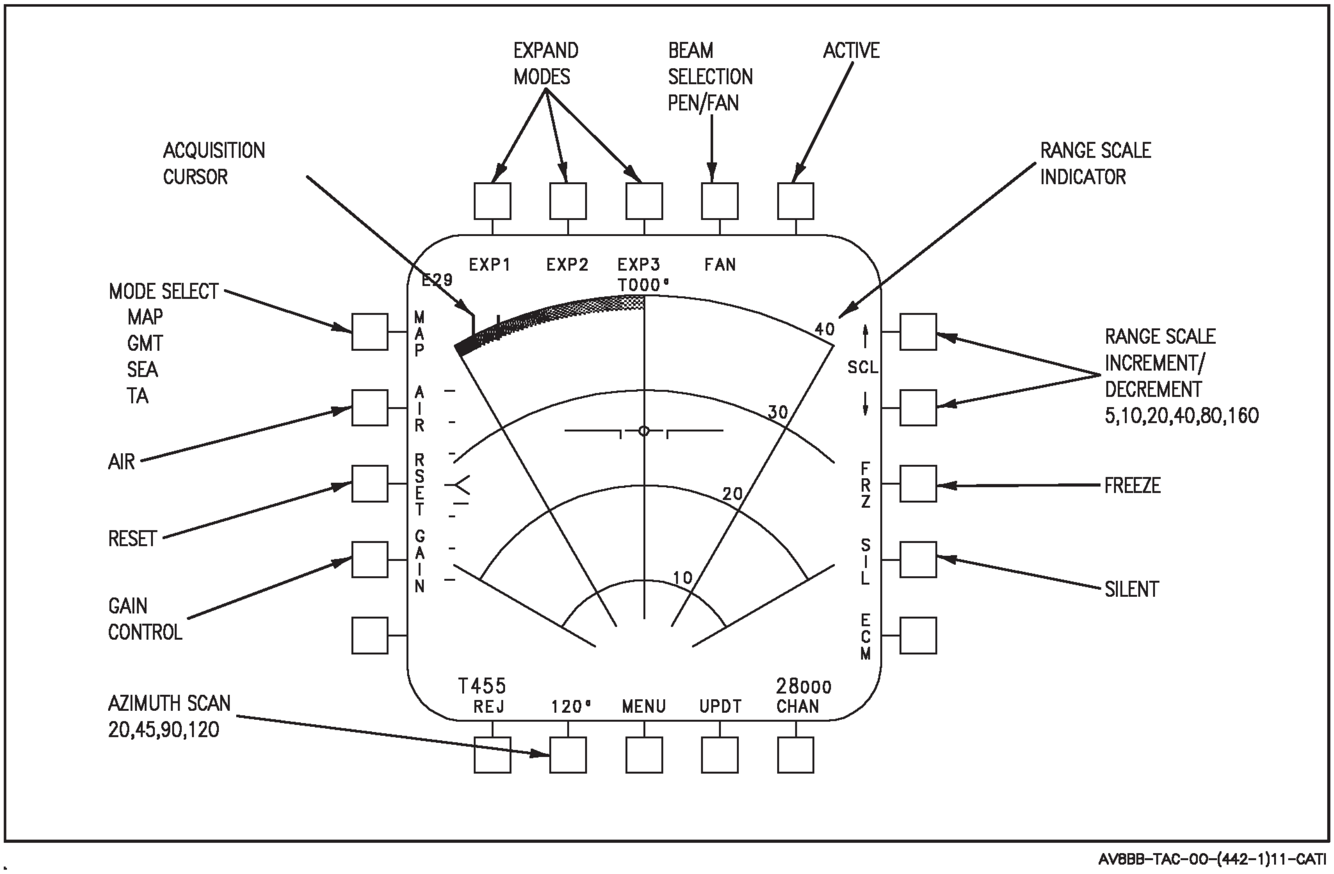

Figure 1-36. RBGM Options

display. See Figure 1-36. Since radar energy is reflected in different amounts by different terrain features and objects, the various intensities of the returns can be used to display a ground map. The radar returns are quantized into eight separate intensity levels, corresponding to the eight shades of gray (green) on the MPCD. The top approximately 1/8 inch of the MAP raster display consists of a gray scale which can be used as a reference to adjust MPCD brightness and contrast. In order to ensure that the full dynamic range of radar intensities are available, the pilot should adjust the MPCD controls such that all the shades of gray are distinguishable and black is indeed black.

The tactical portion of the MAP display is presented in a range vs azimuth, PPI (Plan Position Indicator) sector format grid with zero range at the bottom center of the display. The range represented by the fourth range arc is displayed in the upper right corner of the display. The remaining range arcs divide the display into four equal segments and intermediate range grid distance annotations are displayed on the range arcs unless REJ is selected. The MAP mode provides maximum ranges of 5, 10, 20, 40, 80 and 160 nm. Range scale is changed via the increment/decrement arrows on the upper right side of the display. This can be accomplished by pushbutton or HOTAS.

Lateral displacement of the target symbols from the centerline of the MPCD is indicative of the target azimuth bearing. Azimuth lines are displayed at 0°, 30°, and 60°. The 0° azimuth is referenced to the aircraft ground track, thus, the radar display is presented in a ground-track-up format. The radar provides up to 10° of drift compensation in positioning the antenna azimuth scan to center it along aircraft ground track. Therefore, with a 10° drift, the antenna azimuth scan will be centered on ground track and differ from aircraft heading by 10°. This referencing technique is comparable to the one used for the EHSD digital map (i.e., track up).

The current azimuth scan is displayed next to the menu option. Antenna azimuth scans of 20°, 45°, 90° and 120° are available, either via pushbutton or HOTAS. Limited azimuth scanning is obtained by selecting one of the azimuth scan options other than 120°. This concentrates the energy at a limited azimuth bearing which can possibly improve target resolution by providing more target reflections of a given area.

A limited azimuth scanning sector can be positioned off the aircraft centerline if desired. The pilot depresses the TDC to the action position after the acquisition cursor has been positioned over the desired azimuth scan option. While continuing to hold the TDC depressed, the acquisition cursor repositions to the center of the display and is replaced by the in-video cursor. While the TDC is depressed, scan centering control is available through left-right force on the TDC. The pilot may reposition the selected azimuth scan within the 140° scan limits, provided a scan less than the maximum was selected. The pilot can recenter a limited azimuth scan in the same manner or he can simply reselect the full 120° azimuth scan. In addition to the manual method described above, a limited azimuth scan will automatically center about any designated point (stab cue).

The radar display is INS stabilized in both pitch and roll. If the aircraft climbs or dives, the antenna azimuth scan is automatically lowered or raised to maintain the same elevation angle with respect to the local horizontal plane. Similarly, when the aircraft is rolled into a bank, the antenna rotates in the opposite direction to maintain a level azimuth scan.

An elevation caret represents the actual antenna elevation angle while a horizontal strobe indicates the optimum elevation angle for the range scale, beam shape (pencil or fan), and aircraft altitude. The radar automatically sets receiver gain, beam selection (PEN or FAN), and optimum antenna elevation based on current conditions. However, the pilot has the option of manually changing any or all of these parameters. For example, the pilot can use the antenna elevation control on the throttle to manually position the antenna elevation angle to check the area ahead of the aircraft for significant weather.

If the pilot wishes to reinitialize automatic radar parameters, the reset (RSET) option can be selected. The RSET option reinitializes the elevation angle to the optimum position, commands the auto beam selection (PEN or FAN) and resets the video gain to a nominal level of 5.

1.4.12.1.2 Video gain (GAIN). In the MAP mode (and the expand modes), the radar determines the optimum gain setting for the current conditions and uses that setting as the initial map gain control setting. The pilot may then adjust the gain from that initial setting via the GAIN option. When the GAIN option is selected, it is replaced by up and down increment/decrement arrows with the selected gain displayed as a number between the arrows. This number, ranging from 1 to 9, indicates the relative video gain (system sensitivity) set by the radar. A value of 1 indicates the lowest possible gain setting, while a value of 9 indicates the highest gain setting. A high gain setting increases system RF sensitivity while a low gain setting lowers RF sensitivity.

Auto gain is used most of the time, however, manual gain provides the pilot with the option of selecting a gain which better satisfies current operational requirements. As an example, increasing the gain will increase land/water contrast and make weak returns appear brighter, while lowering gain will cause the more significant targets to stand out against the background.

After the desired gain setting is selected, the GAIN option will reappear automatically if no action is taken for 10 seconds. If the pilot wishes to return to the auto gain settings, he simply selects the RSET option, either via pushbutton or HOTAS.

1.4.12.1.3 Freezing a Radar Display and Silent Operation. There are several situations in which the pilot may wish to freeze a radar display. For example, when using terrain masking, freezing a radar display of the desired area before masking provides a display of the area for continued examination. Also, when conducting covert operations, freezing a radar display will provide a display even after all emitters are secured. Three different methods are provided to freeze a radar display; FRZ (Freeze), SIL (Silent) and EMCON (Emissions Control). The method used by the pilot would depend on the tactical situation.

Selection of the FRZ option, either by pushbutton or HOTAS, freezes the current map video. The radar will continue to transmit and the antenna will continue to scan but the radar display will not be updated. Although this feature does not inhibit radar transmissions, it does allow the pilot to freeze a map display for continued study. For example, this would allow the pilot to freeze a radar display of the target area before descending below the radar horizon or it would allow the pilot to fine tune the in-video cursor on a frozen display. When the FRZ option is deselected, map video is once again updated.

Selection of the SIL option, either by pushbutton or HOTAS, freezes the current video display and commands the radar to terminate radar transmissions. Since radar transmissions are terminated, a steady Maltese cross will be displayed in the lower left corner of the display. In addition, when SIL is selected (boxed), the FRZ option is automatically selected and the ACTIVE option appears under the top right pushbutton.

HOTAS or pushbutton selection of the ACTIVE option commands the radar to transmit for one frame which results in an updated video display. When the ACTIVE option is selected via HOTAS, the cursor remains over the ACTIVE option so that the pilot may command an additional active scan if required. The FRZ legend will unbox and the Maltese cross will be removed during the ACTIVE frame and returned at the completion of the frame. At the completion of the ACTIVE frame, the radar returns to silent operation and the display is again frozen. Unboxing FRZ when SIL is selected causes the radar to blank the map video.

Changing radar modes while SIL is selected also blanks the map video. When SIL is deselected, normal radar transmissions resume and the Maltese cross disappears. In addition, the ACTIVE option is blanked, the FRZ option is unboxed, and the video display is again updated with each radar scan.

1.4.12.2 Expand Modes (EXP1, EXP2 and EXP3). The MAP mode is generally used for navigation, finding the approximate location of targets, and in general providing the *big picture*. The expand modes can be thought of as submodes of the MAP mode which provide the pilot with relatively high resolution ground mapping of small areas for more accurate area search and precise target designation. The expand modes are synthetically created ground maps which provide the pilot with magnified, high resolution (compared to RBGM) maps capable of displaying enhanced details such as city streets, isolated large buildings and small airfields. All of the expand modes are displayed in a range vs cross-range patch map format. See Figure 1-37.

Three expand modes are available; Expand 1 (EXP1), Expand 2 (EXP2) and Expand 3 (EXP3). EXP1, also known as the DBS Sector mode, provides a high resolution map of a fairly large area of the map video. EXP2, also known as the DBS Patch mode, provides a higher resolution map for a more precise look at a specific area. EXP3, also known as the MRSAR (Medium Resolution Synthetic Aperture Radar) mode, utilizes SAR processing techniques to take an even closer look at a very small fixed range perimeter area (1.2 nm × 1.2 nm). EXP1 and EXP2 can be selected out to a maximum range of 40 nm, while EXP3 is only available out to 30 nm.

In the Expand modes, the radar utilizes special processing techniques to provide the higher resolution ground maps. Basic radar principles dictate that angular resolution of the real radar beam is limited by beamwidth which is a function of the ratio of wavelength and antenna diameter. EXP1 and EXP2 use a DBS (Doppler Beam Sharpened) processing technique which increases the angular resolution of the radar antenna. This is accomplished by using doppler

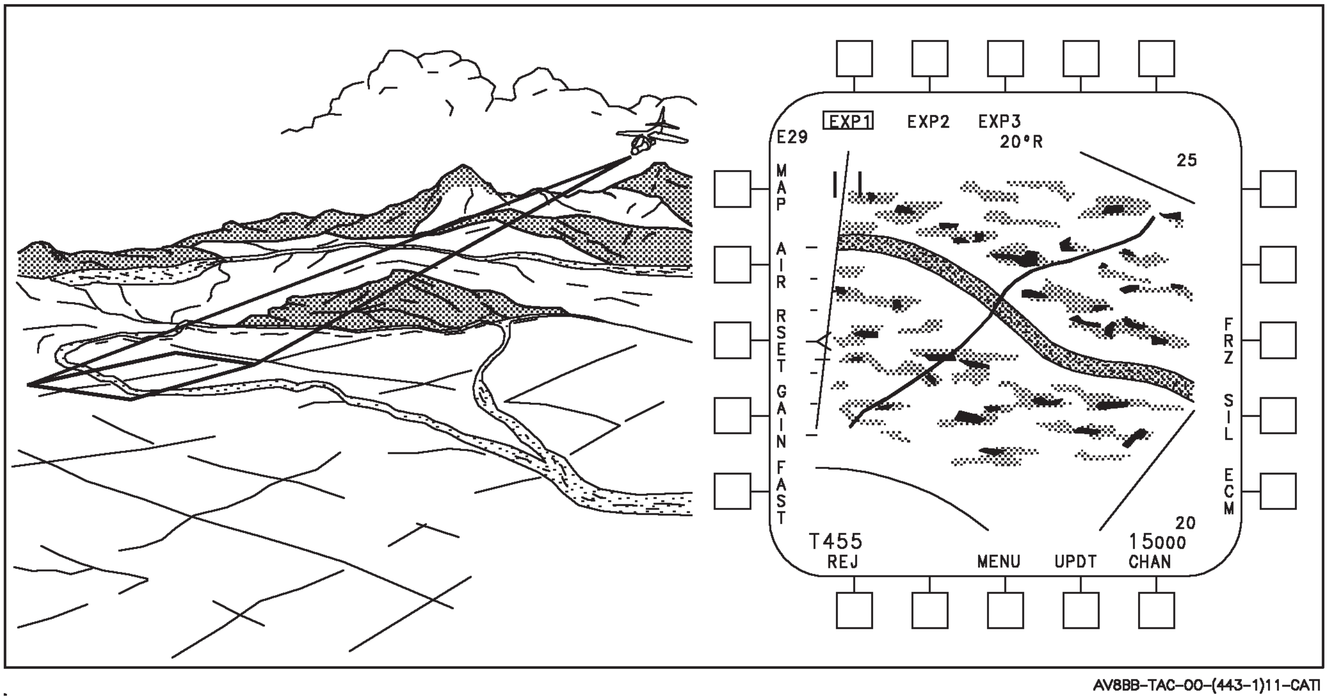

Figure 1-37. Expand Modes

shift to break out multiple radar returns received from various angles within the same real radar beam. EXP3 uses a Medium Resolution SAR ground mapping technique where advantage is taken of the forward motion of the radar (aircraft velocity) to synthesize the equivalent of a very long sidelooking array antenna from the radar returns received over a period of several seconds or more.

In addition to improved azimuth resolution, range resolution is improved in the expand modes by the use of short pulse widths. The pulse widths are adjusted so that range and azimuth resolution approximately match. This is done to make an undistorted image of the expanded map area. The pilot should also note that EXP2 and EXP3 display resolution switches to EXP1 resolution at about 6 miles. This occurs even though the expand mode selection (EXP2 or EXP3) does not change.

The advantage of the expand modes is the improved resolution they provide in addition to displaying a magnified image of a small area. The radar distinguishes small differences in doppler shift produced by objects at different azimuth bearings, hence the radar can resolve objects in azimuth that would otherwise be lost in the real beam radar modes. By sensing doppler shifts, echoes from these returns can be differentiated, even though they are received simultaneously. Target range can be determined by basic pulse delay ranging methods, while the radar determines the target's azimuth using the target's measured doppler frequency and own ship velocity.

In DBS processing, the angular resolution is the same at all ranges, hence the azimuth resolution distance increases with range. EXP1 and EXP2 maps are therefore the same as those produced by a real beam having a very narrow beamwidth; hence the name *beam sharpened*. On the other hand, in EXP3 the length of the array is increased in proportion to the range of the area to be mapped. As a result, angular resolution is independent of range which means that EXP3 provides a constant resolution display of a very small fixed range perimeter area (1.2 nm × 1.2 nm).

Expand mode map formation times are inversely proportional to the angle off track and vary from about 3 to 8 seconds. The greater the angle off track, the quicker the frame will build.

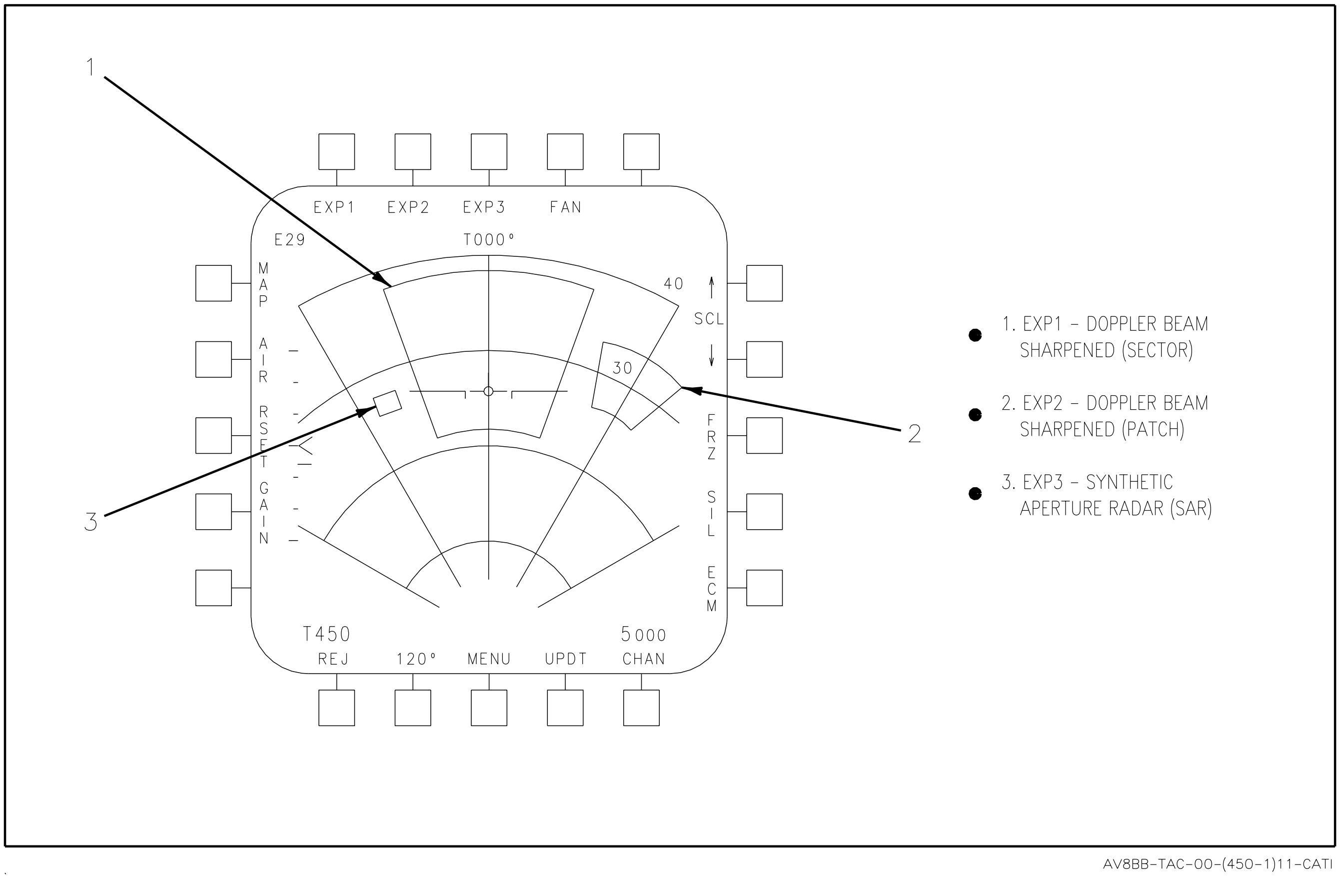

Figure 1-38. RBGM - Expand Corrals

DBS processing directly across the aircraft ground track becomes increasingly difficult to map because of the large shift in doppler frequency and the insufficient spread in doppler frequencies between objects at the same range. For this reason, there is a 6° area on either side of ground track (12° total) in which no radar video is displayed (black). This area, referred to as the *notch* requires the pilot to offset the area to be expanded from aircraft ground track by at least 6° although larger squint angles are preferable.

It is important for the pilot to realize that although the expand modes provide improved resolution, they are synthetically created and are subject to any processing errors created by erroneous inputs. For example, an error known as map shift is caused by any error in the velocities provided by the MC (i.e., INS). Map shift simply means that the displayed map does not overlay the actual position on the ground in azimuth.

Expand modes of the radar can effectively be used to designate certain targets. Radar resolvable point targets such as: hangers on an airfield, ships/boats not pier side (i.e., barge at BT-11), or a dam can easily be targeted via the expand modes of the radar. Once the target is identified on the radar an INS designation can be accurately placed on the radar significant target. This INS designation will allow engagement of the target but will require last minute visual correction to ensure exact pipper placement.

1.4.12.2.1 Expand Mode Selection. The EXP1, EXP2 or EXP3 modes may all be selected by pushbutton or via HOTAS. Selection procedures differ slightly depending on whether or not there is a target designation (WYPT, HUD, radar, etc.).

Selection of an expand mode while undesignated will be covered first. The expand modes may be selected directly from the MAP mode or

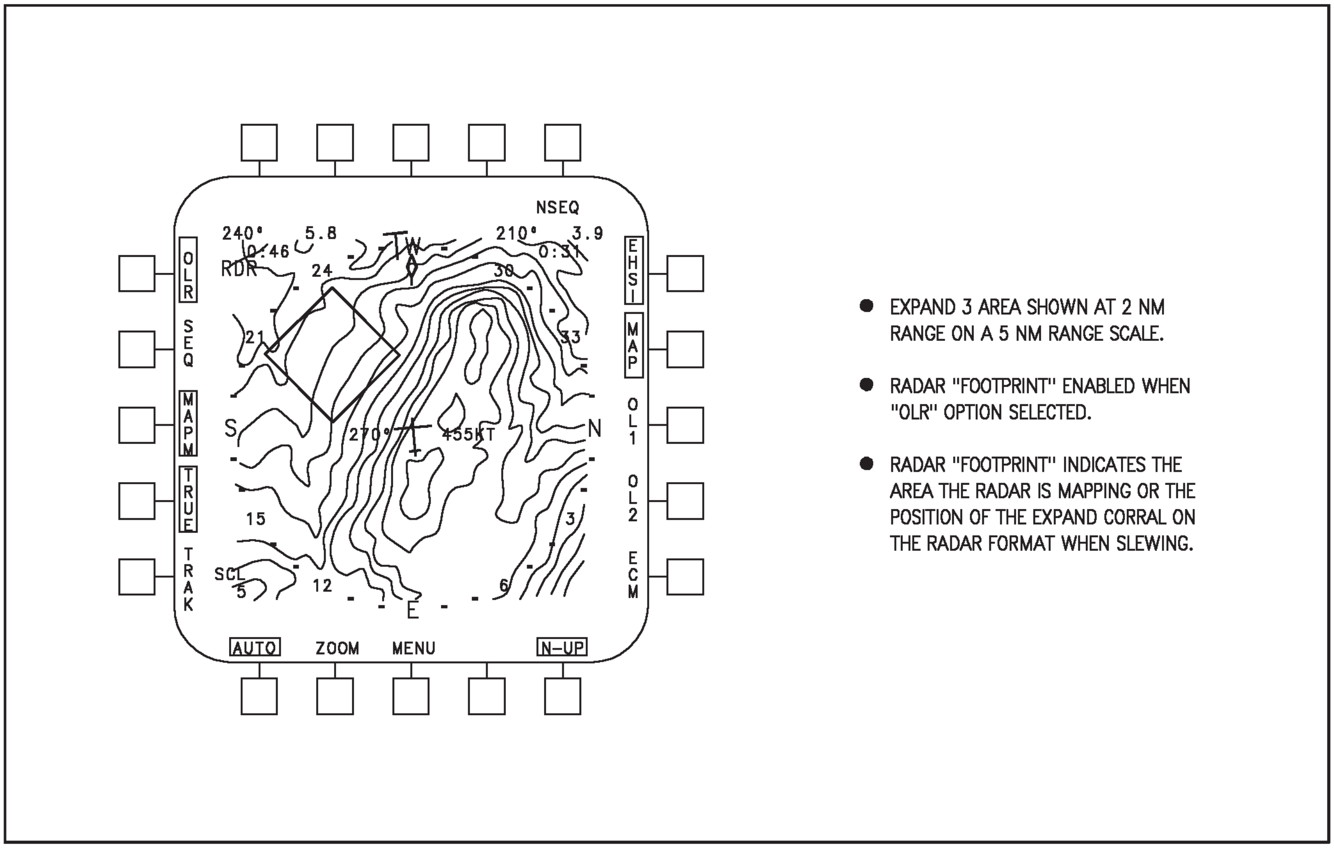

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Figure 1-39. Expand Mode Footprint

another expand mode (i.e., EXP3 from EXP2). To select an expand mode from the MAP mode, the pilot selects the desired EXP option, either via pushbutton or HOTAS. Selecting the EXP option will cause the EXP legend to be boxed and the acquisition cursor will be replaced by the appropriate EXP field of view indicator. This indicator, which appears superimposed over the center of the map video, is commonly known as the *corral*. See Figure 1-38.

The corral outlines the region of the display video which will be processed and included in the EXP display after selection is complete and the expand mode is commanded. The area represented by the corral can also be displayed on the digital map (EHSD). If the OLR option on the MAPM display is selected (boxed), an outline which corresponds to the EXP corral is displayed on the digital map if in range. The digital map corral (OLR), which is default selected on power up, allows the pilot to correlate radar video with the digital map. The corral is removed from the EHSD display if FRZ option in selected or if the DATA option is selected. See Figure 1-39.

NOTE

The location of the EHSD corral will become unreliable and erratic when aircraft altitude approaches or becomes less than the elevation of the current waypoint.

The pilot can use the action or no-action position of the TDC to slew the EXP corral over the area needing detailed examination. When the corral is over the desired region, the pilot depresses and releases the TDC to command the EXP mode and complete selection. After EXP selection is complete, the acquisition cursor is again displayed.

When the EXP mode is commanded, the radar will begin processing of the area defined. The radar initially builds up the first frame of processed video on the display as it scans the selected region. The display will be updated every 3 to 8 seconds. The actual processing time will depend upon the angle off track. The greater the angle off track, the quicker the frame will build and be updated. Display quality will improve with time as the initial display is updated a number of times. The update rate can be increased by selecting the FAST option, which is only available on the EXP displays. Video processing and initial display quality is reduced when the FAST option is boxed, but the display is updated approximately three times faster than the normal processing rate (FAST unboxed). However, display quality will improve in time with FAST boxed. The first frame of data is always obtained at the fast rate.

If a target is designated, initial selection of any EXP mode commands the radar to build the selected EXP display centered around the designated point (stab cue). The maximum and minimum ranges covered by the expanded area are displayed at the top and bottom of the radar display on the right side of the tactical region. The range covered will vary depending on the expand mode selected, the range becoming smaller as the expand modes are stepped up. The pilot can move the EXP display by simply refining the designation. Once refined, the EXP display will recenter about the new designation.

Whether designated or not, any expand mode can be accessed from any other expand mode (i.e., EXP3 from EXP1). However, unless the area or target is quite radar prominent, efficient use of the expand modes is gained by accessing a given expand mode in order of increasing resolution (i.e., EXP1→ EXP2→ EXP3). Indeed, the most efficient use of the expand modes is obtained by designating (WYPT, O/S, etc.) the target first. In this manner, the pilot can refine the designation as the expand modes are *stepped up* in increasing resolution. Target designation is addressed in more detail later in this section.

The MAP mode option is always displayed on the EXP mode displays. If the pilot wishes to return to the MAP mode for a look at the *big picture* or simply exit the expand mode, the selected expand mode should be unboxed. After the MAP mode is selected, successive selections of the mode pushbutton will scroll the radar from MAP to GMT, to SEA, to TA and back to the MAP mode.

1.4.12.2.2 Expand 1 (EXP1). The EXP1 mode provides a high resolution map of a 45° wide sector on the ground map display out to a maximum of 40 nm. DBS processing improves resolution by a factor of 19:1 over that provided by the MAP mode. The EXP1 display contains many of the same options as the MAP mode, however, it is a patch format (range vs cross-range) display which has no range or azimuth grid. Since EXP1 covers a fixed azimuth width of 45°, azimuth scan options are not displayed. The maximum and minimum ranges covered by the EXP1 sector are displayed at the top and bottom of the radar display on the right side of the tactical region. All Expand mode displays have the same pushbutton options and similar formats. See Figure 1-40.

The EXP1 display will be skewed to the right or left if the selected area is not centered on the aircraft ground track. The display will be oriented in the same relative position as if viewed from the cockpit. The fixed 45° wide sector may be positioned off-track up to 60°. An angle-off-track indication, which represents the number of degrees the center of the scan area is off-track, is provided at the top center of the radar display. If the area lies to the right of ground track, the angle number is followed by an R and if the area lies to the left of ground track, the angle number is followed by an L.

EXP1 is normally selected while operating in the MAP mode when further definition of a particular area or target is required. If a target is already designated when EXP1 is selected, the display will be ground stabilized and centered on the radar designation (stab cue). Range will automatically decrement to keep the target in the center of the scan. Thus, as the aircraft passes by the sector being mapped, the range indications decrease and the angle-off-track indication increases. A new target within the sector can be designated to move the center of the display. Only partial maps (or no map at all)

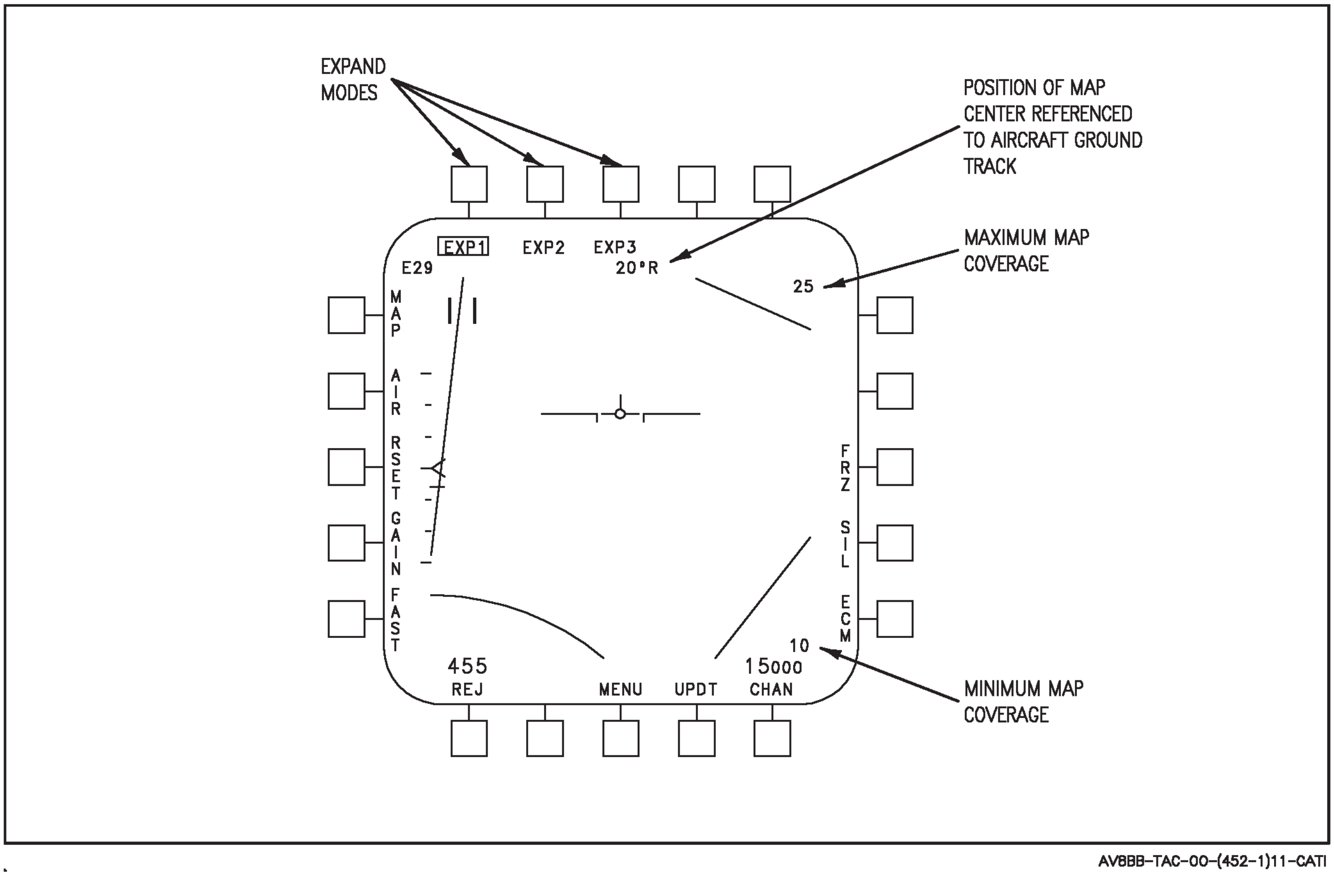

Figure 1-40. Expand Mode Display Options

can be made when the angle-off-track increases beyond about 45° because the radar search pattern is limited by antenna gimbal limits.

If undesignated, the EXP1 display is not ground stabilized and continually moves along with the aircraft motion in *snowplow* fashion providing a passing scene display. The initial *snap shot* moves down the display as the aircraft passes by the area and new sectors are continuously processed to add to the top of the display for the next *snap shot*. If the pilot wishes to view a new sector in a different area, he may deselect and then reselect EXP1 to reacquire the EXP1 footprint (corral).

1.4.12.2.3 Expand 2 (EXP2). The EXP2 mode provides a higher resolution map of a 12.6° wide patch out to a maximum range of 40 nm. DBS processing improves resolution of the patch map by a factor of 67:1 over that provided by the MAP mode. As in the EXP1 mode, maximum and minimum ranges covered by the area are displayed along with the angle-off-track indication. The EXP2 display is oriented in the same relative position as though the patch were being viewed from the cockpit. Like all expand modes, EXP2 is displayed in a range vs cross-range patch map format.

EXP2 is normally selected while operating in the MAP or EXP1 mode when a closer look at a particular area is required. If a target is already designated, the EXP2 patch is obtained directly by selecting the EXP2 option. As in EXP1, the patch will remain centered on the designated point until reaching the antenna gimbal limits. A new point within the display can be designated to move the center of the display.

If undesignated, the EXP2 corral is displayed when the EXP2 option is selected. The corral can be positioned via the TDC over the desired region. Actuating the TDC action switch completes selection and commands the EXP2 mode. The EXP1 mode is commanded immediately if the EXP1 option is selected while operating in the EXP2 mode. If the pilot wishes to move the patch and remain undesignated, he may use the TDC to slew the display. However, if the pilot desires to relate the EXP2 corral to a larger area, he should select the EXP1 or MAP mode and then reselect EXP2 to reacquire the EXP2 corral. Whether a target is designated or not, the EXP2 patch is always ground stabilized. That is, the same surface area will be processed regardless of the aircraft movement until antenna gimbal limits are reached. Display blanking because of antenna gimbal limits begins to appear when the angle-off-track indication approaches 60°.

1.4.12.2.4 Expand 3 (EXP3). The EXP3 mode provides the highest resolution map available. Indeed, EXP3 SAR processing is capable of providing a map with a constant resolution of 30 feet. The EXP3 mode may be selected out to a maximum of 30 nm. The EXP3 mode format (range vs cross-range) is similar to the other expand modes and contains the same options and indications. As in the EXP1 and EXP2 modes, maximum and minimum ranges covered by the area are displayed along with the angle-off-track indication.

EXP3 utilizes a different SAR processing technique than EXP1 or EXP2 (DBS). Instead of covering a fixed angular width like EXP1 (45°) and EXP2 (12.6°), EXP3 processes a fixed range perimeter area of 1.2 nm × 1.2 nm. This provides a display of constant area and constant resolution regardless of range. However, as the aircraft approaches the EXP3 coverage area, more energy is reflected back which can give better definition.

If a target is already designated, the highest resolution display can be obtained directly by selecting the EXP3 option. As in EXP1 and EXP2, the display will remain centered about the designated point until reaching antenna gimbal limits. A new point within the display can be designated to move the center of the display.

If undesignated, EXP3 can be selected from the MAP, EXP1, or EXP2 modes when a very close look at a small area is required. However, selecting EXP3 on the MAP or EXP1 display may be of limited value since the EXP3 corral is so small. Generally speaking, selecting EXP3 from EXP2 is preferable. Remember, stepping up in resolution is an efficient use of the expand modes. When the EXP3 corral is slewed over the desired region, the pilot actuates the TDC action switch to command the EXP3 mode. Within about 6 nm, EXP3 resolution switches to EXP1 resolution. If the pilot wishes to move the EXP3 map and remain undesignated, he may select a larger map display (preferably EXP2) and then reselect EXP3 to reacquire the EXP3 corral. The EXP1 or EXP2 display is commanded immediately if EXP1 or EXP2 is selected while operating in the EXP3 mode.

Whether a target is designated or not, the EXP3 SAR map is always ground stabilized. That is, the same surface area will be processed regardless of aircraft movement until antenna gimbal limits are reached. Display blanking because of antenna gimbal limits begins to appear when the angle-off-track indication approaches 60°.

1.4.12.3 SEA (Sea Surface Search) Mode. The SEA mode is a special search radar mode optimized to detect and display discrete targets (ships or small islands) on large bodies of water. It has functions that eliminate or greatly reduce clutter and noise from sea returns and side lobe returns from nearby land masses that would otherwise be present in the MAP mode. See Figure 1-41.

The SEA mode is selected by depressing the mode select pushbutton until the SEA option appears or the pilot may HOTAS the selection. The operating parameters for the SEA mode are quite similar to those described for the MAP mode except that the maximum range for the basic SEA mode is 80 nm. However, the video display is quite different. Sea returns are not displayed, thus, discrete target detections are synthetically presented on the radar display. Detected returns (targets) appear as computer generated symbols (rectangles) which vary in size in direct proportion to the size of the target. A low contrast synthetic footprint is displayed on each radar sweep to give the pilot an indication of radar coverage at the selected range scale

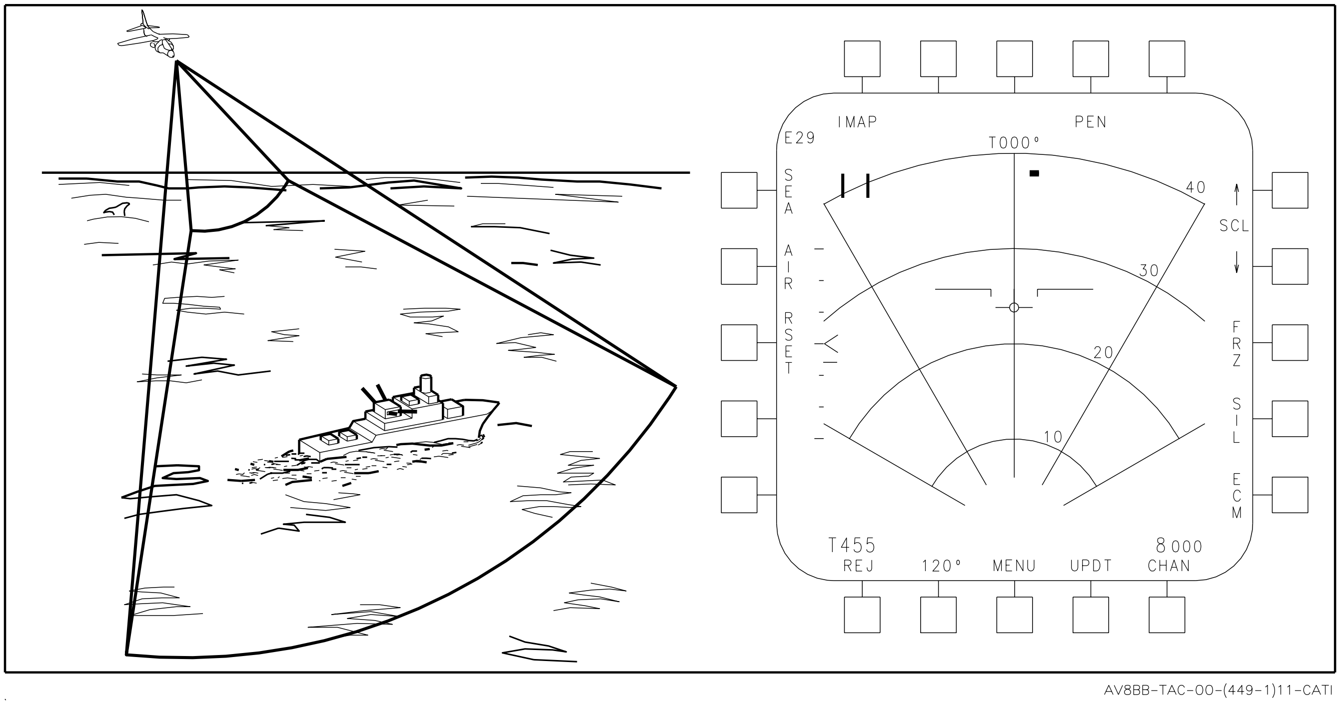

Figure 1-41. Sea Surface Search (SEA)

and antenna elevation. Since SEA video is synthetic, auto gain control is used and the GAIN option is not displayed.

In order to allow orientation of any discrete targets to a coast line and/or islands within the radar coverage area, an interleave map (IMAP) option is displayed in the SEA mode. When IMAP is selected, either by pushbutton or via HOTAS, the radar is commanded to process and display MAP mode video in addition to the synthetic SEA video. In this manner, the radar scans in the MAP mode on a periodic basis (1 scan in 4) in conjunction with scanning in the SEA mode. The result is MAP video with discrete SEA synthetic targets superimposed.

When the SEA mode is interleaved (IMAP boxed) with MAP mode video, the GAIN option is displayed and adjustable as described for the MAP mode. However, changing the gain setting will modify only the MAP video. When IMAP is selected, the range capability of the SEA mode is extended out to 160 nm even though SEA search is still limited to 80 nm. If IMAP is deselected while in the 160 nm range scale, the 80 nm range scale will be commanded. Once IMAP is selected, it remains selected until deselected by the pilot.

1.4.12.4 GMT (Ground Moving Target) Search Mode. The GMT mode provides the pilot with the capability to detect and display, moving ground targets. The GMT mode is selected by depressing the mode select pushbutton until the GMT option appears or the pilot may HOTAS the selection. See Figure 1-42.

The GMT mode provides a synthetic display of target returns similar to the SEA mode display. The only target returns displayed in the GMT mode, however, are from moving targets (trucks or tanks moving down a road) which demonstrate a doppler shift from the background. Ground and fixed target returns are not displayed. The only target returns displayed are from targets moving at greater than about 4 to 6 knots angular velocity.

GMT targets are processed and displayed at maximum intensity and background video is blanked. The returns are displayed as computer generated symbols (rectangles) which may vary slightly in size with the size of the target. For example, a moving train will be a string of relatively large returns whereas a panel truck may only present a very small return.

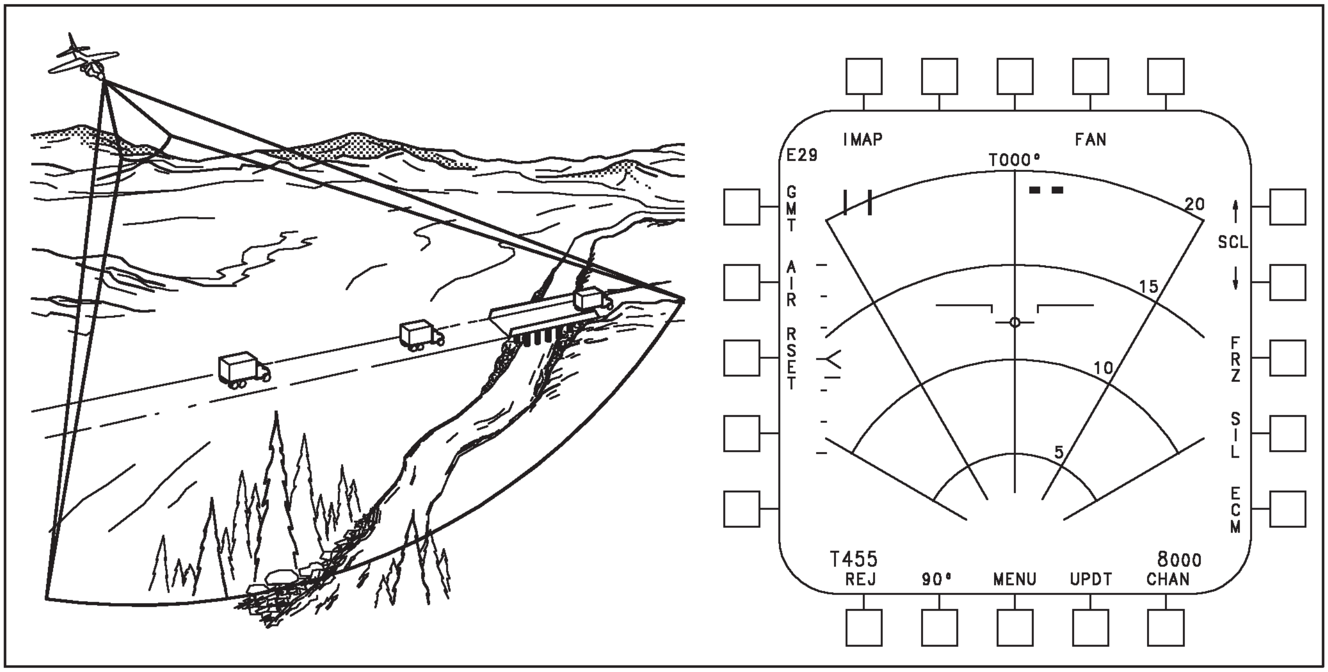

Figure 1-42. Ground Moving Target (GMT)

The operating parameters for the GMT mode are quite similar to the MAP mode with the following exceptions. The 120° azimuth scan is not available and range scale selection is limited to a maximum of 40 nm. Since GMT video is synthetic, auto gain control is used and the GAIN option is not displayed in the basic GMT mode.

A useful option, which is displayed in the GMT mode, is the interleave map (IMAP) option. When IMAP is selected (boxed), either by pushbutton or via HOTAS, the radar is commanded to interleaved operation, in which the radar scans in the MAP mode on a periodic basis in conjunction with the GMT mode. The result is MAP video with GMT synthetic video superimposed. This allows the pilot to orient synthetic GMT targets to the surrounding terrain (roads and bridges). When interleaved operation is selected, the GAIN option is displayed and adjustable as described for the MAP mode. However, changing the gain setting will modify only the MAP video.

1.4.12.5 Radar Track Modes

1.4.12.5.1 Fixed Target Track (FTT) and Ground Moving Target Track (GMTT). See Figures 1-43 and 1-44. If the pilot desires, he may have the radar antenna physically track an aim point on the radar display (MAP, EXP1, EXP2, EXP3, SEA or GMT). There are several situations where a radar track may be advantageous. First, unlike a radar designation, a radar track does not utilize the INS to maintain target position, therefore it is not subject to any INS drift error. Second, a radar track will follow moving targets and incorporate this movement into weapon delivery computations and steering.

The maximum range of a radar track will vary greatly with target size, surrounding clutter, and target movement. An important point to keep in mind when attempting to establish a radar track is that the expand modes give accuracy that a radar track may not have because of beamwidth distortion. This is because radar track is a real beam mode and does not take advantage of the doppler processing techniques utilized in the expand modes. This means that the radar may track any of the expand mode viewed targets

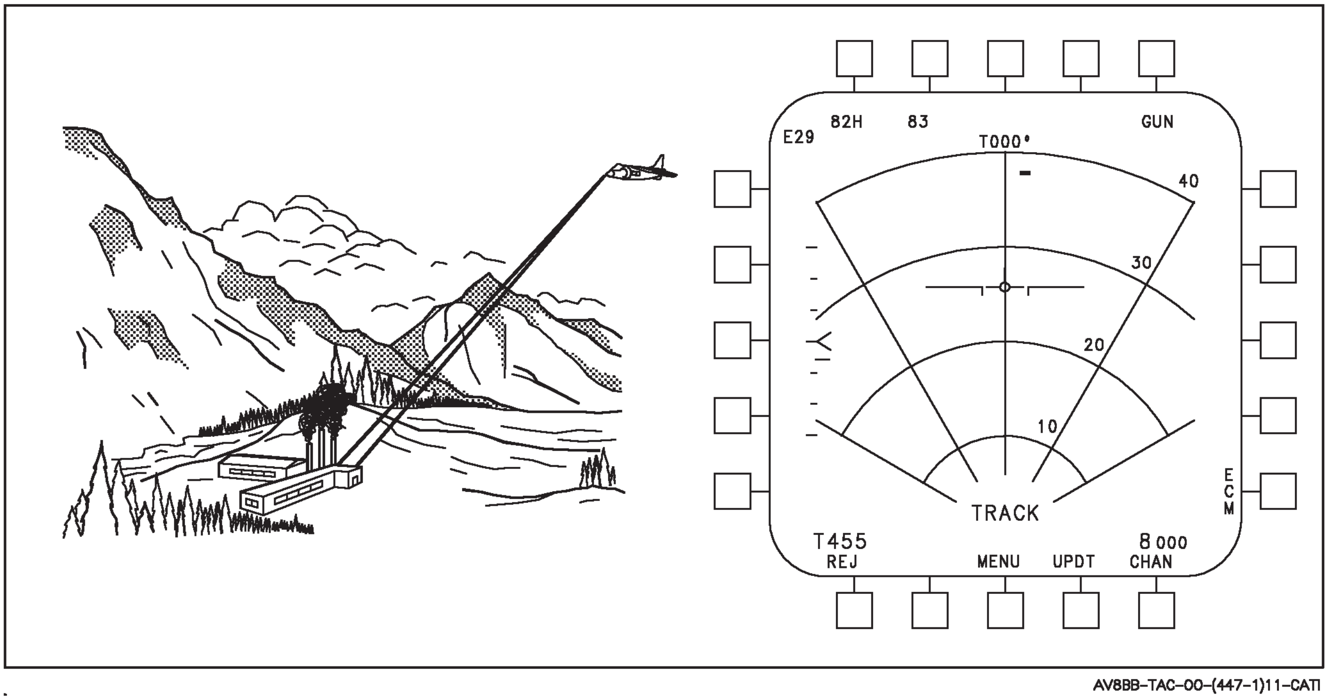

Figure 1-43. Fixed Target Track (FTT)

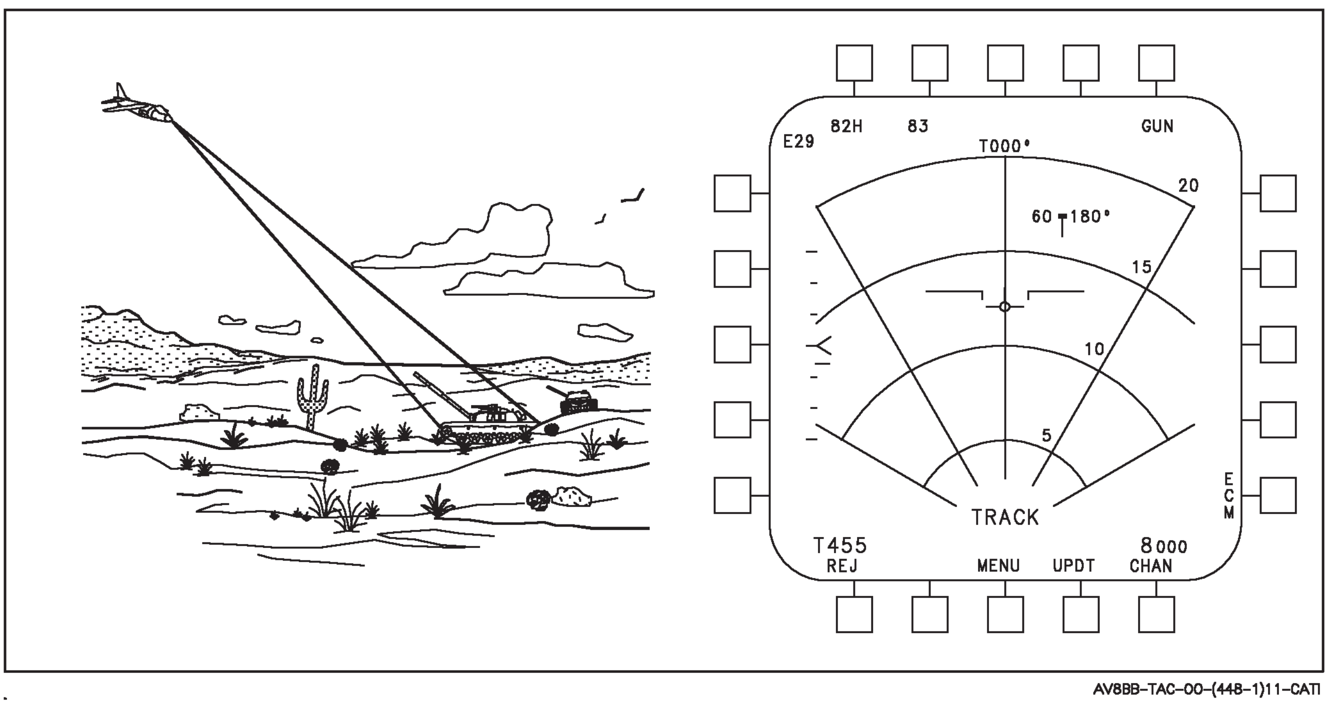

Figure 1-44. Ground Moving Target Track (GMTT)

within its beam coverage rather than the commanded track aim point. As such, it simply cannot resolve the detail available from an expanded display.

When track is initiated from an expanded display, the radar may *wander* between several significant radar returns that are within its real beam resolution cell. Eventually the radar will generally lock onto the strongest return since radar track uses amplitude acquisition to establish the track. The actual track point may be displaced from the intended acquisition point. Additionally, since the radar track displays use synthetic target symbols and no background radar video, the pilot cannot tell from the display if the radar is tracking the intended target or if it has locked onto the civilian facility that is adjacent to the terrorist training barracks until visual confirmation can be obtained.

Tracking from MAP, EXP1, EXP2, EXP3 or SEA is known as fixed target track (FTT) while tracking from GMT is known as ground moving target track (GMTT). This does not mean that the radar can not track a moving target in FTT, rather it is a matter of terminology. For example, if a moving target is tracked in the SEA mode (i.e., a ship), the track symbol will display the target course and speed as long as they are valid. Radar tracking velocities, when valid, are used in the A/G weapon delivery computations.

If the pilot performs a WOF while a target is being tracked (i.e., FTT or GMTT), the radar tracked target will continue as the target instead of the system designating the WO/S. The WOF will still perform the other WOF steps (i.e., select A/G master mode, Baro altitude loop correction (ALT), present position update, and bring up the last selected stores), however, the HUD TD box and steering will be to the radar track target. FTT can only reliably be used on targets that can be resolved as distinct targets in RGBM. If attempting to use FTT on a target that does not present sufficient radar return, FTT will wander or track the wrong target or return to the search mode (SEA, MAP, EXP1, EXP2, or EXP3) and display a stabilized cue and remain a radar designation.

1.4.12.5.2 Radar Track Procedures. Radar track can be commanded on a designated or an undesignated aim point. In either case, the first step is to ensure the TDC is assigned to the radar. If the aim point is already designated, the pilot actuates the sensor select switch aft to command acquisition. The MC blanks the radar operation options on the radar display when the acquisition phase is entered. During acquisition, the stab cue is replaced by the in-video cursor. While in the acquisition phase with the sensor select switch held aft, the pilot can slew the in-video cursor precisely over the desired aim point to be tracked. If the pilot depresses the TDC while slewing the in-video cursor over the aim point, he must remember to release it before commanding the radar to enter the track mode. Track is commanded when the sensor select switch is released. If track cannot be established, the aim point will remain a radar designation (system velocity stabilized).

If undesignated, acquisition is commanded at the HOTAS acquisition cursor position if it is inside the tactical video display region. (If outside the tactical region, no acquisition is commanded.) The pilot simply moves the acquisition cursor over the desired aim point and slides the sensor select switch aft. While the switch is held aft, the radar will enter the acquisition phase with the in-video cursor replacing the acquisition cursor over the aim point. While in the acquisition phase with the sensor select switch held aft, the pilot can slew the in-video cursor precisely over the desired aim point to be tracked. Track is commanded when the sensor select switch is released. If conditions do not allow radar track to be established, the aim point will become a radar designation.

When the radar enters the track mode, the radar displays a synthetic target symbol for the tracked aim point and all other map video is blanked. If the target is moving, the target course and speed (in knots) are digitally displayed adjacent to the target symbol along with a pointer projecting out from the target symbol denoting the ground track vector. The tracking status (TRACK) is displayed in the lower center of the radar display. Radar track status is also indicated on the HUD by the appearance of a TD box overlaying the tracked target. When tracking a target, the radar provides a continuous measurement of slant range and line of sight angles to the target. In this manner, the radar can accurately determine ground range, target bearing, and height-above-target for auto delivery calculations. In the CCIP delivery mode, the radar track provides steering to the target, however, height-above-target is determined by the radar altimeter (if valid and bomb colonized) or baro for CCIP calculations. Remember, normally the pilot would select AGR for the final delivery.

If the radar breaks lock on the aim point, it extrapolates the aim point position and provides track memory status to the MC. The TRACK legend on the radar display is replaced by the track memory status (MEM) legend and a number indicating how long the track has been in memory. In addition, the TD box in the HUD is flashed. If the radar remains in track memory for more than 5 seconds, the MC commands a radar designation on the last valid radar line-of-sight position and it commands the radar to return to the search mode from which track was established.

The pilot can manually break radar track by simply actuating the sensor select switch aft. This will break the radar track but will maintain the tracked aim point as a radar designation. Actuating the undesignate button will undesignate the aim point as well as break radar track.

1.4.12.6 Terrain Avoidance (TA) Mode. See Figure 1-45. In the TA mode, the radar searches the area ahead of the aircraft and uses three (counting black) intensities of synthetic video to display detected obstructions on the radar display. It is important for the pilot to realize that although the TA mode can assist the pilot by confirming what he sees (either unaided or sensor visual), it is not designed to provide a low level, all-weather, terrain avoidance capability.

WARNING

The TA mode of RDR does not present terrain within 1.6 nm of the aircraft. NOT AUTHORIZED FOR USE IN IMC CONDITIONS.

The TA mode is selected by depressing the mode select pushbutton until the TA option appears or the pilot may HOTAS the selection. The TA display consists of a fixed 70° wide scan that is centered on the aircraft's ground track. Range scales of 5 and 10 nm are available. TA range scale selection is maintained independently, that is, the presence of a designation will not cause the range to autoscale.

A simulated template with two clearance plane levels is projected in front of the aircraft to the selected range. These clearance planes, one at the aircraft altitude and one 500 feet below, are used as reference for determining the extent of terrain protrusions. The conventional azimuth and range grid is displayed with the addition of a range arc at 1.6 nm. This arc indicates the range at which the lower clearance plane is below the antenna processing beam width. In addition, the azimuth grid lines are displayed at 0° and +35°.

In level or climbing flight, the template is stabilized to a level attitude. Terrain that is above the upper reference clearance plane (above aircraft altitude) is displayed at an intermediate intensity level. Terrain that is detected above the lower reference clearance plane (below but within 500 feet of aircraft altitude) is displayed at a lower intensity. Terrain detections more than 500 feet below the aircraft are not displayed (black). Thus, video displays near the centerline of the radar display indicate terrain protrusions along the aircraft ground track that must be flown over or around to maintain at least a 500 foot clearance. This indicates to the pilot that he must maneuver toward the clear areas or climb until a clear ground track is indicated to avoid the protruding terrain.

When the aircraft dives, the reference template and the two clearance planes are tilted downward to parallel the aircraft flightpath vector. This changes the clearance plane stabilization reference from a horizontal plane at the aircraft altitude to the aircraft vertical flightpath angle. This function enables the radar to detect terrain protrusions before the aircraft dives so deeply into a valley that recovery is not possible. In the tilted clearance plane situation, the intermediate intensity level video denotes returns from terrain protruding above the aircraft flight vector.

Three display intensity levels are always shown in the wedges at the lower left and right so that the brightness can be properly adjusted.

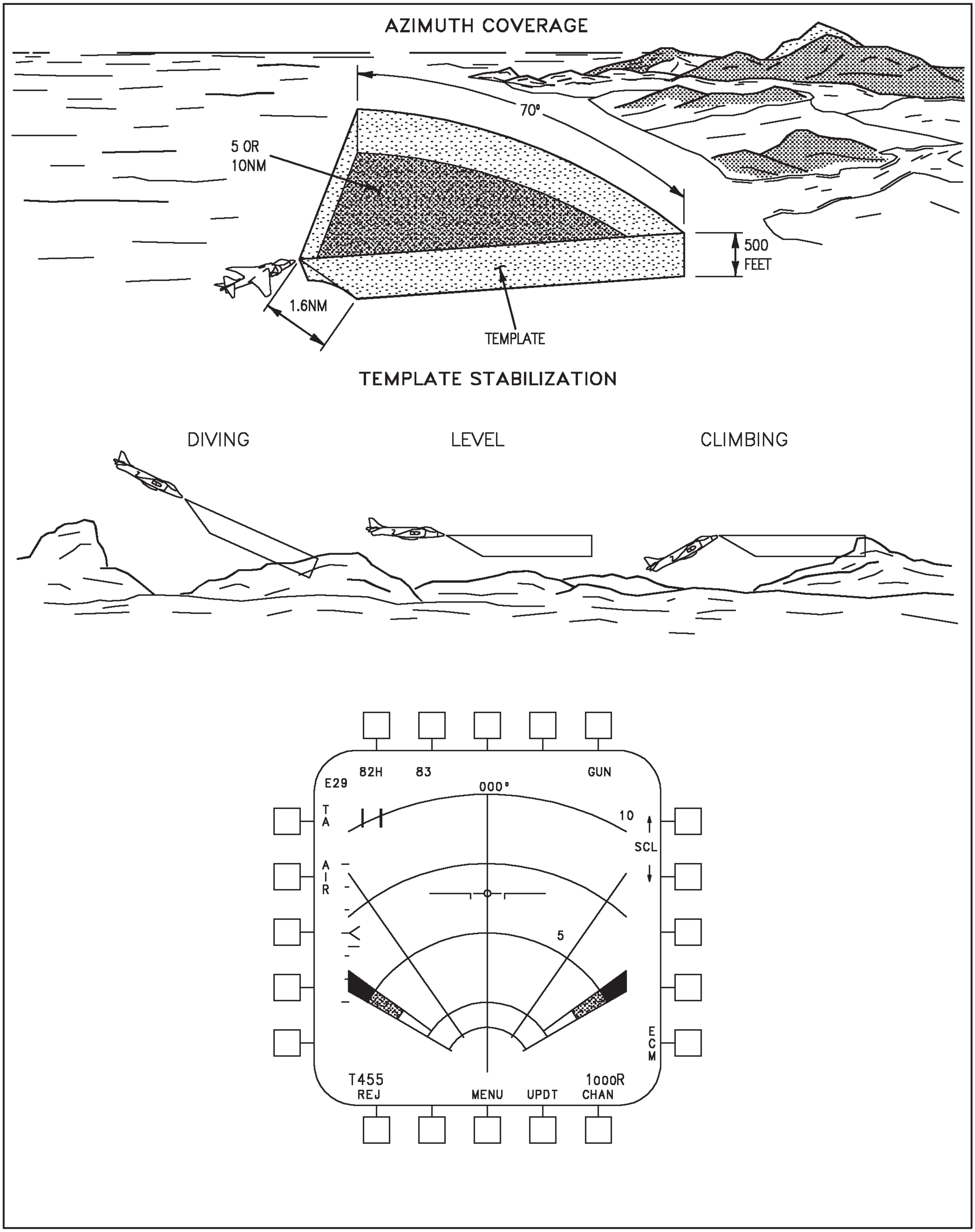

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Figure 1-45. Terrain Avoidance Display/Options

The brightest intensity level is displayed in the top third of the wedge. It corresponds to the intensity of the grid lines and legends on the display. The intermediate intensity level in the middle third corresponds to the clearance plane above the aircraft. The bottom third of the wedge is a lower intensity corresponding to the lower clearance plane.

Navigation using the TA mode is accomplished by maneuvering toward clear areas on the radar display or by climbing until a clear ground track is displayed. The pilot should remember that the TA mode display is a synthetic representation of terrain protrusions, hence radar target detection and designation is unavailable in the TA mode. If the radar detects any failure that would affect the TA mode, a TA FAIL legend will be flashed at a 2 Hz rate near the center of the TA display. The TA FAIL legend will appear whenever excessive rainfall or other adverse conditions are detected which would degrade the TA mode to unacceptable levels, or a failure is detected.

1.4.12.7 AGR (Air-to-Ground Ranging) Mode. The AGR mode provides accurate slant range and doppler velocity error along the commanded LOS and sends the result to the MC. The AGR mode is selected by moving the sensor select switch forward. Initial actuation of the sensor select switch forward also selects the INS sensor mode, assigns the TDC to the HUD, and selects the AGR display (if a radar display is currently displayed). AGR acquisition ranges are from 1,000 feet to 10 nm slant range.

The MC will slave the radar antenna LOS in AGR to the appropriate location based on the following priorities:

1. CCIP cross (gun and rocket reticle). If the dashed CCIP cross (limited) and reflected cue are displayed, AGR ranges to the limited CCIP cross at the bottom of the HUD FOV.

2. Designation (HUD, WYPT, WO/S, etc.)

3. Velocity vector

If the MC determines that AGR data is invalid, AGR will remain selected but ranging data will not be utilized. For example, when EMCON is selected, AGR ranging is inhibited. When EMCON is deselected, the MC will utilize AGR data if valid. AGR data will also be invalid if acquisition ranges are exceeded. When AGR data becomes valid (in range), it will be utilized by the MC. In addition, the radar inhibits AGR in the elevation band from 4° below the horizon to 0.5° above the horizon when slewing a designation upward. This is due to the problems associated with low grazing angles.

There are several cues which inform the pilot when AGR is selected and whether AGR data is valid. Initial selection of AGR (sliding the sensor select switch forward) displays a dot in the velocity vector and selects the AGR display on the right MPCD if a radar display is currently selected. If a radar display is not currently displayed, the pilot can HOTAS the AGR display by simply rocking the castle switch back once and then forward again to reselect the AGR mode. The AGR mode display is essentially the stores display with the addition of AGR specific calligraphic symbology (range and velocity error data). The pilot may change the AGR display via the main MENU or HOTAS (i.e., Head-down FLIR selection) while remaining in the AGR mode.

Although the dot in the velocity vector is a good cue, remember the dot actually represents TDC assignment to the HUD. There are certain cases in which AGR is selected and there is no dot in the velocity vector. For example, if TDC assignment is switched from the HUD to the digital map, either via map update or DATA mode selection, the dot will disappear but the radar will remain in the AGR mode. If there is any question in the pilot's mind whether AGR is selected, he should slide the sensor select switch forward to command AGR.

Generally speaking, anytime the pilot is looking "through the HUD" for the target, it should be an automatic pilot reaction to slide the sensor select switch forward. This not only selects AGR, it ensures that if the pilot slews the HUD TD diamond he is using HUD slew rates and not

DELIVERY MODE	ALTITUDE SOURCE			
	AGR/FTT/GMTT	BARO	RADALT	GPS
AUTO Mode	AUTO	BAUT	RAUT	GAUT
CCIP Mode	CCIP	BCIP	RCIP	GCIP

Figure 1-46. Delivery Mode/Altitude Source Display

radar or map slew rates. If the pilot desires to view the radar display (other than AGR), he simply slides the sensor select switch aft. In this manner, the pilot learns to have the sensor select switch follow his eyes.

When AGR data is valid, an AGR legend will be displayed on the right side of the HUD above the delivery mode legend. If AGR data is invalid (i.e., EMCON, SIL, range limits exceeded, etc.), the AGR legend is removed. The computed delivery mode legend (AUTO, CCIP, etc.) is mechanized to display altitude source in a manner similar to the Day and Night Attack aircraft. See Figure 1-46. For the Radar aircraft, AGR replaces the ARBS as the priority altitude source for weapon delivery computations. See Figure 1-47. The MC altitude source for delivery computations is displayed to the pilot as follows:

The pilot should note that in the AUTO delivery mode, AGR (AUTO displayed) is only utilized during initial designation with AGR valid, during slew with AGR valid, or upon initial selection of AGR after AGR becomes valid. After AGR (slant range) is determined, AUTO will be displayed as an indication that valid AGR was used by the MC to compute height above target.

Slant range, in feet, is provided to the MC for weapon delivery computations and displayed on the AGR display whenever the range data is valid. A velocity error (△VEL) is also displayed below the range readout. This error, in knots, is the difference between the range rate computed by the radar as measured along the radar LOS and the best available (i.e., INS) system derived velocity.

The VEL error is displayed only as an advisory to indicate to the pilot that a PVU (precision velocity update) may be necessary. A VEL error of more than about 3 knots is an indication that the INS may be drifting excessively. If range and range rate data are invalid, the RANGE and VEL readouts are blank and the AGR legend in the HUD is removed.

The AGR mode is deselected by commanding any other radar mode (i.e., reassigning the TDC to the radar, selecting the A/A master mode, PVU, etc.).

1.4.12.8 Precision Velocity Update (PVU) Mode. The PVU mode utilizes the radar in a purely doppler mode to take an accurate measurement of aircraft ground speed. The PVU mode is automatically selected when a velocity (VEL) update or an in-flight alignment (IFA) is selected by the pilot. In the PVU mode, the radar commands the antenna to three distinct look angles to separate aircraft velocity vector components and computes the aircraft's ground speed vector. See Figure 1-48.

In the IFA function, the radar derived velocities are used as a reference during platform gyrocompassing and alignment for the INS platform.

1.4.12.8.1 Velocity Update. The VEL update function is integrated into the normal Harrier update functions. The first step is to select the UPDT option on the RDR, EHSD or FLIR display. The ODU will initialize with the available update options. The velocity update option (VEL) will appear in the window above the REJ option. Selecting the VEL option will command the radar to the PVU mode and enable the PVU

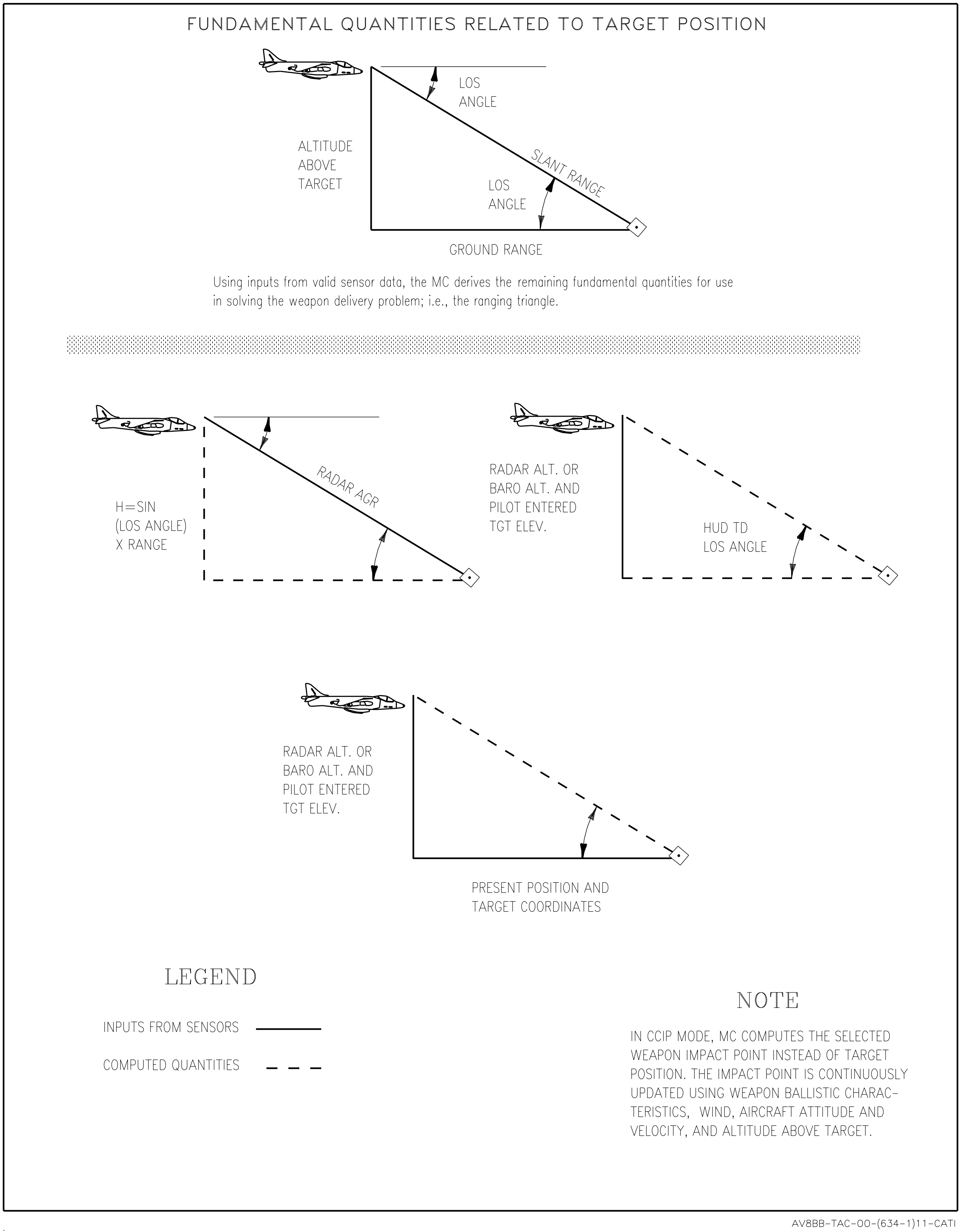

Figure 1-47. Fundamental Quantities Related to Target Position

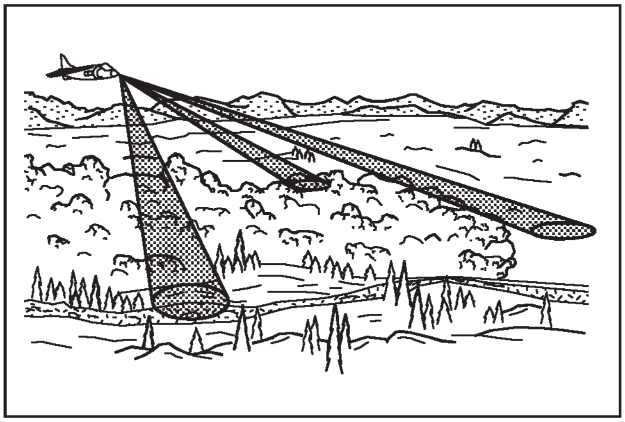

Figure 1-48. Precision Velocity Update

display in place of the RDR display, if present. At the same time, the ODU will blank and display the LAND and SEA options in the first two windows. When LAND is selected, the three space stabilized antenna look angles are as follows:

10° elevation and 45° left
45° elevation and 0° azimuth
10° elevation and 45° right

With SEA selected, the three antenna look angles are as follows:

35° elevation and 45° left
45° elevation and 0° azimuth
35° elevation and 45° right

The applicable LAND or SEA option should be selected by the pilot to optimize the radar antenna lookdown angle for the type of surface you are flying over. For example, over sea at high altitude, or where the terrain returns are at a minimum, the SEA option would be the preferred antenna selection, otherwise LAND is the best option. The LAND option is the default selection.

The radar determines aircraft velocity by measuring the doppler shift in the return echoes. The PVU derived error (the difference between radar derived velocity and best available system velocity) is displayed on the scratchpad in the form of a radial (degrees) and velocity (knots/tenths) errors. An initial error will appear rather quickly, but the longer the radar is allowed to remain in the PVU mode, the more accurate the radar derived velocities will be. Generally, 15 seconds should provide a very accurate correction to the MC velocities. (You may see the velocity error change and stabilize as the PVU progresses). After the error stabilizes, the pilot may accept or reject the error on the ODU.

Accept/reject criteria would depend upon the quality of the initial alignment and overall INS operation (i.e., FULL INS, FIRST ORDER AHRS, etc.). Errors of more than 3 knots or so should be considered for acceptance in order to maximize weapon delivery accuracy. After the error is accepted or rejected, the radar reverts to the previously selected mode.

If accepted, the PVU correction is retained by the MC for weapon delivery computations for a period of approximately 10 minutes, with the correction being gradually phased out over the last 5 minutes. For this reason, it is important that the pilot select the velocity (VEL) update a short period of time prior to weapon delivery. The pilot should note that the PVU correction is utilized for weapon delivery computations only and does not affect INS navigation velocities.

The PVU mode radar display is basically blank, except for a large PVU legend near the center of the display which serves to cue the pilot that the PVU mode is selected and operating. The PVU mode is inhibited in the A/A master mode and during EMCON.

1.4.12.9 In-Flight Alignment (IFA) Mode. On Radar aircraft, while in the NAV or VSTOL master modes, the INS can be aligned inflight by placing the INS switch to the IFA position. The INS IFA mode is essentially a straight and level mode. The INS will go into a form of align hold if certain attitude limits are exceeded. When turns are required, the pilot should make them quickly, coming back to straight and level as soon as possible. While the switch is in the IFA position, the radar is commanded to the PVU mode and the alignment display is presented on the EHSD. Upon initial selection of IFA, continuous PVU mode is commanded. If the continuous PVU is deselected on the ODU, the PVU mode is commanded for 10 seconds of each minute alternating with the last selected radar mode. The use of intermittent PVU mode may increase IFA alignment time and may degrade the navigation accuracy.

In the PVU mode, the radar provides doppler velocities for the INS alignment. As in the radar velocity (VEL) update, the radar lookdown angles are optimized for land or sea return by selection of the LAND or SEA options on the ODU. The SEA option is the default selection for an IFA. If the radar is not operating or if it is inhibited from operating in PVU, the time-in-alignment display flashes and continuous PVU cannot be commanded. When AGR is selected, continuous PVU is deselected, 20 seconds of AGR is commanded, then PVU is commanded 10 seconds of each minute alternating with AGR.

Present position can be provided for the alignment by performing a position update using the UPDT option or by entering the aircraft data via the DATA option. Velocity updates cannot be performed during IFA. IFA can complete a partial SEA or GND alignment or begin with an erected or unerected AHRS system. During the alignment, air data dead reckoning (DGD/ADC) is used for navigation and to maintain a current present position when the INS QUAL number is greater than 5.0. With a QUAL number of less than 5.0, the INS is used for navigation and present position. On the EHSD, ATT NOT OK is displayed until the INS platform is leveled and then a quality number is displayed. When a satisfactory alignment is achieved, OK is displayed next to the quality number. Then the INS can be switched to the NAV mode. Starting with an unerected platform, the IFA may take 14 minutes or longer depending on aircraft maneuvers and PVU quality (19 minutes typical). Upon switching out of IFA, the IFA display and PVU radar mode are deselected.

1.4.13 Radar Weather Mapping. The MAP mode is the best radar display for detecting particularly nasty weather. Sometimes, weather detection is hampered by ground returns in the area that hides the storm. Most often, this occurs in mountainous areas where ground returns are similar and the air mass lifting action in the area breeds the cells. For these reasons, any opportunity to raise the beam above the ground or narrow the beam or both, are techniques that will speed weather detection. Thus, antenna elevation and beam selection are two factors the pilot can use to optimize the radar for weather mapping.

Antenna elevation is a critical factor in mapping weather. In normal MAP mode operation, the radar will automatically adjust the antenna elevation angle based on the aircraft's altitude and the range selected. In order to optimize the radar for weather mapping purposes, the pilot must disregard this auto setting and manually manually slew the antenna straight ahead. This is accomplished by slewing the antenna so as to place the elevation carat at the 0° line on the antenna elevation scale. On the left side of the radar display.

The pencil (PEN) beam is recommended for weather mapping. Normally, auto beam selection is used in the MAP mode, therefore, the PEN or FAN beam could be selected depending on the current conditions. If the FAN option is displayed, the pilot can override auto beam selection and manually select the PEN beam by depressing the FAN option pushbutton or via HOTAS. Using the PEN beam accommodates *gouges* for some basic facts. Since the pencil beam is about 3.9° in diameter, this means that the radar beam will cover about 8000 vertical feet at 20 nm and 16000 vertical feet at 40 nm. These gouges allow the pilot to measure the size of the rain cell, and the height of the cell is a fair indicator of the strength of that cell. The higher, the meaner. If the pilot wishes to return to ground mapping, he can reselect auto beam selection and the optimum antenna elevation for the current conditions by simply selecting the RSET option.

Weather avoidance with the radar is mainly of two types: (1) avoidance of isolated thunderstorms, and (2) penetration of a line of thunderstorms. The process of avoiding an isolated return is one of first identifying the return and then circumnavigating it at a safe distance. Returns from light precipitation (i.e., drizzle) will probably not show up. Returns from moderate precipitation will show as a medium contrast. Heavy precipitation will show as a bright return. If the return is very bright, and actually casts a shadow (radar energy unable to penetrate storm), this indicates very heavy precipitation, probable turbulence and ice, etc. Avoid the very bright weather returns.

When a weather system is detected, its extent should be ascertained. Analyze the weather's layout relative to planned flight path and decide whether to deviate around it or penetrate the line. If the weather system is complex, attempt to determine if your deviation could lead to worsening the situation by flying into a "suckerhole", where a solid system could surround the aircraft. Sometimes, what seems to be a good heading at low ranges will seem foolish when the long range view is analyzed. Remember to make use of all available resources in deciding the best course. For example, ARTCC can sometimes aid in this analysis. They have access to pertinent PIREPS in addition to being able to display weather systems over vast areas.

A simple technique for flying around weather at a preferred distance (say 20 nm) is the "flying disc" technique. Imagine the aircraft is a disc defined by the 20 nm range arc on the radar display. Draw an imaginary tangent from the disc to the edge of the weather and then turn the aircraft the same number of degrees that it would take to get the 0° azimuth grid line to fire parallel to the tangent. After the turn, recheck the heading in the same manner.

Penetration of a line of thunderstorms presents a somewhat different problem. Since the line may extend for hundreds of miles, circumnavigation may not be practical nor even possible. If the flight must be continued and the line penetrated, the main objective is to avoid the more dangerous areas in the line. If the weather returns all blend together in the area to be penetrated, decreasing gain will work to highlight the worst areas. Upon approaching the line, the aircraft is flown through the area which has the weakest or no returns, and which is large enough to allow avoidance of all intense returns by the recommended distances throughout penetration. When possible, the penetration should be made at right angles to the line so as to remain in the bad weather areas for the shortest possible time. Great care must be taken to avoid the dangerous echoes by safe distances. It should be attempted only when continuation of the flight is mandatory and the line cannot be circumnavigated. In all cases, when deviating from flight planned route, advise ARTCC of your intentions, when able.

Severe turbulence, hail, and the icing associated with thunderstorms constitute severe hazards to aircraft safety. It is therefore mandatory that thunderstorms be avoided whenever possible. Although the radar is generally considered an all weather sensor, it operates at a wavelength which provides good weather avoidance capabilities. If the radar is operated and interpreted properly, it can be an invaluable aid in avoiding thunderstorm areas. Several factors affect the radar returns from thunderstorms, and the pilot must be aware of these and the limitations they impose on the radar. The same weather can vary in its appearance on the radar display, depending on selected radar parameters. It is therefore important that the pilot knows how the radar is working for him and how to optimize the radar when using it for weather avoidance and navigation.

The most important factors which affect weather returns are the number and size of the water droplets in the clouds. The predominant weather returns on the radar display are caused by precipitation-size water droplets, not by entire clouds. Intense returns indicate the presence of very large droplets. These large droplets are generally associated with the most hazardous phenomena; those with strong vertical currents which are necessary to maintain these droplets in the cloud. It is possible, however, to encounter such strong turbulence in an echo-free area or even in an adjacent cloud-free area, so avoiding areas giving intense returns will not necessarily guarantee safe flight in the vicinity of thunderstorms.

Exact distances and avoidance procedures recommended by researchers varies, however, they rarely recommend passing closer than 10 miles to intense echoes at low altitude. Avoidance by even greater distances is recommended at higher altitudes. Mission planning should always take note of all areas forecast to have the potential for hazardous weather. In this case, being forewarned is the best motivation for being alert and monitoring an area for weather returns.

Weather returns which appear on the radar display are of interest for two basic reasons. First, since the brightness of a given cloud return is an indication of the intensity of the weather within the cloud, intense weather areas can be avoided by flying through the areas of least intensity or by circumnavigating the entire severe weather area. Second, cloud returns obscure useful natural and cultural features on the ground and can cause a deceptive radar display to be presented. Weather returns could also be falsely identified as a ground feature, which can lead to display misinterpretation.

Clouds must be reasonably large to create a return on the display. However, size alone is not the sole determining factor. Remember, the predominant weather returns are not caused by clouds, rather they are caused by precipitation-size water droplets in the clouds. Indeed, the one really important characteristic that causes clouds to create radar returns is the size of the water droplets forming them. The radar signal is reflected from large rain droplets and hail which are either falling or are suspended in the clouds by strong vertical air currents. Thunderstorms are characterized by strong vertical air currents; therefore, they give strong radar returns.

Thus, attenuation of the radar signal is primarily caused by rain, and to a lesser degree by snow and drizzle. However, wet snow and wet hail can also be quite effective at blocking the radar signal. Ice particles with a coating of liquid water are also especially effective obscurants. Just as the density of surface material affects the reflectivity of an object, the density of clouds affects weather returns. In general, the radar signal penetrates clouds enough to allow the pilot to see storms and thus avoid heavy weather. Thunderstorms or very dense areas of atmospheric moisture are quite radar significant. The moisture can be so dense that it actually reflects radar energy back to the antenna. The more moisture in a cloud, the stronger the weather return.

Cumulonimbus (puffy, cauliflower-type clouds) and thunderstorm clouds are more dense than stratiform clouds and thus will produce a stronger return. In general, heavy fog and stratiform clouds will attenuate radar energy but are not dense enough to reflect enough energy to cause a weather return on the display. Cumulonimbus, thunderstorms, and squall lines are dense enough to cause a weather return on the radar display. Squall lines vary in intensity. The brightest area of a strong return indicates maximum or greatest turbulence, hence do not penetrate a storm front at a strong return (i.e., bright) area.

If the weather is dense enough, just as mountains have mountain shadows behind them, heavy weather such as thunderstorms and squall lines can have no-show, shadow areas behind them. Cloud shadows, like mountain shadows, can either converge or extend to the edge of the display, depending on aircraft altitude. Cumulonimbus clouds and squall lines usually extend to greater altitudes than mountains, therefore, the cloud shadows usually extend to the edge of the display. In fact, a cloud shadow can fan out. Another way to tell weather returns from other returns is to change antenna elevation. When the antenna elevation is raised, other returns weaken but heavy weather returns remain.

In summary, cloud returns may be identified by the following characteristics:

1. Brightness from weather returns varies considerably, but the average brightness is greater than a normal ground return.

2. Weather returns are generally fuzzy with vague edges, whereas cultural returns are sharp and well-defined.

3. Very heavy weather returns often produce shadow areas similar to mountain shadows. Generally , cloud shadows will fan out while mountain shadows converge.

4. Weather returns from a tall thunderstorm do not fade away as the antenna elevation is raised, whereas ground returns do tend to fade as the antenna elevation is raised.

1.5 AIR-TO-AIR RADAR MODES AND OPERATION

The air-to-air radar modes provide threat detection and tracking beyond visual range, under all but the worst weather conditions, plus rapid target acquisition and improved weapon aiming solutions at close-in range. In addition to A/A master mode operation, the radar is integrated to permit limited utilization of A/A functions in VSTOL, NAV, and A/G master modes (AIR option).

Most phases of A/A attack (target detection, acquisition, tracking, and steering), can be performed head-down using the radar display. As a result, the pilot will be able to establish attack geometry at long ranges. A/A attack enhancements will also be realized for close-in, visual ranges. In the air combat maneuvering (ACM) environment, the radar provides automatic target acquisition modes tailored for the ACM environment. It also improves weapon system function through automatic Sidewinder seeker head slaving to the radar line-of-sight (LOS) and the addition of a gun director aiming mode. In the intense ACM environment, these functions will significantly reduce pilot workload through the addition of automated detection and tracking features and improved weapon aiming solutions.

1.5.1 Air-to-Air Radar Modes Overview. The air-to-air radar program performs three basic functions: search, acquisition, and track. There are two other radar operating modes that augment the basic functions. These are Raid and Electronic Counter-Countermeasures. The APG-65 air-to-air program consists of the following modes:

- Search Modes
  - Range While Search (RWS)
  - Velocity Search (VS)
  - Track While Scan (TWS)
- Acquisition Modes
  - Manual Acquisition
  - Auto Acquisition (AACQ - Fast ACQ)
  - Air Combat Maneuvering Modes (ACM)
  - Wide Acquisition (WACQ)
  - Vertical Acquisition (VACQ)
  - Boresight Acquisition (BST)
  - Gun Acquisition (GACQ)
- Track Modes
  - Single Target Track (STT)
  - Track While Scan (Computer Track)
- Other A/A Modes
  - Raid
  - Electronic Counter-Countermeasure (ECCM)

1.5.1.1 Search Modes. Air radar search modes are used for target detection at extended ranges and for maintaining SA. Search modes include RWS, VS, and TWS.

Range While Search (RWS) - RWS provides target detection up to 160 nm. It is usable with all aspect targets including high closure rate, head-on attacks.

Velocity Search (VS) - The VS mode detects air targets as a function of target velocity relative to ownship velocity. It is used for long range detection of head-on targets and has good look-down capability. Only closing targets are displayed on the VS format.

Track While Scan (TWS) - The TWS mode provides multi-target detection and track capability. It can maintain up to 10 track files and display the 8 highest priority tracks.

1.5.1.2 Acquisition Modes. Air radar acquisition modes are used to acquire and lock on to the detected target. These modes include ACM, GACQ, automatic (AACQ), and manual acquisition. The GACQ mode, although technically an ACM mode, can only commanded by selecting the gun.

1.5.1.2.1 Air Combat Maneuvering (ACM) Modes. There are three pilot selectable modes in which the radar automatically locks on and tracks airborne targets. These modes are Wide Acquisition (WACQ), Vertical Acquisition (VACQ), and Boresight Acquisition (BST). Each of the ACM modes is optimized for a specific scan volume and range.

1.5.1.2.2 Gun Acquisition (GACQ). Gun acquisition is automatically selected whenever the A/A gun is selected and the radar is not in STT or another ACM mode. In GACQ, the radar will lock on to and track targets with the GACQ scan volume which approximates the HUD field-of-view.

1.5.1.2.3 Auto-Acquisition (AACQ). The AACQ mode provides auto-acquisition capability at greater ranges than the ACM modes. AACQ does not change scan volume and range parameters like ACM modes but operates within the operating parameters established for the search mode selected (RWS, VS, or TWS). The AACQ mode will not function on the 5 nm range scale.

1.5.1.2.4 Manual Acquisition. In addition to auto acquisition capability, the pilot is able to manually designate and acquire targets using the TDC and the acquisition cursor.

1.5.1.3 Track Mode. There is one true A/A track mode - Single Target Track (STT). Whenever the radar achieves an angle lock on the target, either from auto, manual, or an ACM acquisition mode, it enters the STT mode. Full target track is achieved when all the targeting parameters (angle, range rate, and velocity) are available. The STT mode provides the highest quality target data. This data is used to compute and display launch zones, allowable steering error, and steering for the selected weapon on the HUD and radar display.

1.5.1.4 Other A/A Modes. There are two other radar operating modes which are distinct from but augment the basic detection, acquisition, and tracking modes. These are RAID and an Electronic Counter-Countermeasures mode.

RAID - The RAID mode provides the capability to resolve closely spaced targets through doppler beam sharpening (DBS) techniques. It is only accessible from the STT and TWS modes.

ECCM - This mode provides the capability to determine the presence and location of active ECM sources and automatically adapts the radar for search and acquisition performance to counteract against noise and deception type jammers. Refer to NWP 3-22.5-AV8B, Vol. III, Chapter 6, for the appropriate classified document for more information on ECCM displays and capabilities.

1.5.2 Air Radar Mode Selection. Radar mode selection has been mechanized to provide a balance between automatic features which reduce pilot workload and enhance system performance, and flexibility features which permit pilot intervention when needed. As a result, A/A weapon selection when in NAV, VSTOL, or A/G master mode automatically initializes the A/A master mode and commands the radar to a specific default mode - RWS in the case of Sidewinder selection and GACQ in the case of gun selection with one exception. If the radar is operating in NAV, VSTOL or A/G master mode with the AIR option selected, selecting an A/A weapon does not initialize the default mode but retains the existing AIR mode and operating parameters. This mechanization allows the pilot to step into an A/A attack without losing the SA provided by the current AIR radar display.

With AIM-9 selected, radar acquisition requires pilot action to either command one of the automatic acquisition modes (WACQ, BST, VACQ, AACQ) or perform a manual lock on. With the gun selected, an acquisition mode (GACQ) is automatically selected to expedite the close-in engagement. In either case, STT is automatically performed. The RAID mode is then

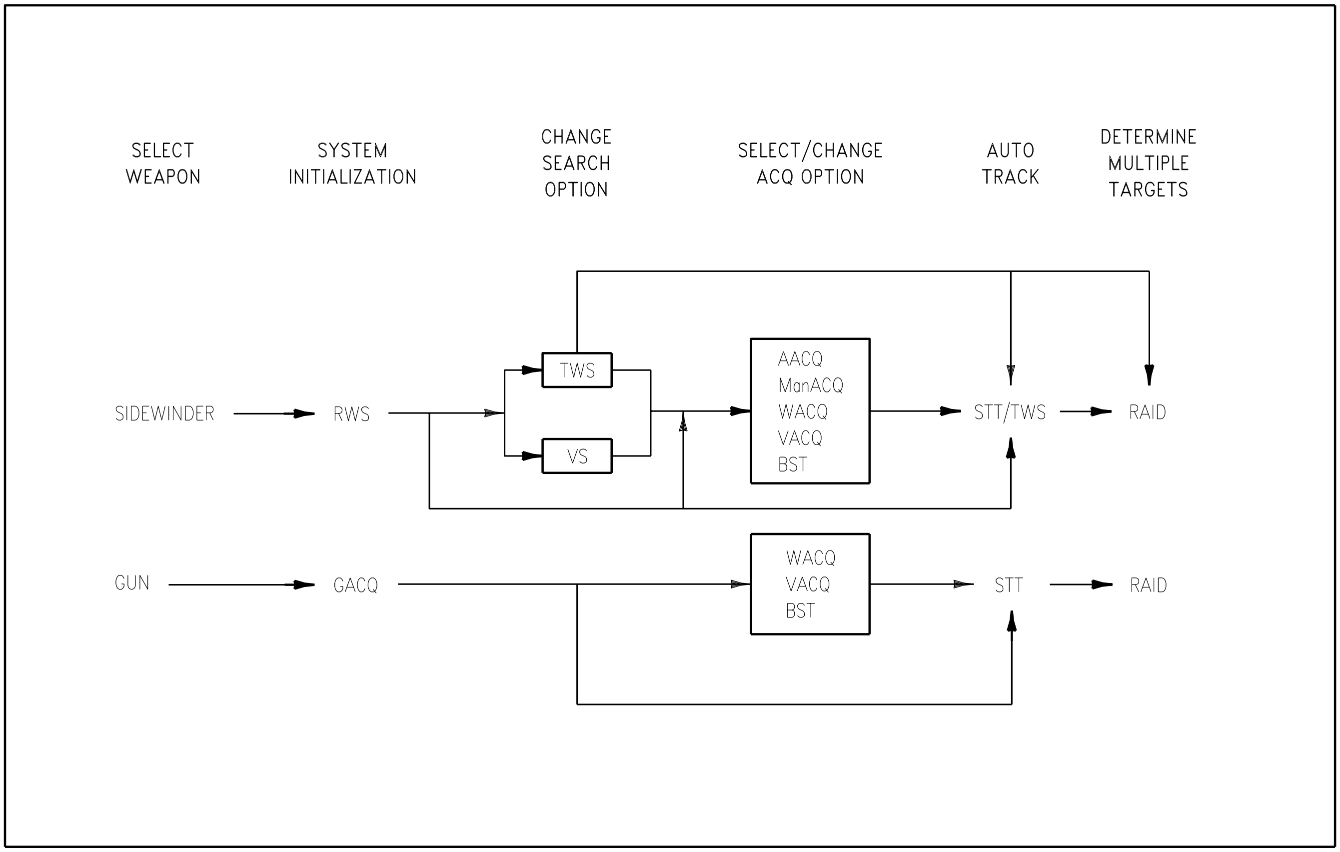

Figure 1-49. Radar Mode Interaction

available for the STT or with a Launch and Steer (L&S) TWS target. The functional relationship between radar modes is shown in Figure 1-49.

Although search and detection capability is available in all master modes, A/A target acquisition and tracking modes are not available while in A/G master mode. Also, the ACM and GACQ acquisition modes are not available in VSTOL and NAV because of HOTAS switch limitations. Although targets can be acquired and tracked in the VSTOL and NAV master modes, weapon launch acceptability region and steering information is not provided until A/A weapon selection has occurred.

1.5.2.1 Air Radar Initialization. As in the Day and Night Attack aircraft, selecting an A/A weapon automatically initializes the A/A master mode if not previously selected. It also commands the radar to the appropriate air radar operating mode based on weapon selection and automatically configures the HUD and right MPCD to display the appropriate A/A symbology. Sliding the A/A weapon select switch on the flight control stick forward or aft selects, respectively, the Sidewinder boresight or SEAM missile mode and commands the RWS mode of radar operation unless the radar is operating in STT, TWS with an L&S target, or the AIR option is boxed. If the radar is already in STT or TWS with an L&S target, the respective mode is retained. If operating in the NAV, VSTOL, or A/G master modes with the AIR option selected, the existing radar operating mode and parameters are retained. Depressing the A/A weapon select switch commands the GACQ mode unless the radar is in STT or another ACM mode is selected. In these cases, the current radar operating modes are retained.

In the A/A master mode, if an air radar display has been replaced by selecting another menu option on the MPCD, the air radar display can be redisplayed by depressing the RDR option on the MPCD MENU format. This recalls the last selected air radar display.

Once a Sidewinder has been selected, reselecting Sidewinder boresight or SEAM on the A/A select switch will step the missile station. If gun is selected using the A/A Weapons Select Switch and then a non-radar mode is selected using the main MENU, the current gun display cannot be reselected using the weapon select switch. Reselecting a gun display requires selecting RDR on the main MENU.

1.5.2.2 AIR Option. In the VSTOL, NAV, and A/G master modes, selecting the AIR option on the MPCD or depressing the APS (Air Program Select) button on the throttle brings up the RWS display without a weapon indication. Selection is indicated by the boxed AIR option. See Figure 1-50. Note that the AIR display does not provide the SET option for changing the values of the initialized radar parameters. In NAV and VSTOL master modes, VS and TWS options can also be selected from the AIR display. The only other AIR radar mode available in the A/G master mode is VS. Deselection of the "AIR" option returns the radar to the default surface mode (MAP mode, 40 nm, 120° azimuth scan, auto beam selection). If NAV or VSTOL is selected from the A/A master mode, the radar initializes with AIR boxed and the appropriate air radar mode. By contrast, if the A/G master mode is selected from the A/A master mode the radar will initialize to the default MAP mode.

On the ground, selecting either Sidewinder or SEAM initiates the RWS mode. Selecting gun initiates the GACQ mode. On the ground, options will be available for selection but transmission will be inhibited as indicated by the

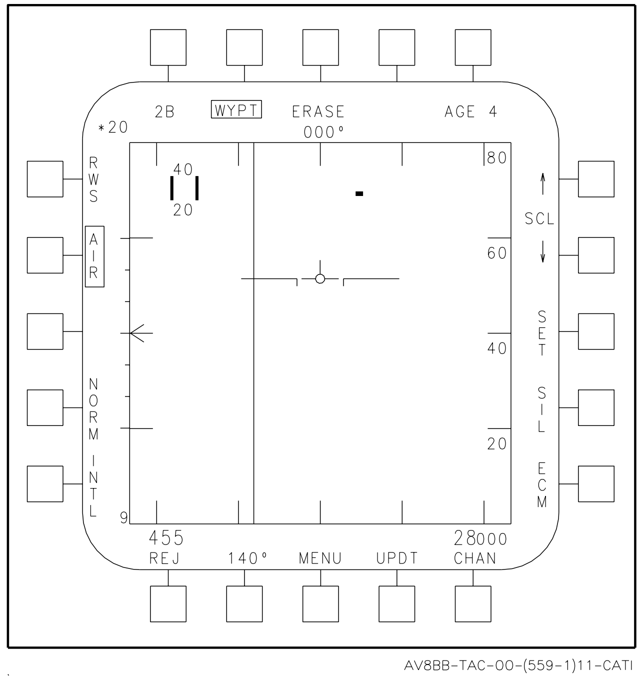

Figure 1-50. Air Radar Format

presence of the Maltese Cross and lack of targets. In the air the same modes will be initialized and the system will be fully operational at airspeeds greater than 70 knots indicated with weight-off-wheels. If the pilot reselects another A/A weapon and a single target track had been established, the STT mode will be retained and the displays configured accordingly for the selected weapon.

1.5.2.3 A/A Mode Initialization Parameters. Associated with each A/A weapon selection (Sidewinder, SEAM, Gun) is a set of radar mode initialization parameters. When power is first applied with weight-on-wheels, a default set of parameters is initialized as shown in Figure 1-51.

PARAMETER	SIDEWINDER	SEAM	GUN	AIR
Mode	RWS	RWS	GACQ	RWS
# Bars	4	4	5	4
AGE	8 sec	4 sec		8 sec
SCL	40 nm	20 nm	5 nm	40 nm
CHAN	AUTO	AUTO	AUTO	AUTO
Azimuth	140°	45°	20°	140°
PRF	INTL	MED	MED	INTL

Figure 1-51. Air-to-Air Radar Default Parameters

Gun initialization parameters are fixed. For Sidewinder and SEAM, the pilot can change PRF, azimuth, elevation bars, AGE, and range initialization parameters using the SET option on the RWS display. The Radar aircraft provides this capability when on the ground for the Boresight mode and in the air for both Boresight and SEAM. The SET option is only available on the RWS format when Sidewinder or SEAM is selected. Selecting the AIR option from a surface radar display will not bring up the SET option since selection between Sidewinder and SEAM is not possible by this mechanization. The 3 minute radar warm-up and the associated operational readiness test (ORT) must also have been successfully completed before radar operating displays are available. The SET option is mechanized as shown below:

Pilot Action	System Response
1. Select desired missile mode (Sidewinder or SEAM) using weapon select switch on flight control stick.	RWS display displayed on right MPCD.
2. Select PRF, Bars, Aging, Range, and Azimuth Parameters as required.	Option legends change to desired values.
3. Depress SET option.	SET option boxes for 2 seconds.

Once the system is reprogrammed for a given missile mode, the new parameters will be commanded whenever the pilot selects Sidewinder or SEAM and the system initializes to RWS (i.e., system is not in STT or TWS with an L&S target). As previously described, with AIR selected in NAV, VSTOL, and A/G modes, the existing operating parameters are retained when A/A is selected. Once in a search mode, the pilot can change radar search parameters as desired stepping to another weapon station maintains these same search parameters. Radar initialization parameters return to their default values upon A/C power up with weight-on-wheels.

NOTE

Selection of TWS and the attainment of an L&S target disables the SET option once RWS is reselected. To clear this condition and regain use of the SET option, cycle from RWS through TWS and back to RWS without letting an L&S target develop. The SET option should then be operable again.

1.5.2.4 A/A Radar Display. There are two basic A/A radar display formats - B-Scan and RAID. All radar displays utilize some form of these two basic formats.

As shown in Figure 1-52, the B-Scan receives its name from the presence of a B-sweep line which tracks the antenna in azimuth.

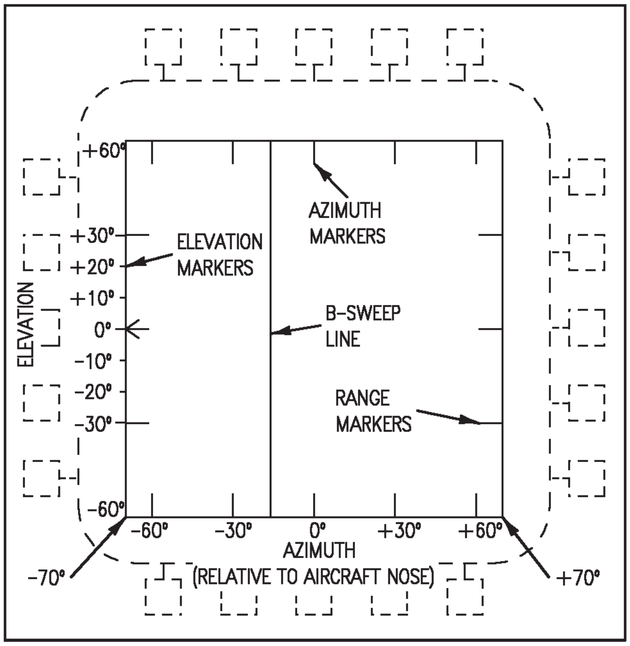

Figure 1-52. Air-to-Air Radar B Scan

The antenna elevation and azimuth tic marks are fixed references located on the left and top/bottom of the display respectively. The range tic marks are variable depending on the range scale selected or, in the case of the VS mode the velocity limit selected. In the B-Scan format, the range scales are labeled because they are variable. The azimuth and antenna elevation tic marks are not labeled since they represent actual, fixed values.

A unique feature of the B-Scan format, as compared to the surface radar grid format, is that "ownship" is represented across the entire bottom of the display rather than the bottom center. As a result, if the target blip is maintained at the same azimuth during closing, a direct collision course to an intercept or rendezvous point can be flown. This represents the quickest course to the intercept and any left or right drift will result in a miss. In addition, the target range can be read directly from the display since the geometry is rectilinear.

Also distinguishable in the above display formats are two separate display areas - the tactical and non-tactical regions. As compared to some of the surface radar formats which represent radar video return, all A/A radar formats are synthetic displays which provide radar return data in the B-Scan format. Radar targets are displayed in an area enclosed by the azimuth and range grid (the tactical area). The area outside of this is designated as the non-tactical area and is used to display radar mode options and other situational data as in the surface radar formats.

Another major distinction between the tactical and non-tactical areas is the operation of the acquisition cursor in each area. When slewed outside the tactical region within the area of a HOTAS able option, all selections for that option will be displayed. Selection is made by placing the acquisition cursor over the selection and depressing and releasing the TDC. HOTAS selections are unique to individual A/A radar formats and are described in the respective format sections.

1.5.3 Air Radar Options and Symbology. Air radar options are dependent on the mode selected. Unlike the surface radar mode options, the presence of an air radar option legend on a display does not necessarily indicate its availability for selection. Some operating parameters are automatically set by the radar depending on specific operating conditions. The legends in these cases remain displayed to provide SA of the operating condition (e.g. PRF shifts in STT) even though the associated pushbutton is not functional.

1.5.3.1 Pulse Repetition Frequency (PRF). In the air-to-air radar mode, the PRF option provides for pushbutton or HOTAS selection of three PRFs: high (HI), medium (MED), or interleaved (INTL). Selecting PRF via the pushbutton method will scroll through PRFs following the order HI, MED, INTL, and then repeat. If the HOTAS method is used, the PRF is selected upon release of the TDC over the option after which the acquisition cursor returns to the stowed position. In RWS and TWS, subsequent depressions of the PRF option commands the radar to the next PRF. The displayed PRF changes immediately, however, the radar does not actually change to the new PRF until the end of the current elevation bar. In a number of instances, PRF is not pilot selectable. For example, in VS, only high PRF is used; thus, HI is continuously displayed and PRF cannot be changed. In addition, the PRF is not pilot selectable under the following conditions:

Condition	PRF
RWS 5 nm range	MED
TWS 5/10 nm range	MED
VS	HI
ACM modes	MED
GACQ	MED
STT	Radar selects best

1.5.3.2 Automatic Gain Control (AGC) - Detection Sensitivity. The air radar relative AGC (sensitivity) indicator (1 to 9) is defined such that 9 equals 90 percent or better of normal detection range, 8 equals 80 percent of normal detection, etc. AGC is also displayed head-up at the lower right of the HUD. Although a manual gain option is not available, the pilot does have indirect control over the AGC setting via the antenna elevation control switch. The pilot should maintain awareness of the radar sensitivity indicator (AGC). See Figure 1-53. If the gain is low, the pilot can correct or change it by elevating the antenna elevation angle to ensure acceptable sensitivity level.

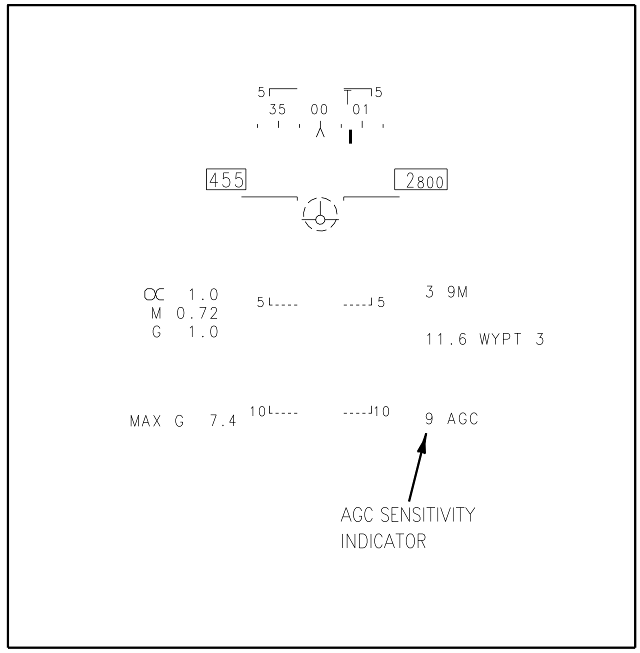

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Figure 1-53. Heads-Up AGC Sensitivity Indicator

1.5.3.3 SET Option. A/A radar SETs are the stored radar operating parameters that are commanded whenever a new Sidewinder missile (Boresight or SEAM) is selected. Two SETs are provided; a Boresight set and a SEAM set. Default values for both SETs of radar search parameters are initialized whenever the aircraft is powered up with weight-on-wheels. Refer to paragraph 1.5.4.1.9 for default SET parameters.

The SET option allows the pilot to store new initialization parameters for the Sidewinder. The SET option is only available in RWS with Sidewinder or SEAM selected. Although both SETs are available airborne, only the boresight mode is available with weight-on-wheels. To SET the radar parameters, the pilot selects a Sidewinder missile and then selects the appropriate radar parameters. Depressing SET will enter the current displayed selections of PRF, azimuth scan, bar scan, range scale, and target aging into the MC as the stored set values. The SET option will be boxed for 2 seconds when selected to indicate a valid data entry. Whenever a new Sidewinder mode (i.e., SEAM to boresight) is selected, the radar is commanded to the SET search parameters for that mode. While in A/A master mode with Sidewinder selected, the pilot reselects Sidewinder Boresight or SEAM, then a Sidewinder station step occurs and the radar mode and search parameters remain the same. If the aircraft master mode is NAV, VSTOL, or A/G and the radar is operating in an Air radar mode (i.e., AIR option), then the existing radar mode and search parameters are maintained rather than going to the SET values. The SET option is not displayed on the air radar display in NAV, VSTOL, or A/G.

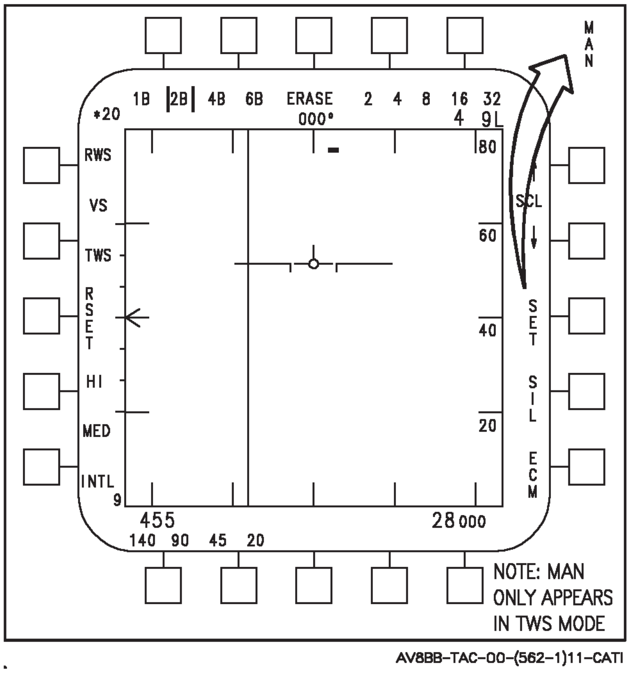

Figure 1-54. A/A HOTAS Selectable Options

NOTE

Selection of TWS and the attainment of an L&S target will disable the SET option once RWS is reselected. To clear this condition and regain use of the SET option, cycle from RWS through TWS and back to RWS without letting an L&S target develop. The SET option should then be operable again.

As in surface radar operation, options are selectable using the pushbuttons on the MPCD and using the HOTAS TDC control. HOTAS selectable A/A parameters are shown in Figure 1-54.

As in the surface radar modes, HOTAS operation is implemented through the TDC control. The pilot must no-action slew the acquisition cursor into the non-tactical region of the display to acquire the desired option. When the acquisition cursor is in the area of an option, all available selections for that option are displayed. The pilot then slews the cursor over the desired selection and depresses and releases the cursor. All options except azimuth scan are selected when the TDC is released. The azimuth scan option is selected when the TDC is depressed.

After air radar HOTAS option selection, the acquisition cursor automatically returns to the stowed position except after selection of the range scale increment/decrement arrows and azimuth scan (until TDC is released). When HOTASing the SCL option, the cursor remains over the selected arrow to permit re-selection. It does not return to the stowed area unless another HOTAS option is selected or it is manually stowed by the pilot.

1.5.4 Range While Search (RWS). RWS is generally considered the primary search mode. RWS offers a full range of operating parameters and also provides the most consistent and reliable transition to single target track. See Figure 1-55.

The RWS mode provides an all aspect target detection capability for both high closure rate, head-on attacks and low closure rate, tail attacks. In normal operation, the RWS mode utilizes both high and medium PRF waveforms interleaved on a bar to bar basis. Employment of a MPRF provides a lower average power output; however, it reduces the clutter problem which can hinder tail aspect target detection in HPRF.

The long range, head-on target detection capability is still retained, however, by the employment of the HPRF waveform on alternate elevation bars. The MPRF waveform covers all target aspects which means that there are no clutter notches in the RWS mode display. However, MPRF detection ranges will generally be less than with HPRF since the average power output is less; fewer pulses of energy are transmitted. During interleaved operation, the HPRF and MPRF waveforms are alternated at the end of each antenna scan and at the beginning of each multibar frame to ensure both HPRF and MPRF coverage at all altitudes.

Target detections in the RWS mode are presented on a range versus azimuth display. HPRF target detections are range resolved by an FM

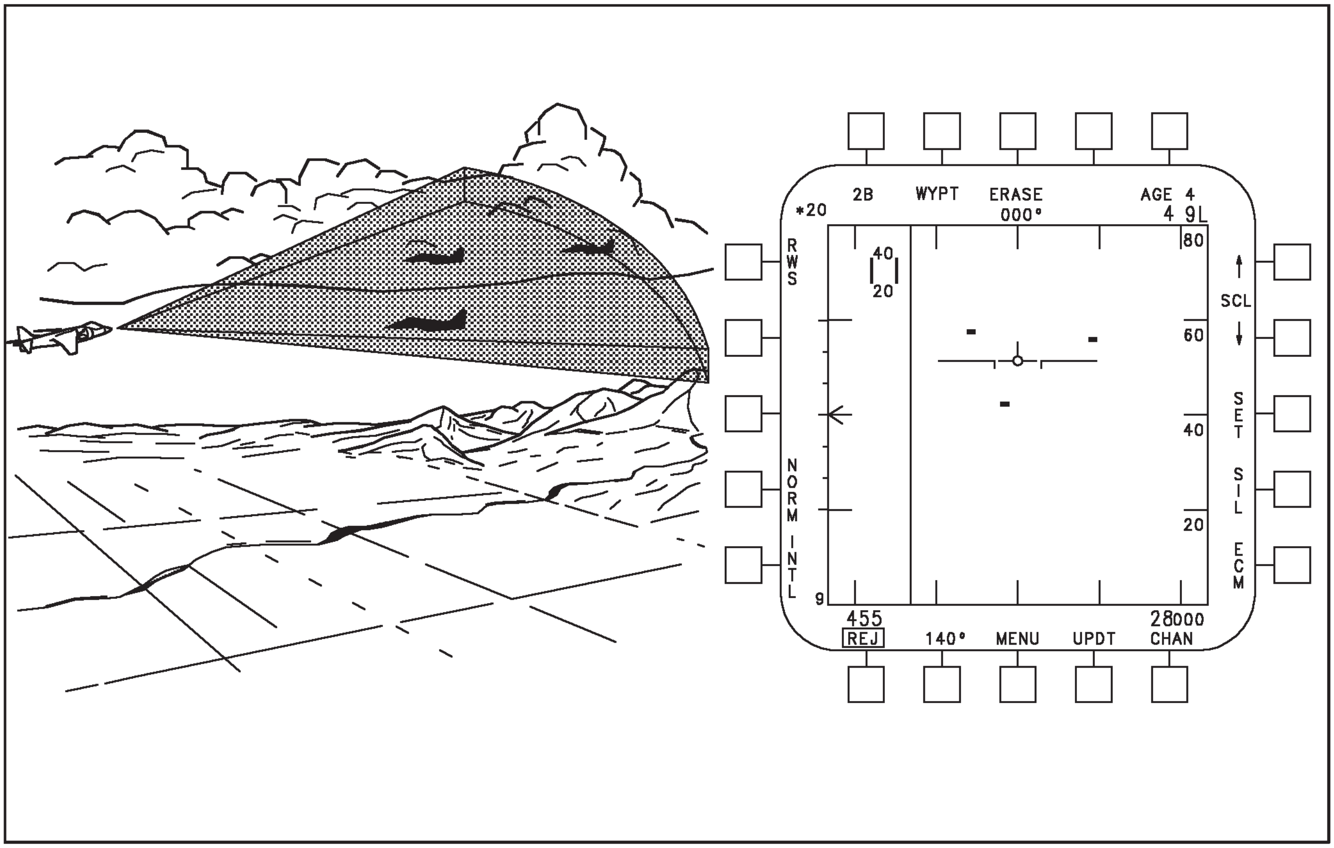

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Figure 1-55. Range While Search (RWS)

ramping method while MPRF detections are range resolved by the range bin (slot) method.

The interleaved HPRF/MPRF waveform is generally selected in the RWS mode, but either HPRF or MPRF can be selected exclusively if the tactical situation dictates. For example, the RWS HPRF mode might be the only alternative for determining the range of bogeys detected in the VS mode and making a tactical assessment. Conversely, if close range targets are the only concern, MPRF may be the best solution. The MPRF waveform has the best capability in the tail aspect lookdown environment where target returns are competing with main beam and side lobe clutter. The lower power output reduces clutter returns while still providing enough power for near range target detection.

1.5.4.1 RWS Selection and Options. The RWS format is automatically initialized and displayed on the right MPCD upon missile selection unless the AIR option is selected in the NAV, VSTOL, or A/G master modes. In that case, the existing AIR mode and options are maintained when Sidewinder is selected. The RWS mode legend is on a scrollable option with VS and TWS available for selection with either mode displayed. Available options and RWS symbology are shown in the Figure 1-56.

All the options displayed on the RWS format are selectable as briefly described below.

1.5.4.1.1 Pulse Repetition Frequency (PRF). In RWS at ranges greater than 5 nm, the pilot can select high (HI), medium (MED), or interleaved (INTL) PRF. Successive depressions of this pushbutton will scroll through HI, MED, INTL, and wraparound to HI. At 5 nm and less, the radar will automatically select and display MED PRF and other options will not be available for selection. If the target range then transitions past 5 nm the previously selected PRF will be commanded by the system. PRF is a HOTAS selectable option.

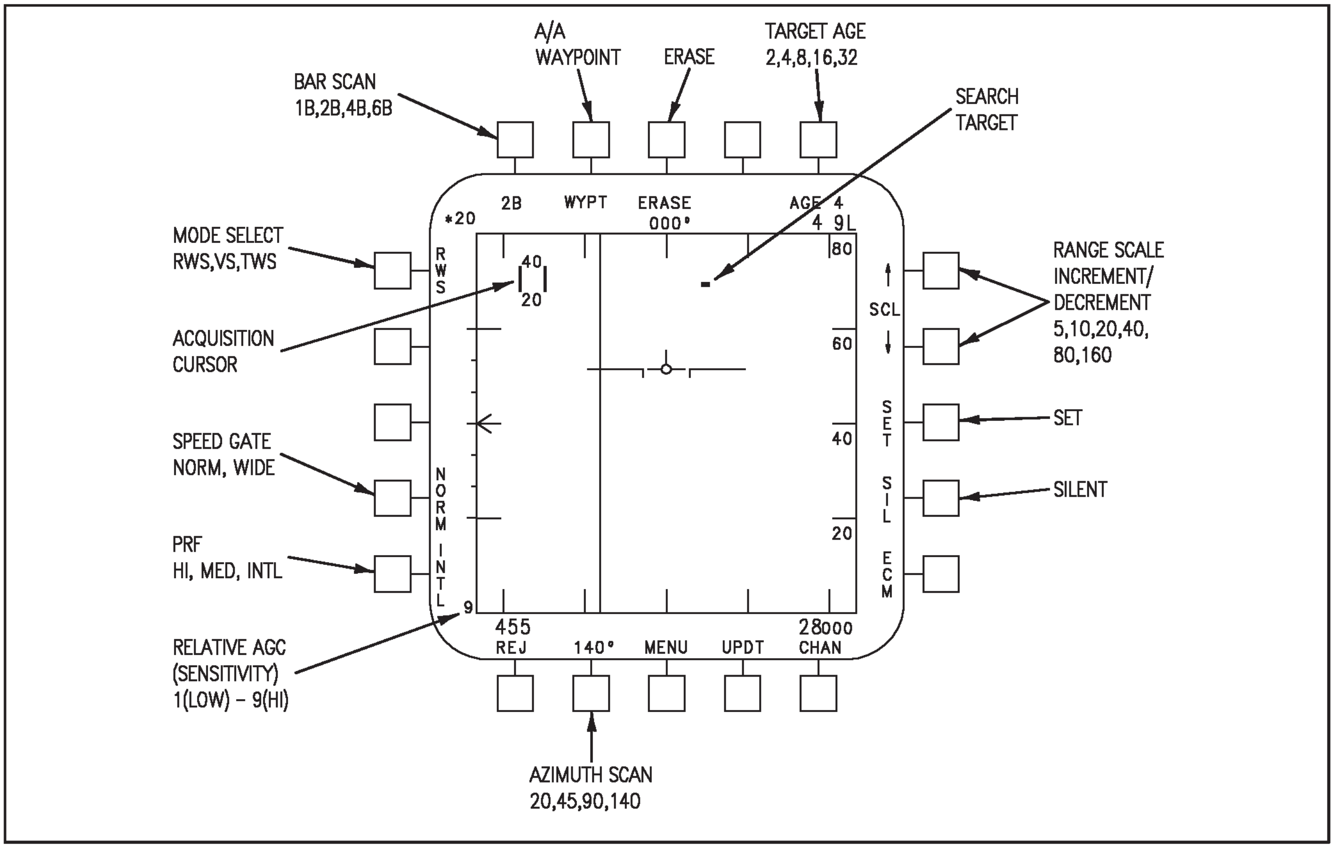

Figure 1-56. RWS Symbology and Options

1.5.4.1.2 Speed Gate. NORM and WIDE speed gate options are selectable by the pilot in RWS. This radar option utilizes doppler velocities to reject slow moving targets based on target speed. Successive depressions alternate NORM/WIDE legends and radar operation as appropriate. NORM indicates that targets with speeds less than 60 knots will be rejected by the system for display. WIDE increases the cutoff to 90 knots, thereby reducing the potential number of targets for display. The system defaults to NORM on power-up.

1.5.4.1.3 Mode Select. Successive depressions will scroll through RWS, VS, and TWS search modes with wraparound to RWS.

1.5.4.1.4 Elevation Bar Scan. In order to optimize the search area or target space, the radar beam is normally scanned in a raster pattern. The path of the beam is called the search scan pattern. The region covered by the scan is called the scan volume or frame; the length of time the beam takes to scan the complete frame is the frame time. Each sweep of the beam is referred to as a BAR scan. In RWS, bar scan options are 1B, 2B, 4B, and 6B. Successive depressions will scroll these options with wraparound to 1B. Bar scan options are HOTAS selectable. When the acquisition cursor is slewed in the bar scan HOTAS region, the WYPT legend is deleted and bar scan legends are displayed. Upon initialization, the antenna scan is centered about the horizon. It can then be changed using the antenna elevation control on the throttle. The elevation bar scan in conjunction with the selected azimuth scan determines the scan volume.

1.5.4.1.5 A/A Waypoint. The WYPT option provides SA of the currently selected steerpoint (waypoint, designated offset, or mark point). A standard waypoint or offset symbol is displayed (if in range) to indicate its location. An arrow is provided to indicate true or magnetic north depending on pilot selection. The WYPT option is boxed at aircraft power-up with weight-on-wheels.

1.5.4.1.6 Erase. The ERASE option removes the current target file history to quickly declutter the display. At the next scan, the radar will begin displaying targets again. Because this option operates for such a brief period, its selection remains unboxed. It is also HOTAS selectable.

1.5.4.1.7 Target Aging (AGE). Successive depression of the AGE option scrolls the age settings through 2, 4, 8, 16 and 32 seconds with wraparound to 2 seconds. To indicate target aging, brightness levels of the target blip decrease over the selected aging period according to the following schedule. This option is HOTAS selectable.

Storage Selection	Target Symbol Brightness
2	Max for 2 seconds
4	Max for 2 seconds one half for 2 seconds
8	Max for 2 seconds one half for 6 seconds
16	Max for 2 seconds one half for 6 seconds one fourth for 8 seconds
32	Max for 2 seconds one half for 6 seconds one fourth for 24 seconds

1.5.4.1.8 Range Scale (SCL). The SCL option utilizes up and down arrows to increment/decrement the range scale. In RWS, range scale options include 5, 10, 20, 40, 80 and 160 nm ranges. These can be incremented or decremented by depressing the respective arrow option or by HOTAS. Unlike other HOTAS options, the cursor does not return to the parked position but overlays the selected arrow option to facilitate scrolling through range selections. The selected range scale is displayed on the right side of the display inside the tactical area at the respective tic marks.

1.5.4.1.9 SET. The SET option provides the capability to store the radar RWS parameters of PRF, azimuth scan, bar scan, range scale, and target aging as the new initialization parameters for the Sidewinder missile. Two independent sets are available for Sidewinder Boresight and SEAM modes. Depressing SET enters the current displayed selections into the MC as the stored values. The option is boxed for 2 seconds when selected to indicate a valid data entry. This function can also be performed withWOW for Sidewinder Boresight. The SET option is HOTAS selectable. The following default set options are used:

Boresight	Seam
140° Azimuth	45° Azimuth
Boresight	Seam
4 Bar Elevation	4 Bar Elevation
INTL PRF	MED PRF
8 Second Aging	4-Second Aging
40 nm Range Scale	20 nm Range Scale

NOTE

Selection of TWS and the attainment of an L&S target disables the SET option once RWS is reselected. To clear this condition and regain use of the SET option, cycle from RWS through TWS and back to RWS without letting an L&S target develop. The SET option should then be operable again.

1.5.4.1.10 Silent (SIL). Depressing SIL boxes the legend and commands the radar to inhibit RF transmission at the end of the current bar scan while continuing to passively process received signals. In addition to the boxed SIL option, the Maltese cross is displayed at the lower left corner of the display to indicate the radar is not transmitting. When selected, the radar can be commanded to retransmit by depressing the TDC when the acquisition cursor is inside the tactical border. The radar will transmit for two frames if INTL PRF is selected and only one frame if MED or HI PRF is selected. During transmission the Maltese cross is removed while the SIL option remains boxed. The SIL option is HOTAS selectable.

1.5.4.1.11 ECM/ECCM. Depressing the ECM option brings up the ECM display which can then be used to enable/disable the ECCM mode of radar operation. When ECCM is boxed on the ECM display, the radar processes with full ECCM capability. When unboxed, the radar will not perform any active processing of noise and deception type jammers nor display most of the passive ECCM cueing. On power up, the system automatically defaults to ECCM selected (boxed). When on the ECM display, deselecting the boxed ECM legend returns the display to the last selected radar display. The ECM display selection is HOTAS selectable, however, the ECCM option on the ECM display is not HOTAS selectable.

1.5.4.1.12 Channel. The CHAN option provides access to RF channel sub-options for selecting either the RF channel or channel set in which the radar will operate. When CHAN is depressed, the UPDT and CHAN legends are replaced by manual (MCHN) and channel set options respectively. The pilot can then select the desired channel manually by scrolling through the manual channels (10 through 15, 17 through 22, and 25 through 31) or select auto channel sets (A through G and *). Refer to NWP 3-22.5-AV8B, Vol. III, Chapter 6, for channel set deconfliction recommendations.

1.5.4.1.13 Update. The UPDT option allows immediate access to the available update options on the ODU from the air radar display. Only the TACAN and overfly update methods are available in the A/A master mode.

1.5.4.1.14 Azimuth Scan. In RWS, azimuth scan patterns of 20°, 45°, 90° and 140° are selectable. Successive depressions of this switch will incrementally scroll through these selections from smaller to larger with wraparound to 20°. The scan width is indicated by the scanning B-sweep along the azimuth grid and the digital readout above the azimuth scan option pushbutton. This function is also HOTAS selectable. When the acquisition cursor is placed in the azimuth scan option area, the REJ legend is deleted to provide space for the available options. When the TDC is depressed with the cursor over the desired azimuth scan, the cursor is replaced by the acquisition cursor positioned at the current scan center. Movement of the cursor will then relocate the limited azimuth center of the scan pattern upon TDC release.

1.5.4.1.15 Reject. In RWS, the REJ option can be used to declutter the radar display. There are three levels of declutter available - normal, reject 1, and reject 2. Normal is indicated by the unboxed REJ legend which provides full display symbology, a boxed REJ 1 removes the horizon bar and velocity vector. A boxed REJ 2 removes all of REJ 1 plus the range numbers except for the maximum value at the top right. Successive depressions of the reject option will scroll through REJ, REJ 1, and REJ 2 with wraparound to REJ. The system is initialized to normal (REJ unboxed) on power up. The reject option is not HOTAS selectable.

1.5.5 Velocity Search (VS). The VS mode is employed for long range target detection. See Figure 1-57. The radar transmits all energy at a HPRF which provides a very high average power output.

High average power output results in a greater amount of energy returning from the target. This increases probability of detection (P_D) for targets with high closures.

Detected targets are presented on a velocity versus azimuth display. The doppler shift of the target return signal is measured by the radar and a synthetic symbol is presented on the radar display at a position representative of the target closing velocity. No attempt is made to display

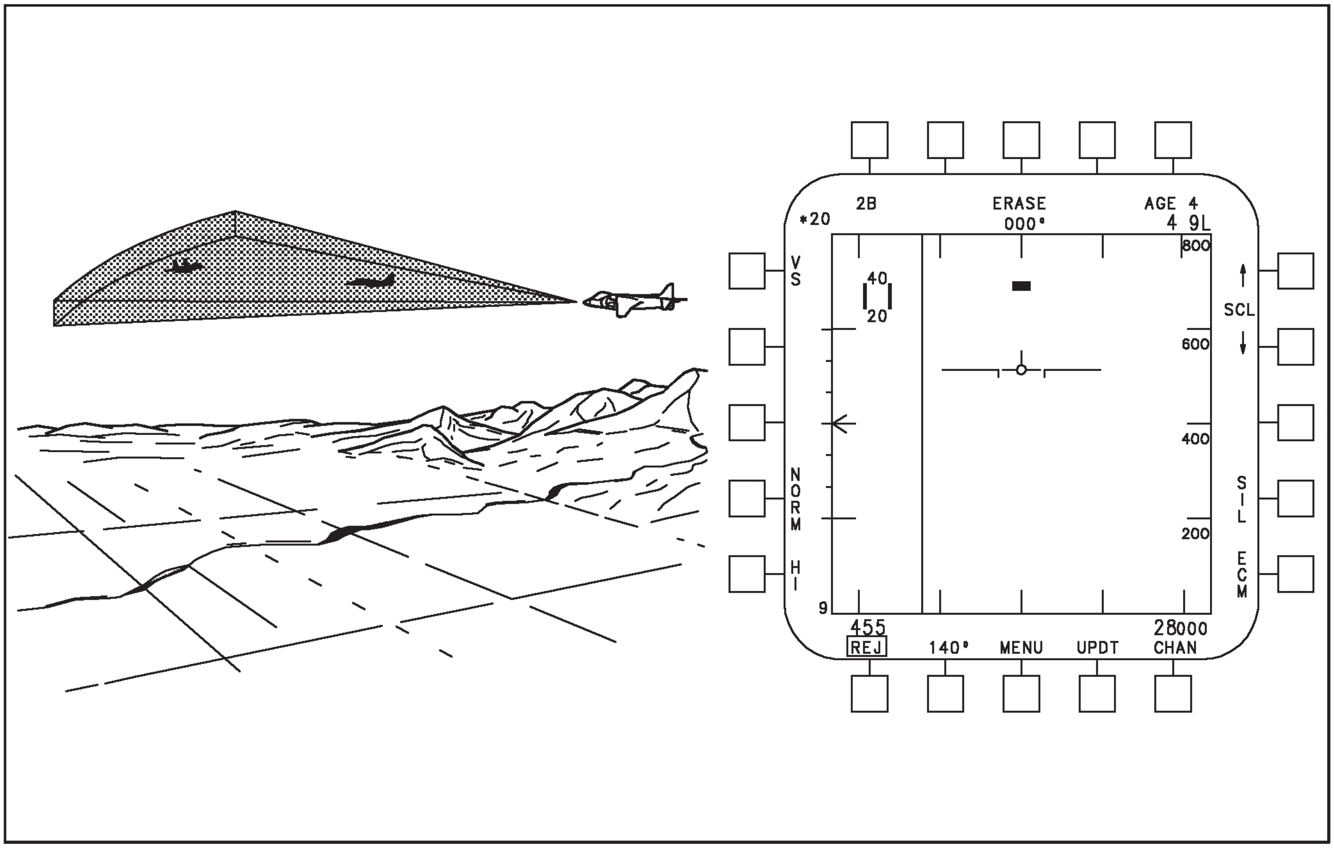

Figure 1-57. Velocity Search (VS)

targets with a closing velocity equal to or less than ownship since these target returns would generally be obscured by clutter returns. Clutter returns (main beam and side lobes) have a closing velocity equal to or less than ownship velocity. This clutter notch limits VS mode target displays to only nose aspect bogeys which are the primary concern during long range search.

The VS mode also provides a superior capability for detecting nose aspect targets in the lookdown regime. Clutter returns resulting from aiming the radar transmissions down toward the earth are not in the velocity search display spectrum and do not obscure the nose aspect target returns as they might in the range spectrum. The primary limitation in the VS mode is that there is no display of beam or tail aspect targets. The velocity versus azimuth format itself presents several other limitations. For one, targets generally tend to become bunched together towards the bottom of display. Also, the display has limited value for intercept purposes because target geometry is more difficult to interpret.

The VS mode is also useful in separating target returns from weather returns. Weather returns generally have a closing velocity equal to or less than ownship and are not presented on the display. However, weather reduces the amount of radar energy that reaches the target and, thus, decreases the probability of detection.

Thus, VS and RWS complement each other in that VS covers a velocity spectrum of possible threats while RWS covers a range spectrum. The pilot's ability to change modes between VS and RWS takes advantage of this versatility, thereby enhancing overall target detection capabilities and minimizing radar blind zones caused by weather, ground clutter, distance, and target aspect.

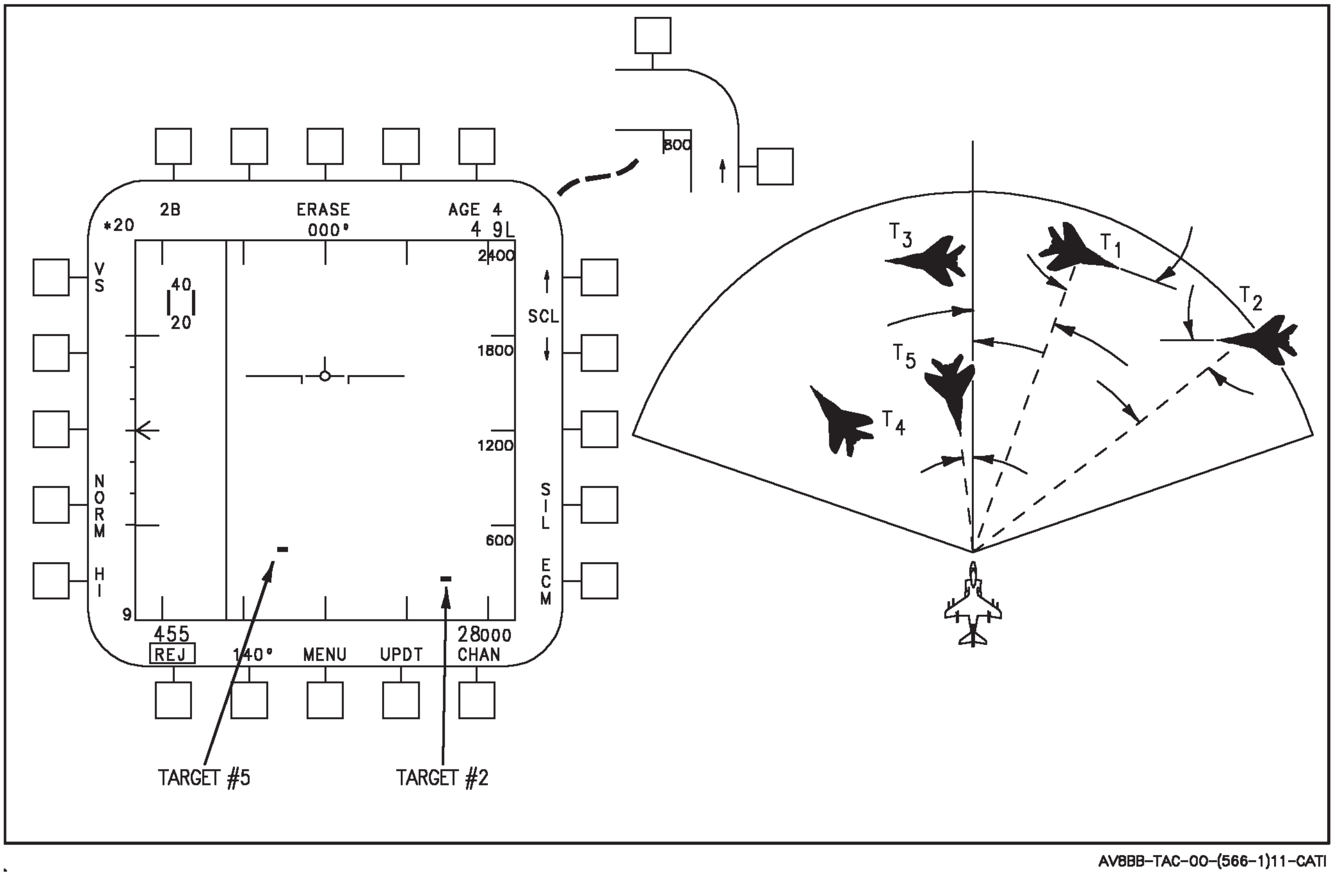

Figure 1-58. VS Display

1.5.5.1 VS Display. The VS display is velocity versus azimuth bearing. See Figure 1-58. Vertical deflection of target symbols from the bottom of the display is proportional to the target velocity along the LOS. The bottom of the display represents ground velocity. Thus, only targets with closing velocities greater than ownship are displayed. The remainder of the velocity spectrum is filtered out by processing circuits as it contains high level ground and weather returns (clutter). This filtered out spectrum also includes returns from beam and tail aspect targets since their closing velocities are always equal to or less than ownship ground velocity. In the VS mode, the basic RWS format and options are displayed except that the WYPT option is deleted and speed gate, SCL, and PRF functions are changed as described below.

1.5.5.1.1 Speed Gate. In VS, the speed gate function only applies to closing targets. NORM rejects targets whose component of closing velocity with respect to ownship is less than 60 knots. WIDE similarly rejects targets whose closing velocity component is less than 90 knots.

1.5.5.1.2 Scale. In VS, the SCL option selects either 800 or 2400 knot velocity scales. On power-up, the system initializes to the 2400 knot scale. Successive SCL option depressions will alternate the scale option and displayed scale values. The velocity scale represents the target's velocity along the ownship line-of-sight.

A/A Waypoint - The WYPT option is deleted since the scale is in velocity not range.

1.5.5.1.3 PRF. Since the VS mode operates only in HI PRF, the PRF option pushbutton is not operational or HOTAS selectable. The HI legend is displayed to indicate the operating PRF.

The top of the VS display is labeled either 800 knots or 2400 knots depending on the selected velocity scale. With the 2400 knot scale selected, targets are displayed based on the 2400 knot velocity scale. With the 800 knot velocity scale selected targets are displayed based on the 800 knot velocity scale, and the detected targets within the 800 knot to 2400 knot region appear at the top edge of the display. Also, while in the 800 knot velocity scale, targets within the 800 knot to 2400 knot region can be manually acquired.

Target symbols near the bottom of the attack format do not necessarily represent targets closest in range. Target symbol position is only indicative of the target velocity along the LOS and a close range nose aspect target near ownship velocity vector may appear high up on the display. Target symbol displacement from the bottom of the display is equal to the target velocity along the LOS.

Limited azimuth scanning is obtained by selecting one of the azimuth scan options other than 140°. This concentrates energy into a smaller airspace and increases the probability of target detection in the selected sector. If desired, the limited sector scans can be positioned off the aircraft centerline.

The antenna elevation can be manually positioned with the elevation control. The resultant antenna elevation angle is denoted by the elevation caret on the elevation scale. The upper and lower altitude limits of the radar beam coverage at the acquisition cursor symbol range for a complete scan frame (all bars selected) are displayed adjacent to the acquisition cursor. An imaginary 80 nm range scale is assumed for determining the acquisition cursor range and the resultant antenna beam altitude coverage.

Target history displays, if selected, may not be as obvious on the VS display as on a range display. The target symbol does not move vertically unless the target velocity changes. Azimuth changes, however, are tracked as usual. VS can be exited by entering STT on a detected target or by simply selecting another radar mode.

1.5.6 Track While Scan (TWS). The TWS mode provides a special display which enhances the pilot's assessment of the tactical situation. Target detections are ranked in threat priority by the MC. The priority ranking is based on the ratio of the bogey closing velocity to its range; targets with a high closing velocity to range ratio receive a high ranking. Thus, close range bogeys with a high closing velocity are given the greatest priority since they are the most immediate threat. See Figure 1-59.

The top 10 priority targets are computer tracked. The eight targets with the shortest time to go (most immediate threats) are displayed as inverted half box symbols with protruding target aspect angle pointers. Target symbols for the top eight targets are numerically prioritized from 1 to 8. Additional target detections that have lower priorities than the top 10 are simply displayed as standard search detected target symbols.

The top eight priority targets are stored in the primary track files. The additional two targets ranked just below the top eight are stored in the secondary track files. Targets in the secondary track files are automatically swapped with the lowest priority target in the primary track files when they obtain a higher ranking. Targets detected outside the selected range scale will not be put in the track files. However, if a range scale change is made and a previously filed target now falls outside the new range scale, the target will not be deleted from the file. This target is retained on the radar display pegged at the top limit in range, but still indicating target azimuth bearing. The target can be assigned as the L&S target by the radar if it should progress to highest priority.

1.5.6.1 L&S Target. The radar automatically assigns the priority 1 target as the L&S target and the numeral 1 is replaced with a star symbol if TWS was entered from a search mode. Attack computations (steering and launch range markers) are presented on the radar display for the L&S target. The L&S target is also distinguished from the other filed targets on the display by the Mach and altitude numerics adjacent to the target symbol, a target range caret on the range scale at the L&S target range, and numerics denoting the L&S target closing velocity. Mach and altitude numerics are also displayed adjacent to the highest priority non-L&S target. A

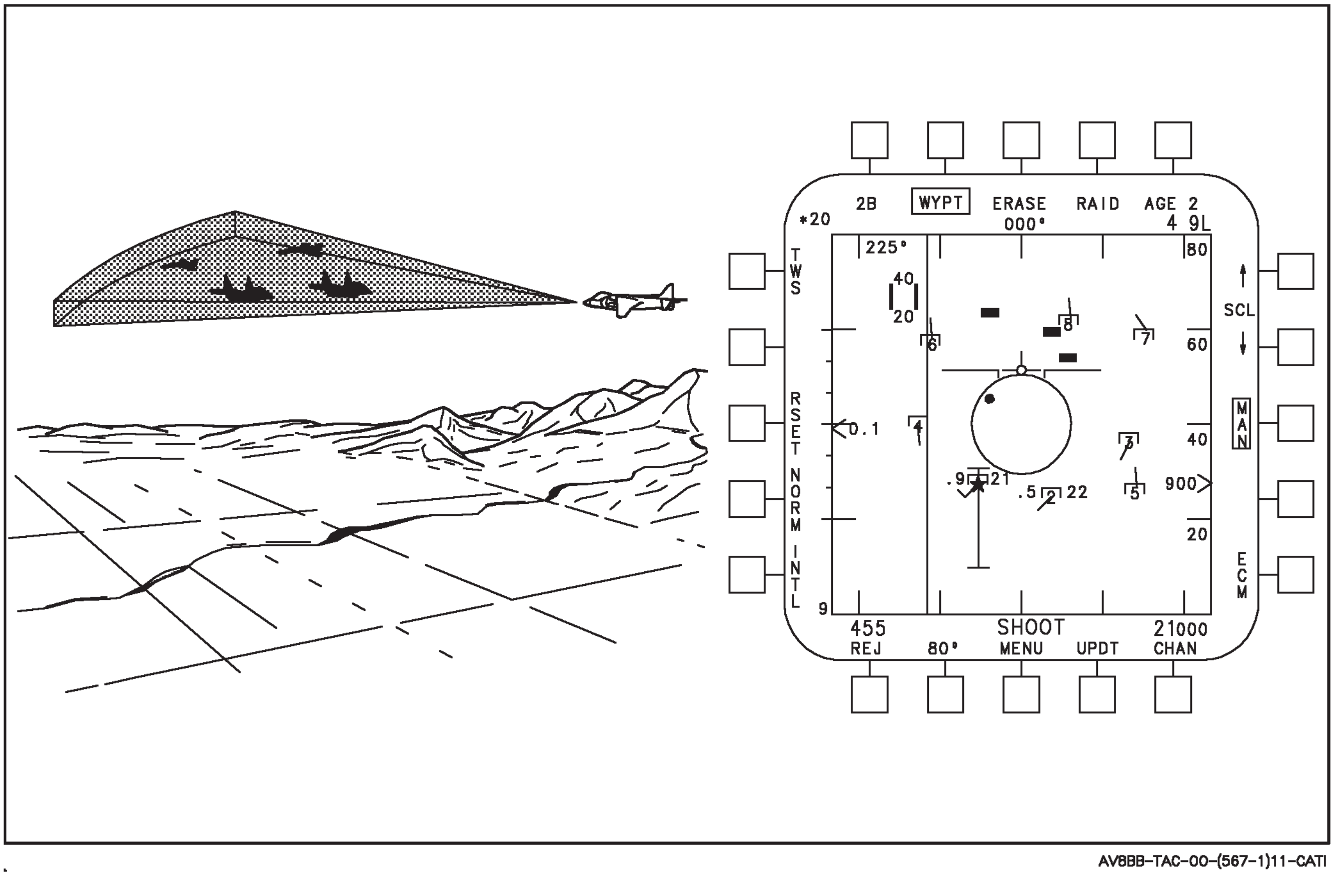

Figure 1-59. Track While Scan (TWS)

target azimuth line (half intensity) is also displayed through the L&S target. The attack computations are based on the L&S target motion and geometry. The pilot can change the L&S target by:

1. Sequentially depressing the undesignate button (steps to next highest priority target).

2. Slew cursor over a filed target and either depress the TDC or select AACQ.

The radar can be commanded to STT directly out of the TWS mode by designating the L&S target. In addition, the radar automatically goes to STT on the L&S target when the RAID mode is commanded.

If TWS is entered from STT, the STT target is assigned as the L&S target even though it may not be the highest priority target. When the TWS mode is entered from STT, the STT target is treated as a manually filed target. A manually filed target is immune from the primary track file on the basis of ranking. The target can be entered into the normal ranking structure by selecting the RSET option on the TWS display. In TWS, the same logic is followed by commanding STT if an L&S target or an unfiled target is under the cursor. However, if a non-L & S track file is under cursor, AACQ selection will reassign that track file as the L & S target. Similar to the RWS and VS mode of operation. If there is no target under the acquisition cursor, selecting AACQ in TWS will command STT on the L & S target or on the closest unfiled target if an L & S target is not established. If there are no target detections, the radar will command STT on the first detection. Once the radar is in STT, the pilot can *bump* the acquisition by reselecting the AACQ position. This establishes a range/ azimuth exclusionary window about the current STT target to preclude immediate reacquisition, and commands the radar to search the scan

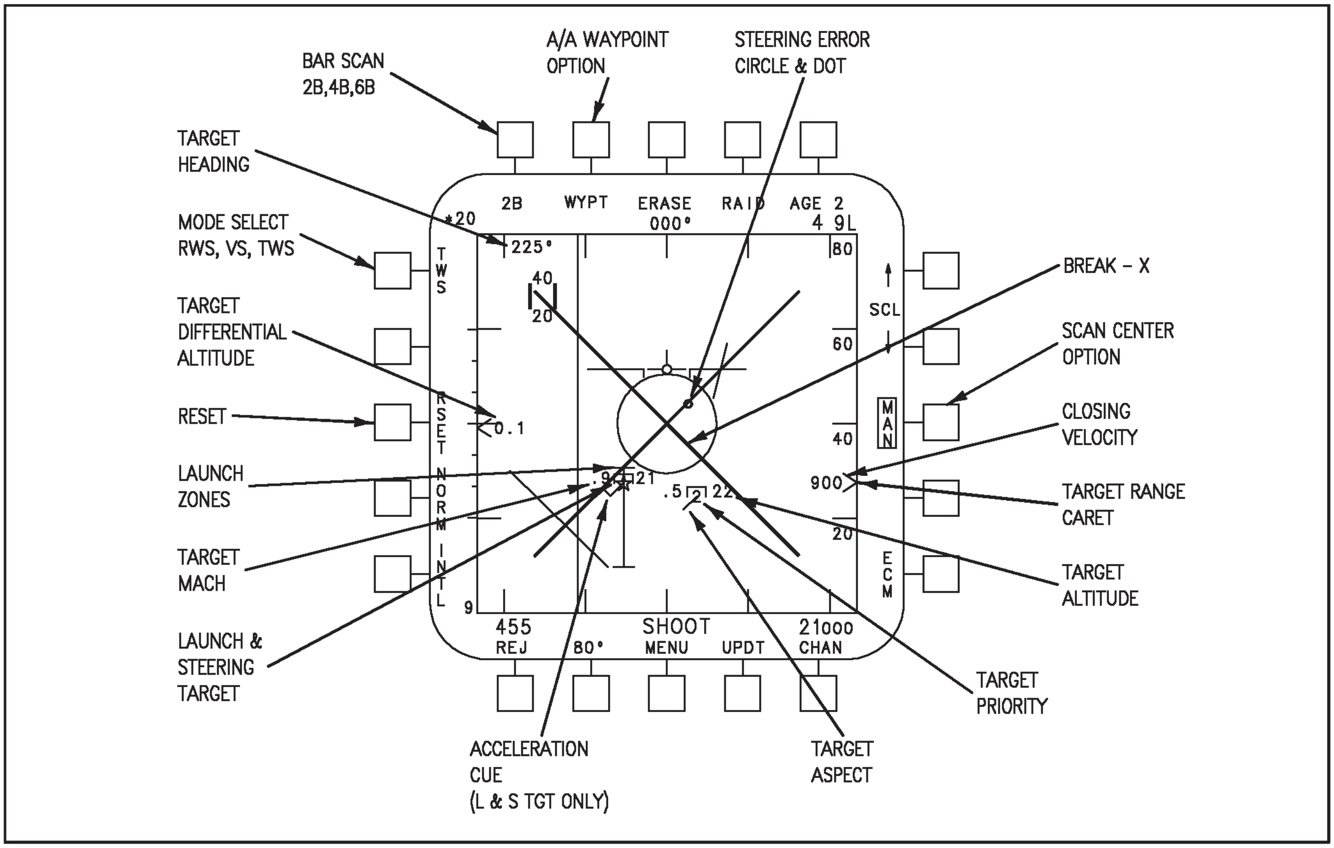

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Figure 1-60. Track While Scan Format

volume and attempt lock on of the first detected target outside the exclusionary window. If no new targets are found after searching one frame (two if INTL PRF), the radar will command STT on the previously selected target.

1.5.6.2 TWS Format. TWS symbology and option changes are shown in Figure 1-60. Added options include RAID, MAN/AUTO scan center, and RSET functions. The SIL option has been deleted. Symbology changes include weapon steering information and tracking data for the L&S target and display of the eight highest priority track files. These and changes to option select parameters are described below:

1.5.6.2.1 PRF. In TWS, with range scales larger than 10 nm, HI, MED, and INTL options are available for pushbutton or HOTAS selection. For ranges of 10 nm or less, the radar only operates in MED PRF. In this case, the MED legend is displayed but not pilot selectable.

1.5.6.2.2 Reset (RSET). The added RSET option provides a rapid means to reassign the L&S target to the radar determined first priority target following pilot initiated prioritization changes. When depressed, RSET is boxed for two seconds, the L&S target is reassigned to the radar determined highest priority, and the track file symbology is changed accordingly. This option is HOTAS selectable.

1.5.6.2.3 Bar Scan. In TWS, elevation bar scan options are 2, 4, and 6 bars (2B, 4B, and 6B). Selecting an elevation bar scan fixes the azimuth scan width: 2B-80º, 4B-40º, and 6B-20º. As in RWS, this option is HOTAS selectable.

1.5.6.2.4 WYPT. As in RWS, selecting the WYPT option boxes the option and displays the current steering aimpoint symbol. When designated, the circular waypoint symbol is replaced with a diamond. The arrow represents magnetic or true north as selected on the map menu

(MAPM) display. When selected, the magnetic/ true bearing and range from the waypoint to the L&S target is displayed below the WYPT option just outside the tactical region.

1.5.6.2.5 Erase. In TWS, selecting the ERASE option deletes the current target history for non-filed targets only. Track files are not erased. This option is HOTAS selectable.

1.5.6.2.6 Raid. The RAID option is not HOTAS selectable. Depressing the RAID option boxes the RAID legend and expands the area about the L&S target. See the RAID assessment mode for more information on RAID.

1.5.6.2.7 Target Aging. In TWS, the assigned aging applies only to non-filed targets. Successive depression of the AGE option scrolls through the aging levels the same as previously described for RWS. The AGE option is HOTAS selectable. Two second aging is initialized when entering TWS.

NOTE

Two second aging will remain selected when TWS is exited.

1.5.6.2.8 Auto/Manual Scan Centering. This option allows either automatic or manual positioning of the antenna scan center in both azimuth and elevation. The TWS mode initializes with manual scan centering (MAN boxed) selected. Auto selection is indicated by the unboxed MAN legend.

When automatic scan centering is selected, the azimuth scan and elevation bar and the azimuth and elevation scan centers are changed to keep the L & S target and as many track files as possible in the scan volume based on a prioritization scheme which maintains the centroids of the scan about the highest priority filed targets. It should be noted that the antenna elevation control on the throttle is not functional with auto selected when an L&S target exists. This mechanization maintains track on the L&S targets and reduces pilot workload.

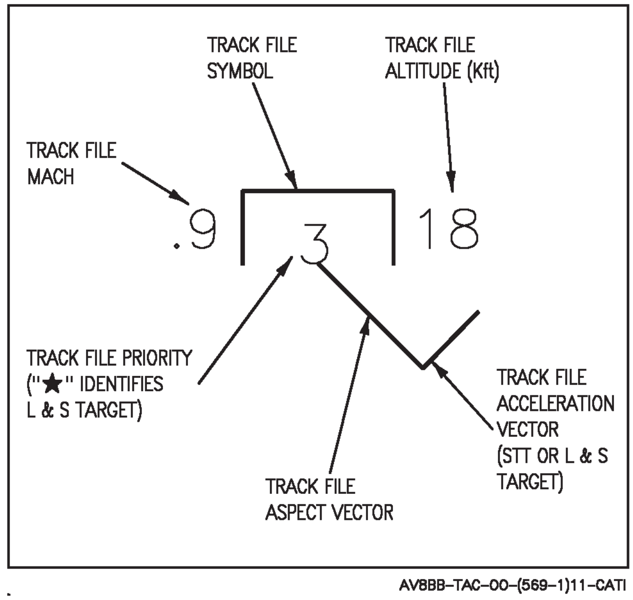

Figure 1-61. Track File Symbology

When MAN is selected (boxed), the scan center initializes to the last radar center command during the auto scan. The pilot can then change scan center elevation by using the HOTAS antenna elevation control on the throttle. To change its azimuth, the pilot must hook the azimuth option using the TDC HOTAS function. When the TDC is depressed and held, the cursor is automatically placed at the last azimuth scan center. The pilot can then slew the cursor to the desired azimuth. When the TDC is released, the current cursor location becomes the new azimuth scan center. The system will not permit a scan center location which does not allow full gimbal travel and automatically adjusts the scan center if it is placed less than one-half the gimbal travel. As long as MAN is selected, the antenna scan center can be repositioned as indicated.

1.5.6.2.9 TWS Targets. Three types of targets are distinguishable on the TWS display - unfiled targets, filed targets, and the L&S target. See Figure 1-61. In the TWS mode, the radar automatically establishes track files on the top ten targets on a range over range rate basis. The target with the shortest time-to-go is the number one ranked target of a maximum of eight filed targets which can be displayed at any one time. A tracked target is displayed as a half box.

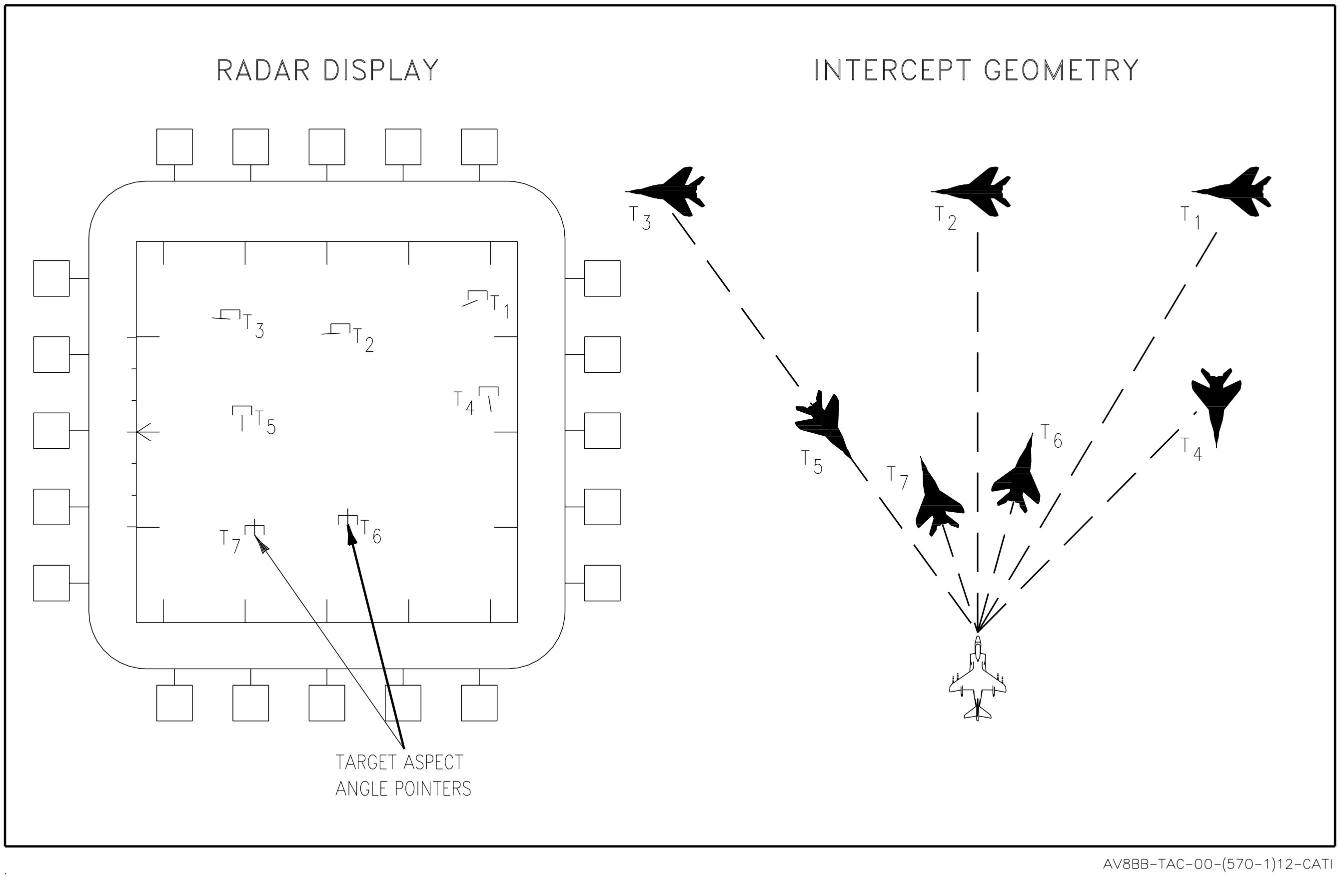

Figure 1-62. Target Aspect Vector Geometry

Target ranking is indicated by the number at the center of the half box. The radar system automatically designates the highest ranked target as the L&S target (★) and numbers the other filed targets 2 through 8. If the pilot designates another target as the L&S target, the radar determined highest priority target is given a number 1 ranking and ★ replaces the priority number of the pilot designated L&S target. Target Mach number and altitude are displayed left and right of the file symbol for the L&S target and the highest priority non-L&S filed target. A target aspect angle pointer is displayed for all filed targets. The aspect vector is a fixed length pointer which continuously indicates the horizontal angle that is created by the radar LOS and the target's heading. Figure 1-62 depicts the relationship between the file aspect vector and target intercept geometry. If the L&S target turn rate exceeds 3g's, an acceleration vector is also displayed. The acceleration vector is displayed normal to the end of the target aspect vector and grows in length as a function of target acceleration.

When the radar reaches its limit of filed targets (10), all other detections, up to 128, will be displayed as solid rectangles the same as the target blips shown in RWS and VS modes.

1.5.7 RAID Assessment Mode. When a target is acquired at long range (relatively speaking), the RAID mode can be used to resolve whether the tracked target is a single target or a raid of two or more targets in close formation. See Figure 1-63. This, in turn, provides an indication of the total number of targets in the raid as well as their relative position from the tracked target. The RAID mode can be activated when the radar is in STT or the TWS mode by actuating the RAID option on the display. In the TWS mode, the radar automatically shifts to STT on the L&S target before initiating RAID processing. When the MC receives the RAID command, it

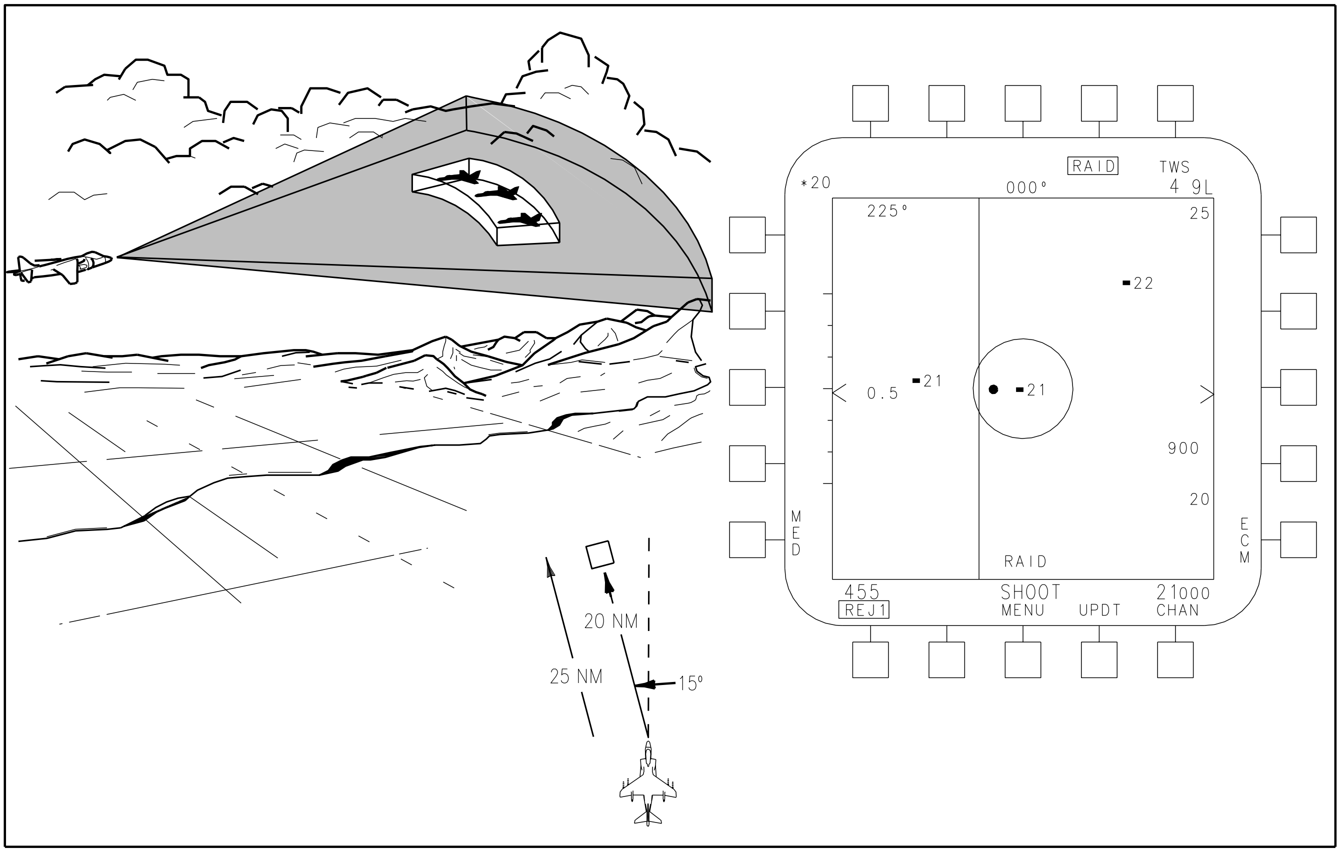

Figure 1-63. RAID Assessment - RAID

commands the radar to perform RAID processing. The radar switches from the track PRF to medium PRF to obtain improved range and velocity (doppler) coverage of the tracked target. Multiple PRF's are transmitted during the time on target to provide for range and doppler ambiguity resolutions. To provide adequate spatial coverage, a multi-position sawtooth raster scan is utilized when range is less than 26 nm. See Figure 1-64. Azimuth and elevation monopulse signals are used to determine the azimuth and altitude of the target(s). Narrow band doppler filters and doppler beam sharpening techniques are used to enhance target resolution.

The RAID display is range versus cross range (5 nm by 5 nm) centered on the STT target. The sector in space being searched is denoted by the range numerics on the right side of the grid. Resolved target altitudes are displayed adjacent to the target symbols in thousands of feet. Range and azimuth resolution is indicated by multiple target separation on the display.

The target being tracked in STT is fixed at the center of the display along with the range caret on the right border. When the STT target range changes, the range scale numerics change in a like manner to keep the target and range caret centered. Attack steering (ASE circle and steering dot) on the STT target is retained on the RAID display. The B-sweep position on the RAID display indicates the azimuth bearing of the target centroid.

The active phase of the RAID mode requires approximately 1 second processing time out of every 4 seconds. Therefore, for 75 percent of the duty cycle, the radar performs its normal STT functions. However, the RAID display is retained during STT processing.

The RAID antenna scan is a seven-point sawtoothed pattern about the tracked target when the target is within 26 nm. The sawtooth pattern is designed to maintain search of a specific elevation about the tracked target as target

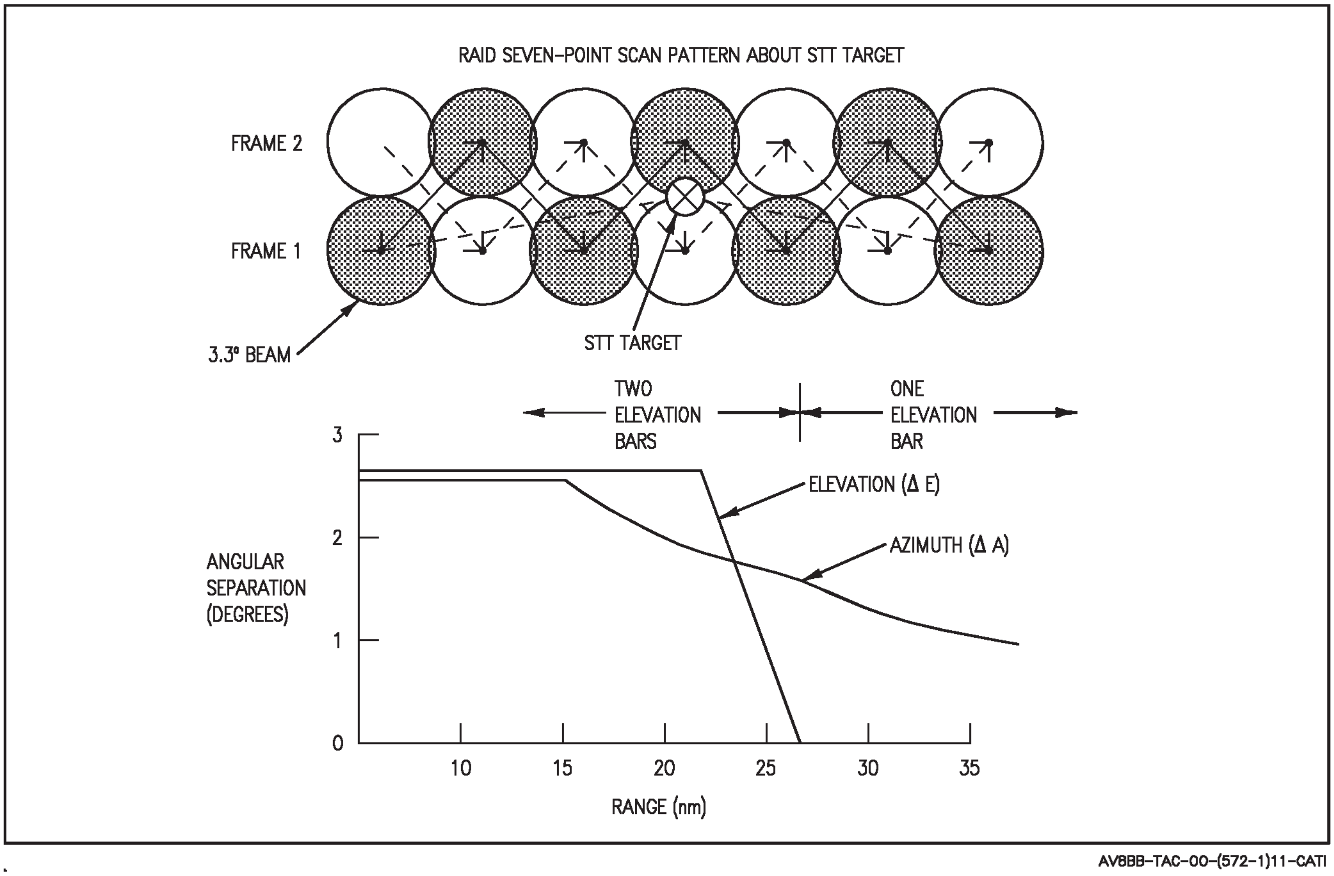

Figure 1-64. RAID Elevation Coverage

range decreases. At target ranges beyond 26 nm, the seven points become a straight line (single bar). The single bar provides sufficient elevation coverage about the tracked target at these ranges. Target hit data is processed on each of the seven antenna look points and correlated with the other look points to prevent double processing of the same target.

When the pilot commands the RAID mode, the radar may or may not enter active RAID processing. If the pilot commands the RAID mode when the RAID available bit has been set, indicating that the radar is capable of performing RAID processing, the MC removes the radar display grids and displays a RAID cue. If the conditions are such that the radar cannot perform RAID processing, the MC displays the RAID cue, but continues to present the STT attack display. This condition is present when there is a high probability of STT break lock (memory track or near gimbal limits).

An IN RNG (in range) cue appears on the RAID display in place of a SHOOT cue when the target centroid is within R_{max} but complete SHOOT cue criteria is not satisfied. This cue alerts the pilot to ready the weapon system for missile employment. When all SHOOT criteria are met the IN RNG legend changes to SHOOT.

1.5.8 Single Target Track (STT). The radar enters the STT mode after a successful target acquisition. STT can be accomplished by using one of the automatic target acquisition modes described below, or the pilot can manually command STT. Manual acquisition is performed by the pilot placing the acquisition cursor over the desired target and then actuating the TDC action switch. After track is established, the radar continuously monitors the target position by tracking it in range, velocity, and angle. STT provides the MC with track quality data sufficient enough to make accurate computations for

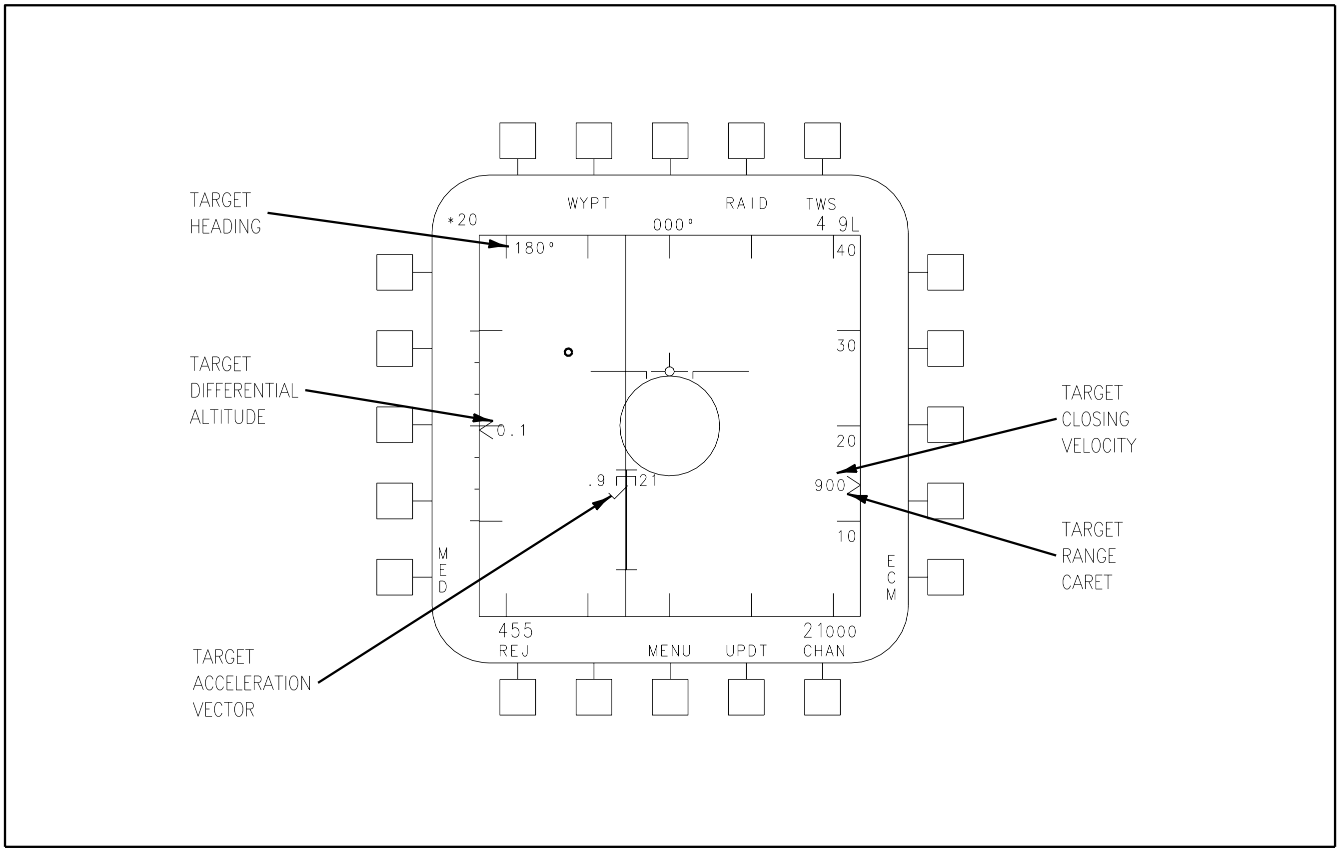

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Figure 1-65. Single Target Track Display

either Sidewinder or gun attack. Attack symbology on the radar display and HUD denotes the launch envelope zones for the selected weapon. See Figure 1-65.

1.5.8.1 STT Display Format. The STT display is a very clean display. All options are deleted except for WYPT, RAID, TWS, ECM, CHAN, UPDT, MENU, and REJ as shown in Figure 1-66. The PRF displayed is controlled by the radar and is not selectable by the pilot. The WYPT option operates identically to the TWS mode in providing both the location of the waypoint and the relative bearing and range from the waypoint to the STT target. A TWS option is provided to select or return to the TWS mode of operation from STT. Selecting TWS retains the single target track as the L&S target while providing SA of other detected threats available from the TWS display. The TWS option is located at the top right to distinguish it from the search mode options which are mechanized differently. In STT, selecting TWS commands the TWS format whereas, in the search modes, the TWS legend indicates the current radar search mode and TWS selection scrolls to brings up the RWS display, (if selected via pushbutton). The acquisition cursor is not displayed since lock on has already been achieved. A reduction in workload is achieved by auto range scaling in STT. Auto range scaling maintains the STT near the center of the display by incrementing the range scale when the track range is 93 percent of the range scale and decrementing the range scale when track range is 45 percent of the range scale.

When target track is established by the radar, the standard rectangular target symbol is replaced by an inverted half box symbol (similar to TWS). A pointer projects from the bottom center of the inverted box symbol in a direction indicative of the target velocity vector with respect to ownship. This pointer represents the target aspect angle. A line pointing down toward the bottom of the display indicates a nose aspect; a line pointing left or right indicates a beam

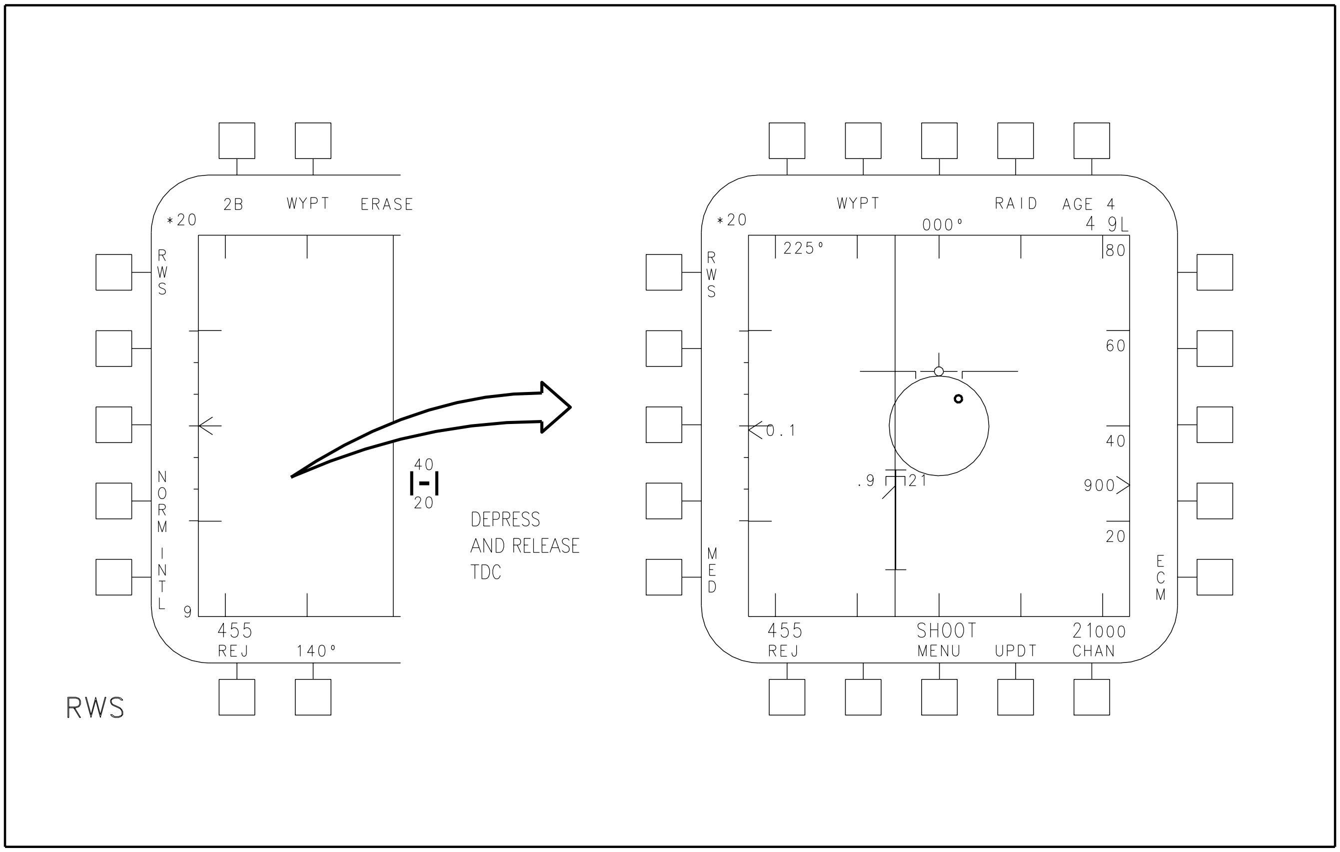

Figure 1-66. Manual Target Acquisition

aspect; and a line pointing up indicates a tail aspect. A target acceleration vector flag is added to the end of the target aspect vector when that target is exceeding 3g acceleration. The flag is displayed perpendicular to the target aspect vector in the direction of the acceleration vector. The target speed (Mach) and altitude (kft) are also displayed adjacent to the target symbol.

1.5.9 Manual Target Acquisition. The manual acquisition method can be used by the pilot to acquire a specific target on the radar display in RWS, VS, or TWS. See Figure 1-66.

Manual target acquisition is initiated by using the TDC to place the acquisition cursor over the desired target. After the acquisition cursor is positioned over a detected target, the TDC action switch is actuated. Target symbols may not appear on the display with every antenna sweep. Target fades may be caused by a change in target elevation. Target fades can also result when the PRF being employed on a particular scan bar eclipses the target return. Changing the antenna elevation setting in search of a fading target is to be avoided until the PRF completely cycles. A PRF cycle requires two antenna scan frames during exclusive HPRF operation and four antenna scan frames during interleaved HPRF/MPRF operation. There should not be any target eclipsing problem during exclusive MPRF operation. As soon as acquisition is initiated the MC issues a manual acquisition command to the radar. The radar:

1. Disables manual control of antenna elevation.

2. Begins a search of the stored target file for the most recent target within the acquisition cursor.

3. Begins moving the antenna to the azimuth position indicated by the acquisition cursor. Target acquisition is not enabled until the antenna reaches the designated position.

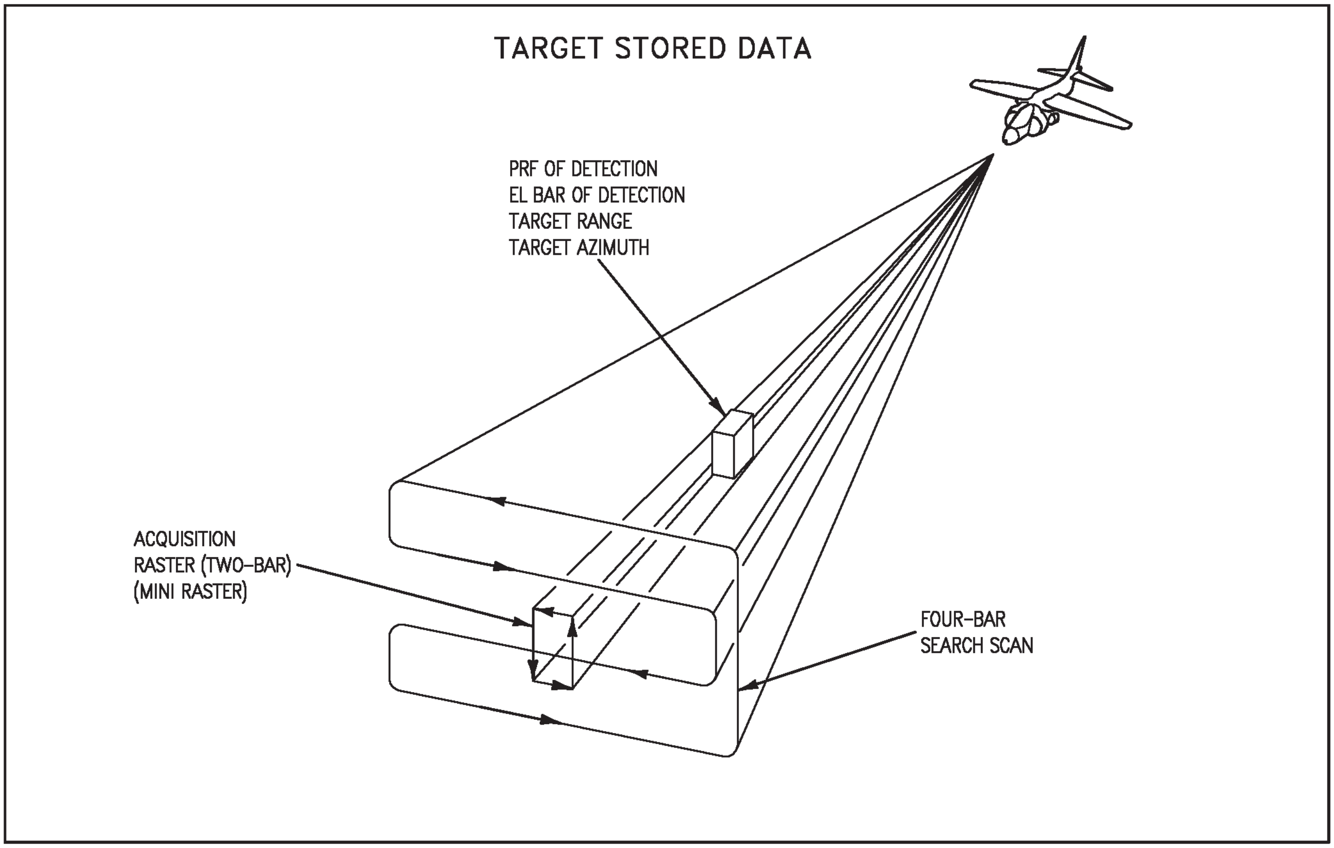

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Figure 1-67. Acquisition Raster-MINI-Raster

When the antenna reaches the designated azimuth position, the radar:

1. Centers the acquisition raster scan (mini raster) on the elevation bar of the stored target. If no stored target is found, the same number of elevation bars previously used in search (but not less than two) are selected for the raster scan. See Figure 1-67.

2. Operates in the PRF that was used to detect the stored target.

3. Enables acquisition of a live target within the range (or velocity) and azimuth window about the acquisition cursor.

Detection of a live target hit stops the acquisition raster. Upon detection of a second live hit within 0.5 second, the track loops are closed and a period of 1.5 seconds is used to establish a valid track. A valid track is denoted by presentation of an attack display on the HUD and radar display. See Figure 1-67.

If no live or stored target is detected within the window within 2 seconds, the radar returns to the search mode PRF commanded, centers the raster scan at the center of the elevation coverage at the time acquisition was initiated, and restores full manual control of the antenna raster scan to the pilot. After manual control of the acquisition raster is restored, the pilot can change the azimuth position of the acquisition raster scan using the TDC. The radar remains in acquisition mode until a single target track is achieved, a return to search command is received, or one of the automatic acquisition modes is commanded.

It should be noted that the mini raster commanded during acquisition can be used to enhance target resolution. If the acquisition cursor is placed just above or below a target and acquisition is commanded, the mini raster will enhance resolution in its scan volume and possibly break out additional targets in azimuth. In this case, the acquisition cursor must be carefully placed or track will be commanded as described.

1.5.10 Target Monitoring. Whether the target is acquired manually or automatically, once the target is acquired, the radar automatically maintains track of the target movements with respect to ownship. This is accomplished by range, velocity, and angle tracking filters. When a target parameter being monitored changes, the change is detected by the filter and the filter output repositions the range/velocity tracking gate over the target. In the case of an angular position change, the antenna is repositioned over the target. The target is tracked in angle and velocity during HPRF operation; tracked in range, velocity and angle during MPRF operation; and tracked in angle and range during LPRF operation. Closed loop range tracking is not performed during HPRF operation but target range is made available through HPRF FM ranging or MPRF burst ranging techniques.

The radar attempts to switch to MPRF after target lock on in HPRF if the signal to noise ratio is adequate. MPRF track provides more accurate target ranging than the FM ramping method used for HPRF target ranging.

The radar attempts to switch to LPRF track when the target enters the main beam clutter region if the target range is less than the main beam clutter range, and an adequate signal to noise ratio exists. This clutter problem occurs when the target maneuvering presents a beam aspect. The low power output provided in LPRF reduces the clutter problem but still retains enough energy for short range track.

In some conditions, the target return may be lost altogether. This could occur when a LPRF track transfer cannot be effected when the target enters the main beam clutter region. It could also occur when the target is lost in noise or it moves outside the antenna gimbal limits. The radar extrapolates the target position until either STT is re-obtained or a preset extrapolation time limit is exceeded. A MEM cue appears on the radar display and the TD box on the HUD is flashed when the radar is extrapolating the target position. The extrapolation time is also displayed. Reacquisition of the target is automatically initiated at the end of the extrapolation time. The radar returns to search at the last known target altitude if the target is not reaquired within 2 seconds. When the target is lost beyond the antenna gimbal limits, the radar immediately returns to search; the antenna azimuth and elevation scan center remains at last known location of the target prior to break-lock.

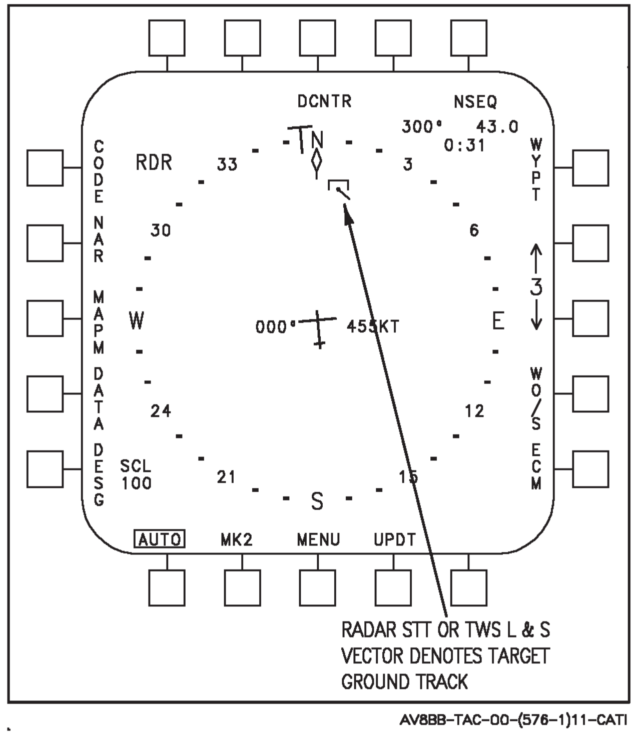


Figure 1-68. A/A EHSD

When the target being tracked in HPRF or MPRF enters the main lobe clutter (MLC) region and a LPRF track transfer cannot be effected, the radar positions the tracking gates as close as possible to the MLC without having the MLC affect the target signal to noise ratio. If the target actually enters the MLC notch, its position is extrapolated until it is predicted to emerge from the MLC notch region. At this time, a MLC search phase is initiated for an emerging target. The first target detected near the MLC notch is declared the emerging target and HPRF/MPRF track is resumed. If a target is not found during the MLC search phase within 15

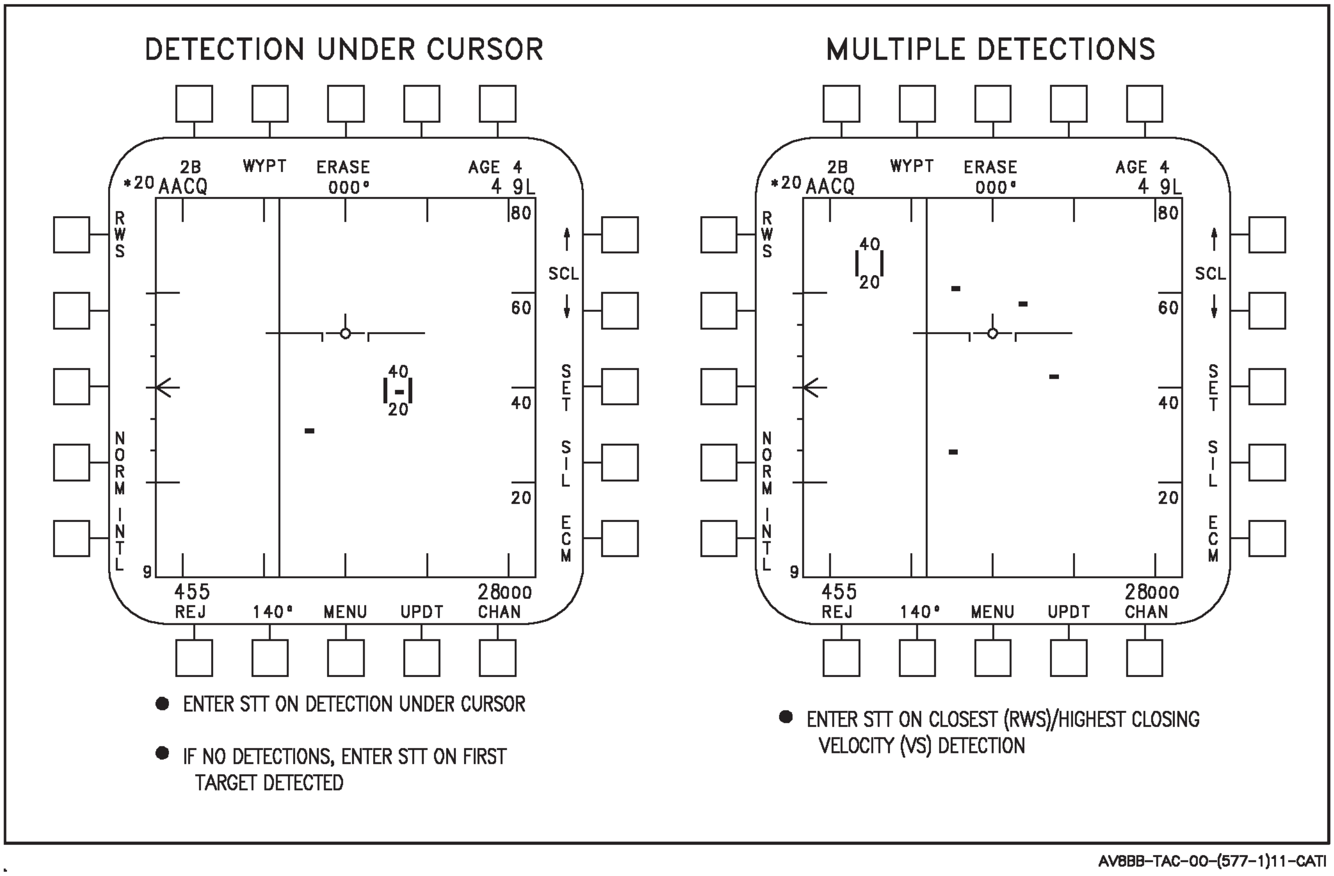


Figure 1-69. Auto Acquisition in RWS/VS

seconds, reacquisition is initiated. As in the case of a target lost in noise, if it is not reacquired within 2 seconds, the radar returns to search.

1.5.11 Tracked Target Symbol on EHSD. A useful feature which helps the pilot's SA of a tracked target is the display of a target symbol on the EHSD. See Figure 1-68. The radar STT or L&S (TWS) target is overlayed on the EHSD. In addition, a vector is displayed with the STT/L&S target symbol which indicates the target's ground track. The DCNTR option appears only in the A/A master mode.

1.5.12 Automatic Target Acquisition. Single target track (STT) can be performed manually by the pilot or automatically by the radar. See Figure 1-69. As noted, manual target acquisition is performed by placing the acquisition cursor over the desired target and then actuating the TDC action switch, however, this requires the pilot to look down at the radar display. The automatic acquisition modes bypass the need for a head-down look at a display and the possibility of losing sight of a visual target. The automatic target acquisition modes (i.e., AACQ and the ACM mode) are obtained by simply actuating the sensor select switch or by just selecting the gun. Quite simply, automatic target acquisition is faster and easier than manual target acquisition. In the automatic target acquisition modes, the radar searches a predetermined volume of space and attempts to lock on the first target detected within that scan volume.

There are two general types of automatic target acquisition available to the pilot; the auto acquisition mode (AACQ and Fast ACQ) and the ACM modes (BST, WACQ, VACQ, and GACQ). AACQ is actually a sub mode of the selected search mode (VS, RWS, or TWS) and retains the search parameters of the particular mode, while ACM modes have their own search parameters. The ACM modes are designed to be used at close range where it is essential for the pilot to stay head-up and maintain a visual lookout, while the auto acquisition mode (AACQ and Fast ACQ) provides a fast and easy way to command automatic target acquisition at ranges farther out than the ACM modes allow.

1.5.13 Auto Acquisition Mode (AACQ). The AACQ mode provides an easy, head-up means to automatically acquire targets at ranges beyond the ACM modes. AACQ does not change selected search parameters like the ACM modes but operates within the presently selected search parameters (RWS, VS, and TWS). AACQ is selected by sliding the sensor select switch aft whenever operating in the A/A master mode, or in the NAV master mode while operating with an A/A radar display (i.e., AIR boxed). Which target is acquired depends on the mode in which AACQ is selected.

1.5.13.1 Operation. The sensor select switch has a dual function depending on whether the radar is tracking or not tracking a target and which radar mode is currently operating. If radar is in RWS, VS, or TWS, momentary aft selection commands the radar to the auto-acquisition (AACQ) mode using existing search parameters and initializes the radar, radar display, and HUD for AACQ operation. A useful submode of AACQ is a feature known as Fast ACQ. In Fast ACQ, the pilot places the acquisition cursor over the desired target and then slides the sensor select switch aft as in selecting AACQ. When Fast ACQ is selected, the radar first determines if a target is located under the acquisition cursor. If a target exists, the radar slaves the antenna to the target, and commands acquisition. If no target exists, the radar continues AACQ and attempts to lock on and track the first target detected.

If the acquisition cursor has not been placed over a target, selecting AACQ commands track on the closest target in RWS or the highest closing velocity detection in VS. If no detections are present, the radar enters STT on the first detection.

In TWS, the same logic is followed by commanding single target track if an L&S target or an unfiled target is under the cursor. However, if a non-L&S track file is under the cursor, AACQ selection will reassign that track file as the L&S target. See Figure 1-70.

Similar to the RWS and VS mode of operation, if there is no target under the cursor, selecting AACQ in TWS will command STT on the L&S target or on the closest unfiled target if an L&S target is not established. If there are no target detections, the radar will command STT on the first detection. See Figure 1-71.

Once the radar is in STT, the pilot can *bump* the acquisition by selecting the AACQ position. This establishes a range/azimuth exclusionary window about the current STT target to preclude immediate reacquisition, and commands the radar to search the scan volume and attempt lock on of the first detected target outside the exclusionary window. If no new targets are found after searching one frame (two if INTL PRF), the radar will command STT on the previously selected target.

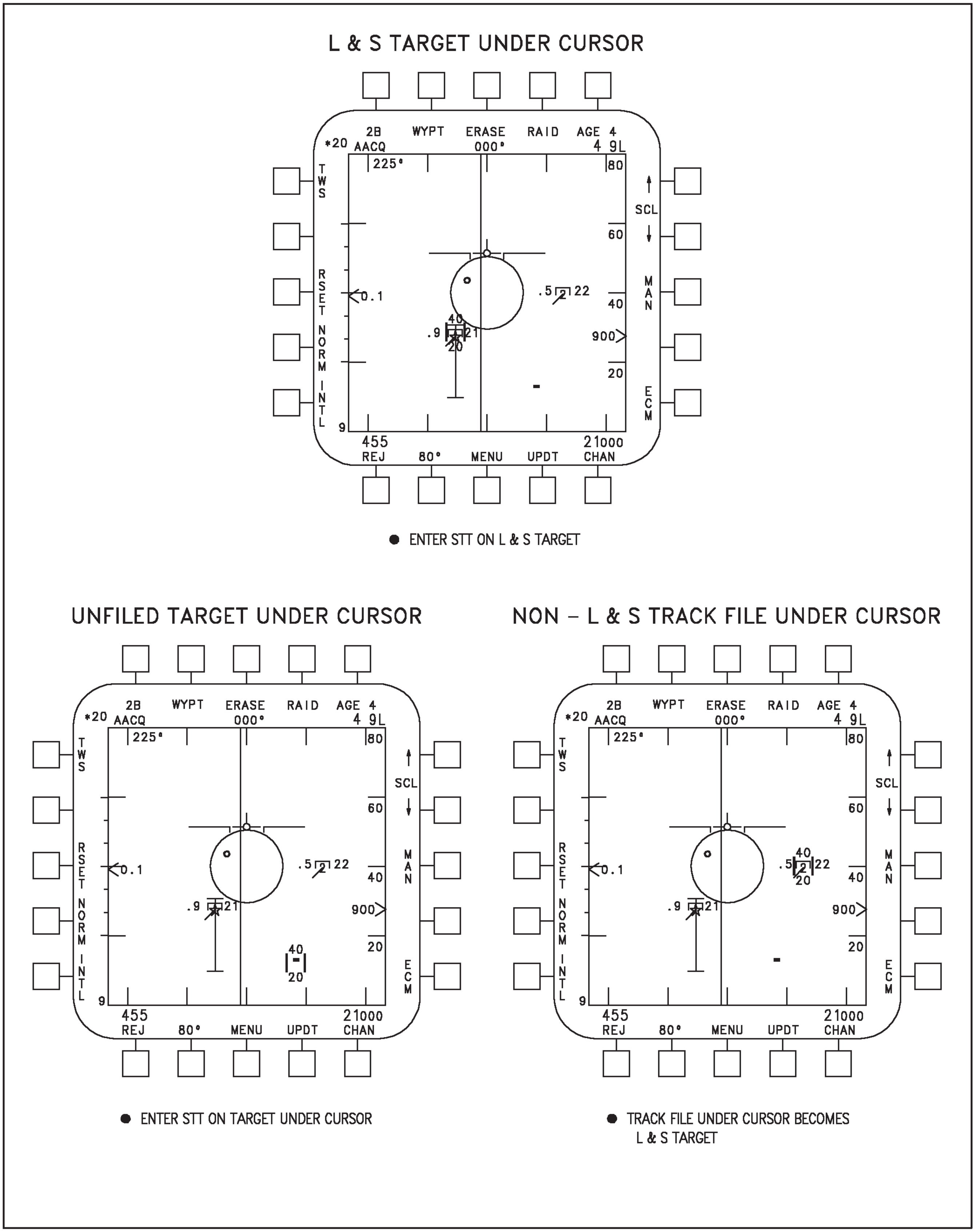
It is important to note that all of the previously described A/A radar modes are available to the pilot while operating in the NAV master mode via the APS (Air Program Select) button on the throttle. This provides the pilot with the capability to rapidly transition between surface mapping and A/A search and track while still managing pertinent A/G systems (i.e., Digital Map, NAVFLIR, etc.). Thus, the pilot is better able to maintain overall mission SA (both A/G and A/A in the Ground Attack Role).

1.5.14 Air Combat Maneuvering (ACM) Modes. The ACM modes are HOTAS selected A/A modes which are designed to be used at close range where it is essential for the pilot to stay head-up and maintain a visual lookout. In the ACM configuration automatic acquisition modes are available for selection. Automatic acquisition modes allow targets to be automatically acquired by the radar thereby bypassing time consuming manual acquisition procedures. The ACM modes consist of BST, VACQ, WACQ and GACQ. The radar automatically provides displays, acquisition, and antenna positioning to search and acquire close-in targets. When an ACM mode is selected, the radar exits the existing mode and starts ACM search. If the radar was in STT, the radar will reject the tracked target. The radar will acquire the first target detected in the antenna scan pattern and command STT.

In the ACM and GACQ modes all options except for ECM, CHAN, UPDT, MENU, and REJ are deleted. The PRF legend remains but is fixed in MED for the short range acquisition modes. The acquisition cursor is also not available in these modes. All of the ACM modes, except WACQ, have a *bump* feature. Reselection of the ACM mode rejects the target being tracked and radar search resumes where the previous target was acquired. The radar will not reacquire the same target for a limited time period. Exit from an ACM or GACQ mode is summarized as follows:

Mode	Method of Exit
BST	Depress undesignate button/ depress TDC
WACQ	Depress undesignate button
VACQ	Depress undesignate button/ depress TDC
GACQ	Select sidewinder boresight or SEAM

The radar returns to the RWS mode if range track was established, otherwise, the radar returns to the mode from which ACM was first entered. An ACM mode may also be deselected by exiting the A/A master mode.



AV8BB-TAC-00-(578-1)11-CATI

Figure 1-70. Auto Acquisition in TWS, Target Under Cursor

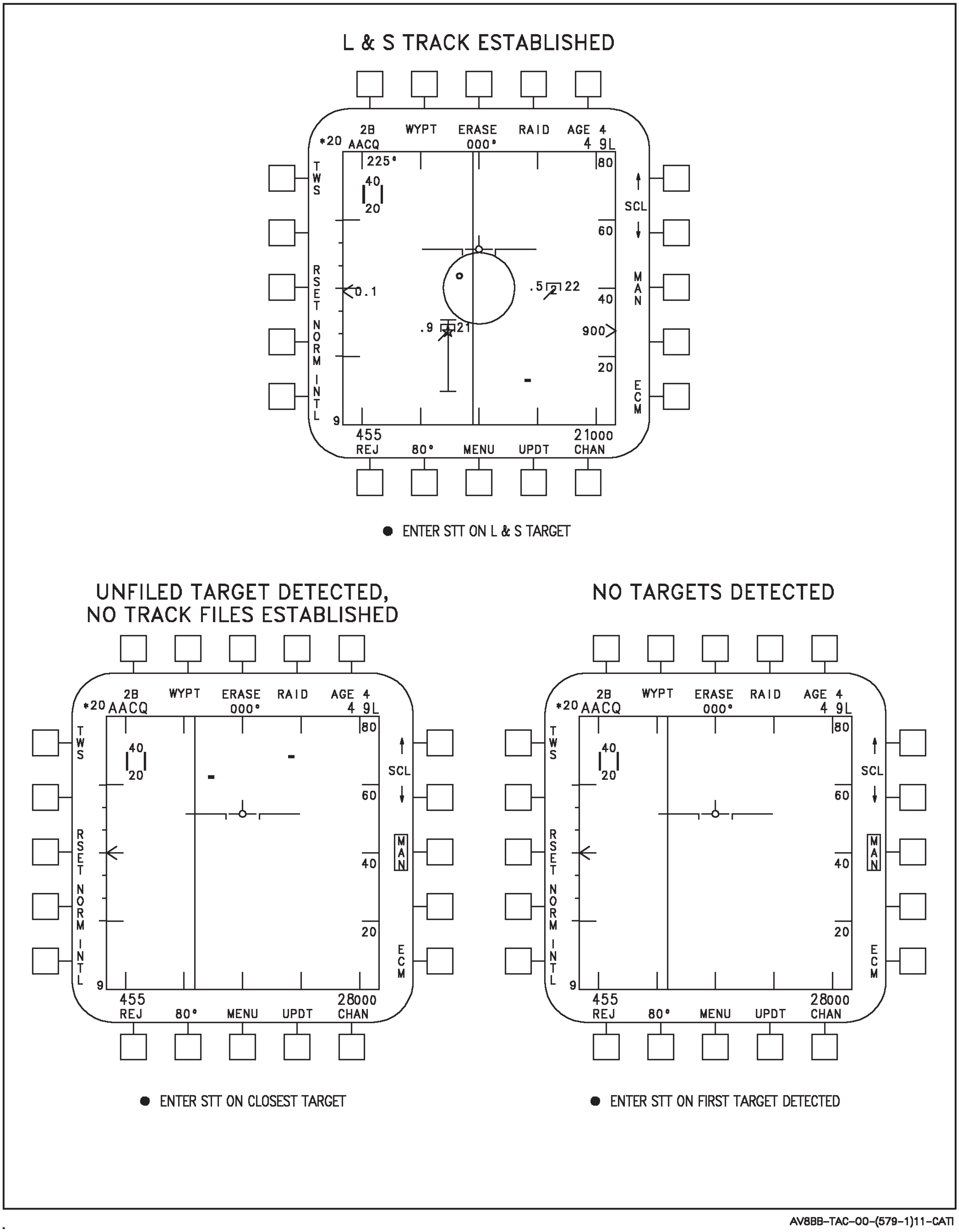


Figure 1-71. Auto Acquisition in TWS, No Target Under Cursor

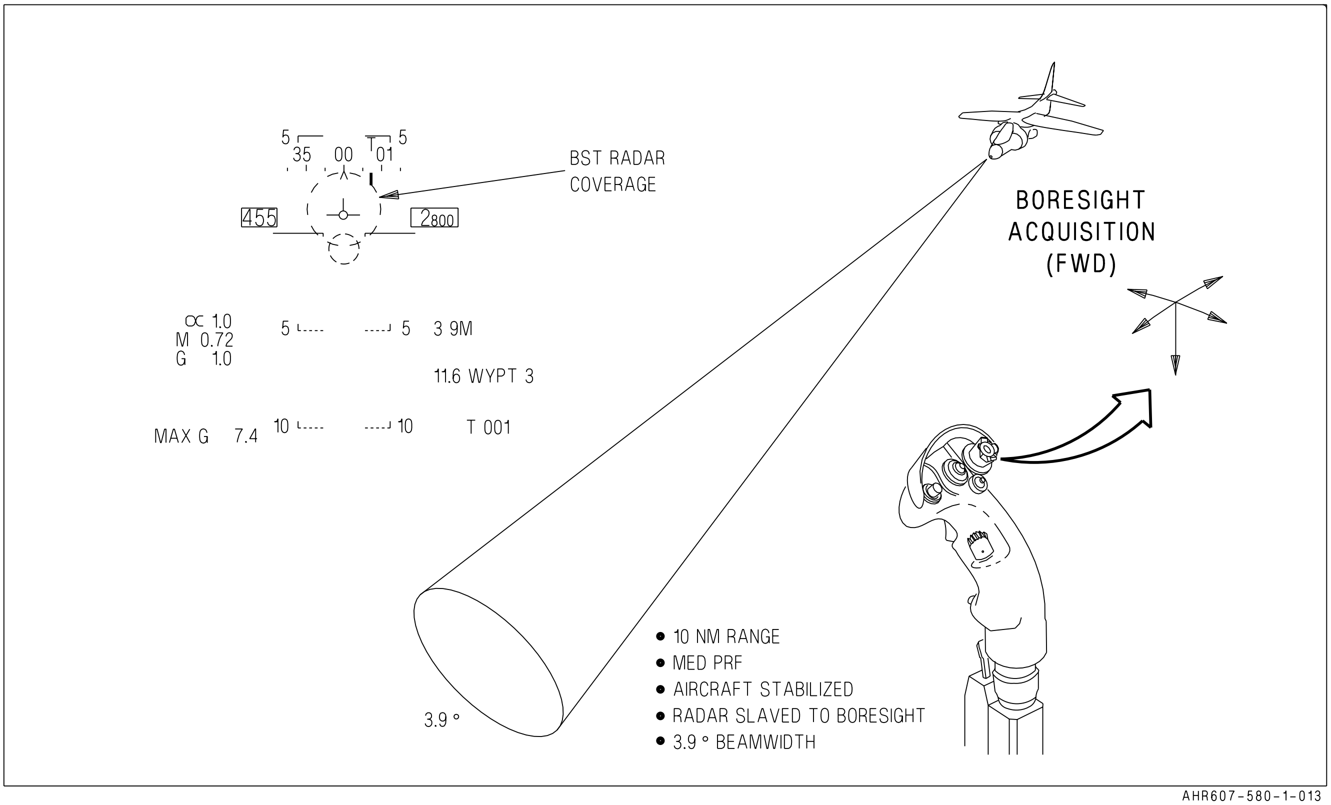


Figure 1-72. Boresight- BST

1.5.14.1 Boresight Mode (BST). In the BST mode, the radar antenna positions to aircraft boresight (no scan) and remains pointed dead ahead. The BST mode is selected by sliding the sensor select switch forward when operating in the A/A master mode. In order to give the pilot a radar coverage cue, the radar beam FOV (3.9°) is depicted on the HUD by a dashed circle. The pilot simply maneuvers the aircraft to place the target in the boresight scan volume. The radar automatically acquires the nearest target in the radar beam within a range of 10 nm. See Figure 1-72.

Since BST involves the pilot in a head-up situation, no BST legend is displayed head-down nor is the acquisition cursor displayed. See Figure 1-73. After lock on, the radar enters STT and tracks the target. If the wrong target is acquired, it can be *bumped* by reselection of the BST mode. In this case, reacquisition of the *bumped* target is inhibited for 2 seconds. If another target

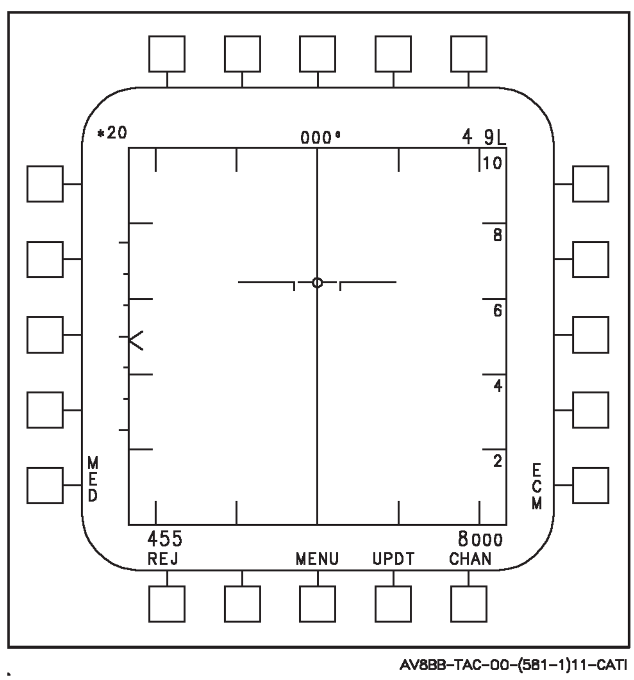


Figure 1-73. Boresight MPCD Display

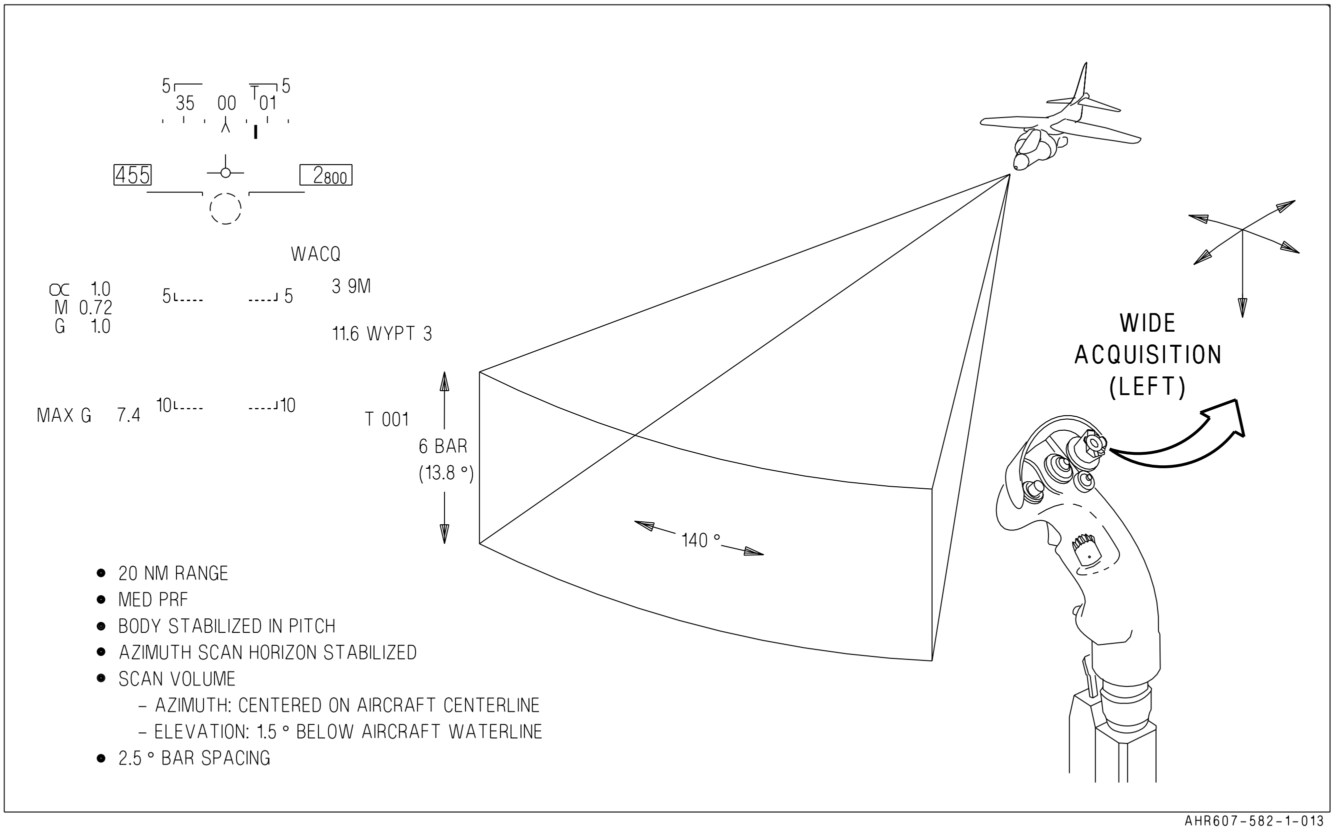


Figure 1-74. Wide Acquisition - WACQ

is not acquired (in 2 seconds), the radar will attempt to acquire the original target.

Remember, although Figure 1-73 displays a Sidewinder selected, the BST mode is also selectable with the gun selected.

1.5.14.2 Wide Acquisition (WACQ). The WACQ mode is selected by sliding the sensor select switch to the left when operating in the A/A master mode. When WACQ is selected, the radar is initialized to the RWS mode, 20 nm range, 140° azimuth scan, medium PRF, and 6 bar elevation scan pattern (13.8° elevation). In WACQ, the scan volume is centered about 0° azimuth and 1.5° below the waterline in elevation. The scan center is body stabilized while the azimuth sweeps of the antenna will always remain parallel to the horizon. See Figures 1-74 and 1-75.

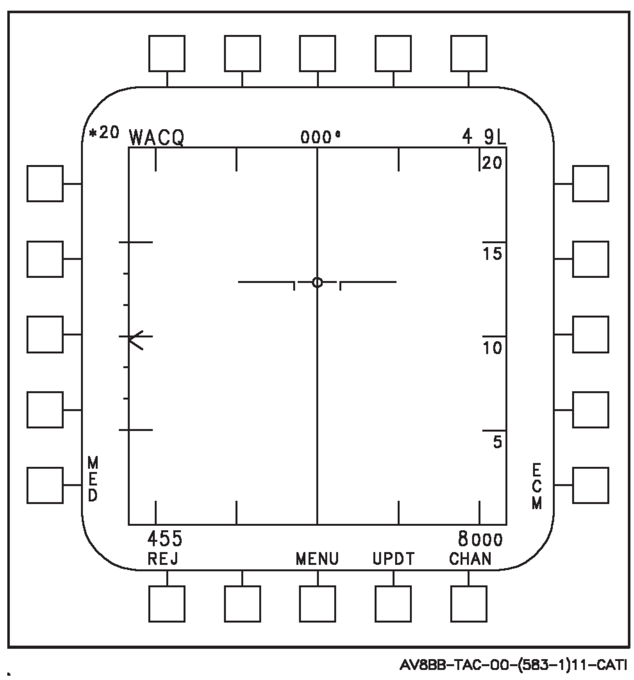


Figure 1-75. WACQ MPCD Display

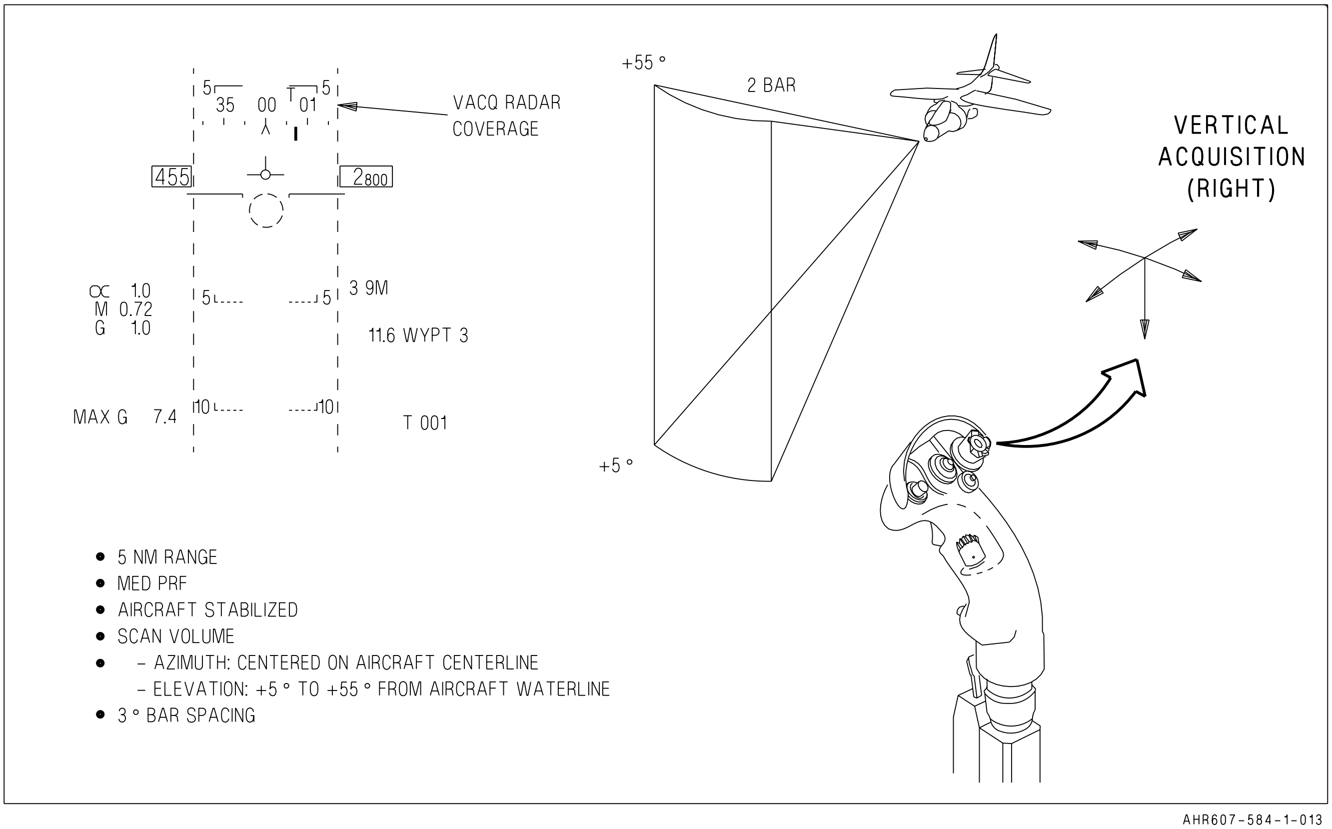


Figure 1-76. Vertical Acquisition- VACQ

The WACQ mode provides a capability in those situations where the pilot knows the potential threat is fairly close but has no clear idea of exactly where the threat is located. A WACQ legend is displayed in the HUD to cue the pilot of WACQ selection. WACQ, because of the size of its scan pattern, may possibly be used head-down and is indicated by the WACQ legend in the left hand top corner of the MPCD display (similar to AACQ). In this mode the radar's automatic acquisition scan volume is 140°/6 bar out to 20 nm and locks onto the nearest detected aircraft. Although WACQ is discussed as an ACM mode, it is important to remember that WACQ covers a large scan volume. Be patient, it may take awhile to acquire a specific target. It takes about 13 seconds to cover the scan volume. Since WACQ is commanded by the MC rather than being an internal radar mode, WACQ does not have a bump capability.

1.5.14.3 Vertical Acquisition Mode (VACQ). VACQ is an ACM mode in which targets located above the nose are automatically acquired. For this reason, VACQ is particularly useful in acquiring targets during hard maneuvers. The VACQ mode is selected by actuating the sensor select switch to the right when operating in the A/A master mode. When VACQ is selected, the radar scans a vertical sector aligned with the aircraft centerline. The VACQ scan coverage is ±3° from centerline in azimuth and + 5° to + 55° above waterline in elevation and is referenced to the aircraft in pitch and roll. See Figures 1-76 and 1-77.

The general scan coverage area is denoted on the HUD by two vertical dashed lines spaced 5.2° apart. These lines do not represent the actual scan of the antenna while in VACQ. VACQ cannot detect targets in the HUD FOV. Since VACQ has substantial mode-unique HUD symbology, no VACQ legend is required. The radar automatically acquires the first target detected in the vertical search pattern out to a range of 5 nm.

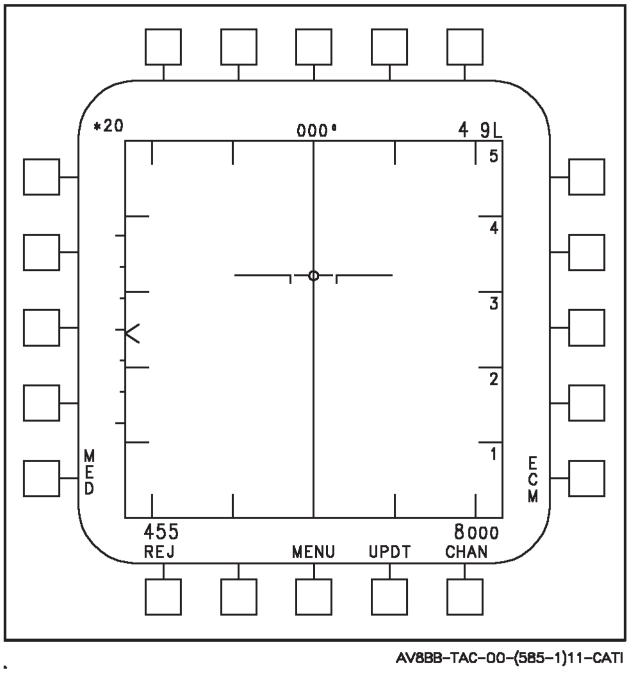


Figure 1-77. VACQ MPCD Display

After lock on, the radar enters STT and tracks the target. If the wrong target is acquired, it can be *bumped* by reselection of the VACQ mode. In this case, reacquisition of the *bumped* target is inhibited for 2 seconds. If another target in not acquired (in 2 seconds), the radar will attempt to acquire the original target. This feature is known as bump acquisition.

1.5.15 Gun Acquisition Mode (GACQ). Despite the ever increasing sophistication of airborne weapons systems and countermeasures, the gun retains vital tactical importance in the context of modern aerial warfare. Engagements which commence beyond visual range often proceed into the visual arena and then into gun range. While all missiles possess minimum range limitations, the gun knows no such limitation and denies sanctuary as a result. A gun is the only weapon available to the pilot which cannot be deceived by chaff, ECM, or flares. In addition, the gun is relatively inexpensive, simple, dependable, and extremely lethal. See Figure 1-78.

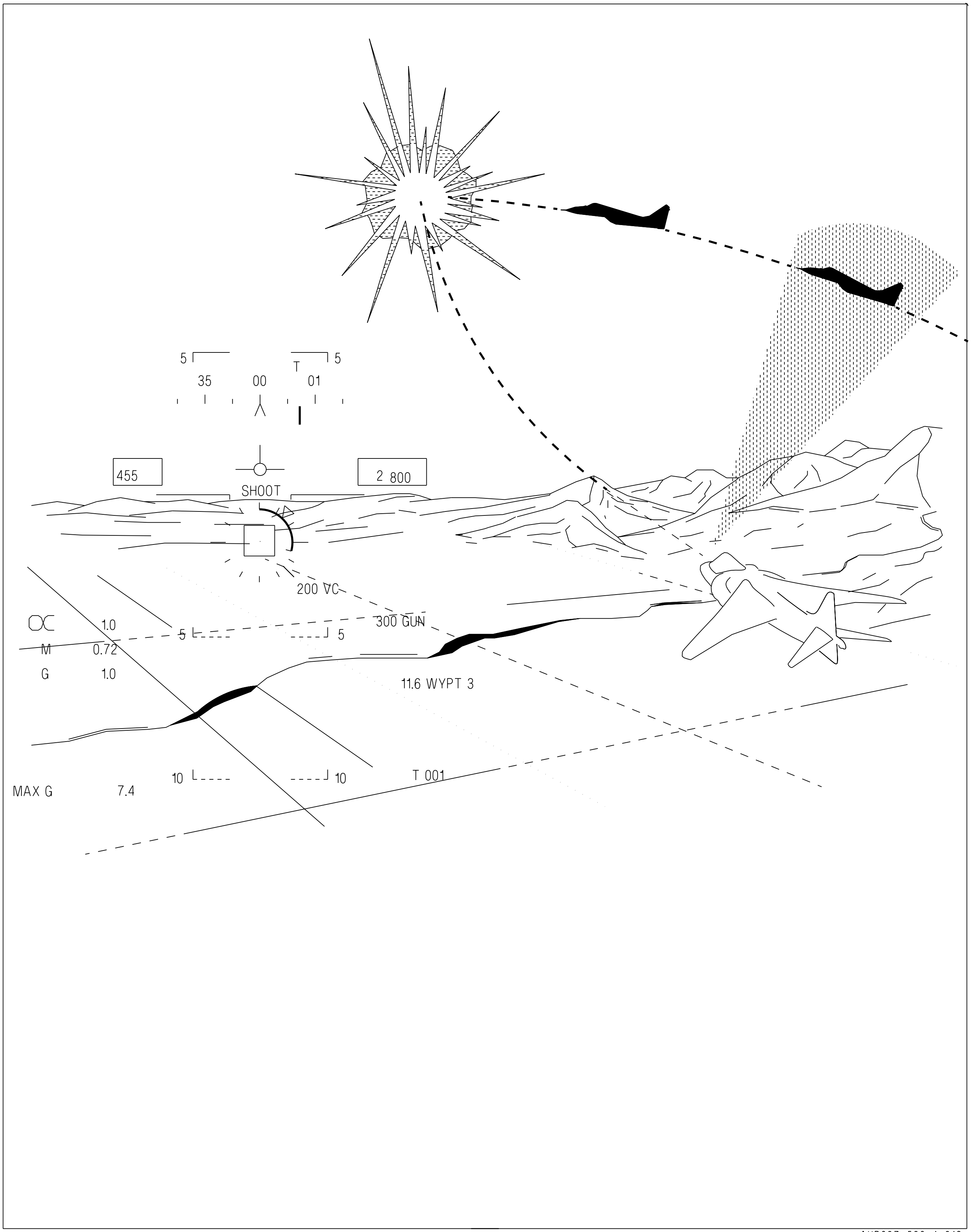


Figure 1-78. Gun Acquisition Display

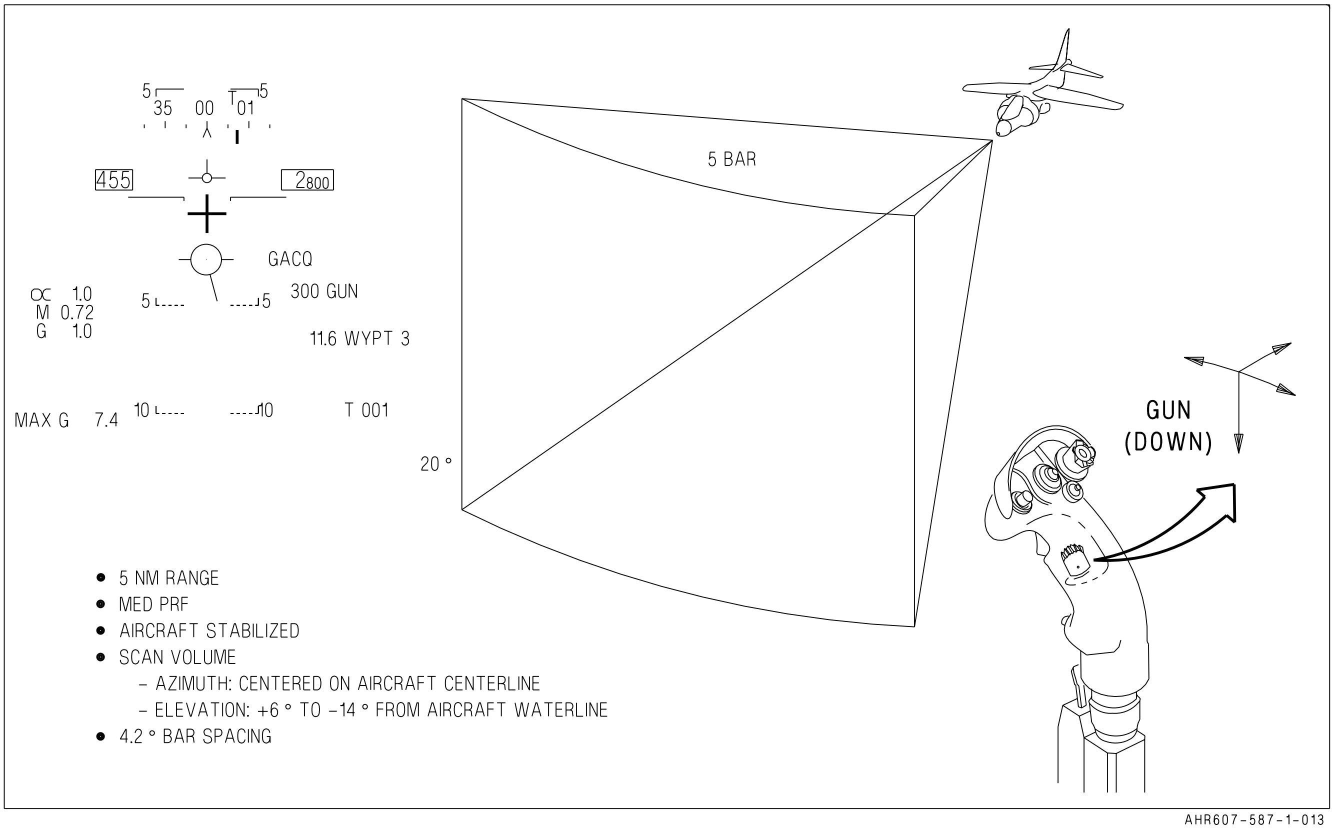


Figure 1-79. GACQ- No Radar Track

1.5.15.1 A/A Gun Operation

1.5.15.1.1 Radar Not Tracking. As in the Day and Night Attack aircraft, selecting the A/A gun automatically configures the weapon system for gun attack. Weapon aiming is automatically displayed and the trigger is enabled for firing the gun if all firing conditions are met. In the radar aircraft, if the radar is not in STT or an ACM mode, selecting gun commands the GACQ mode. With the addition of the radar, three gun sight reticles are now available. These include the lead computing optical sight (LCOS), the backup gun sight (hot gun cross), and the gun director which utilizes radar determined target range, velocity, and acceleration for positioning the reticle. See Figure 1-79.

GACQ is the primary mode for automatically acquiring visual targets within the HUD FOV out to a range of 5 nm. Minimum range is 500 feet. GACQ is selected by selecting the gun. The GACQ mode is automatically commanded unless the radar is already in STT or another ACM mode. In this case, actuating the undesignate switch will always return the radar to GACQ. The GACQ scan pattern approximates the HUD FOV and no special symbology is provided on the HUD other than the GACQ legend indicating this mode. Like the other ACM modes, GACQ is an automatic acquisition mode and the radar attempts to lock on and track the first target detected within the scan volume. Initially, the LCOS sight is displayed on the HUD until radar data is available for computing gun director aiming. The LCOS sight initializes to the long range reticle and can be alternated with the short range reticle by successive depressions of the cage/uncage switch on the throttle. The hot gun cross is always displayed in air-to-air mode when the gun is selected unless occluded by the director gun reticle.

The radar display on the MPCD during GACQ is shown in Figure 1-80. Without radar track, the

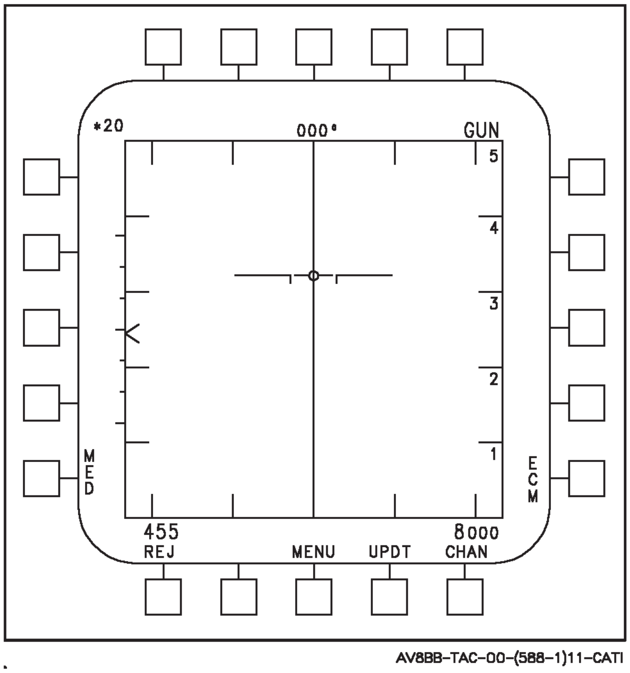


Figure 1-80. GACQ- Radar Not Tracking

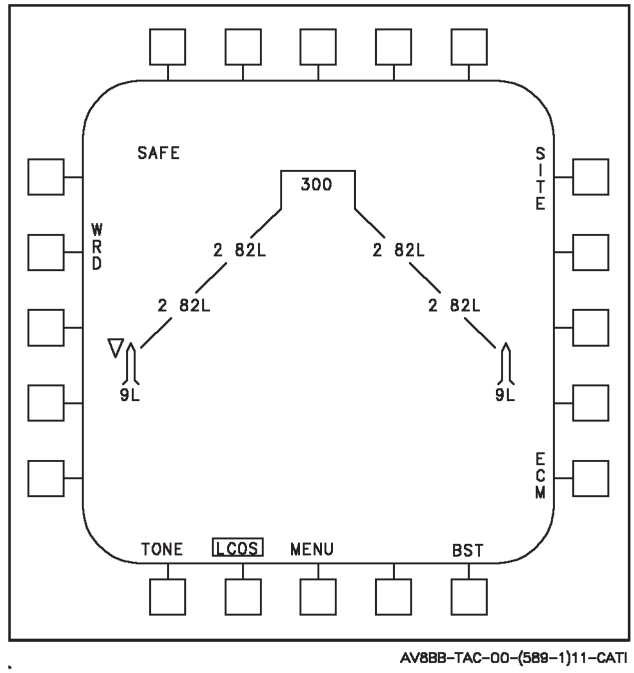


Figure 1-81. LCOS Option Selection

MPCD radar format displays a B-scan appropriate to GACQ. Other indications on the MPCD include the gun legend and appropriate GACQ options. The acquisition cursor is not displayed while in GACQ. Since gun acquisition involves the pilot in a head-up situation, no GACQ legend is displayed head-down. When GACQ is initialized, the radar is commanded to AUTO channel control. Although initialized to AUTO channel, manual channel control is available for selection.

It is important to remember that anytime the radar is in GACQ, the pilot can select any of the other ACM (BST, VACQ, WACQ) modes to change acquisition parameters. In this case, the gun remains the selected weapon but the radar enters the selected ACM mode and the HUD and MPCD radar displays change accordingly. The advantage of having four automated acquisition patterns available in this mode is to manually optimize the scan volume of the radar based on the ACM environment.

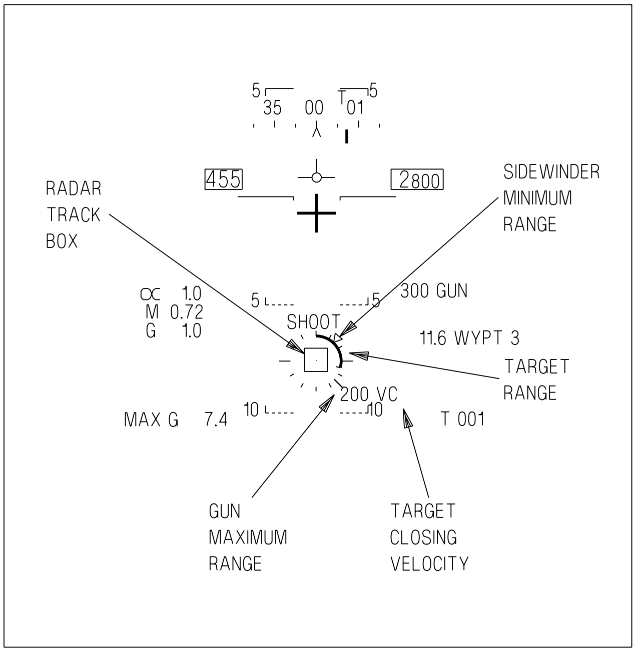
If a target is acquired, the normal STT radar format will be displayed and the gun director aiming reticle will be presented on the HUD. Any time radar track is broken with gun selected, the displays revert to LCOS gun mode. Once a target is locked on, subsequent selection of gun will not break radar lock. The pilot can manually break lock by pressing the undesignate switch which returns the radar to the GACQ mode. Also, bump acquisition is not available with the gun selected in STT.

The LCOS mode can be manually selected from the STRS format by depressing the LCOS option. The LCOS option forces the system to be in the lead computing optical sight mode even if the radar is in STT. On aircraft power-up, the LCOS option initializes disabled. See Figure 1-81.

1.5.15.1.2 Gun Director Sight. When radar lock on is achieved in GACQ, or when selecting gun from the Sidewinder mode with a STT target, the gun director aiming reticle is immediately displayed on the HUD. See Figure 1-82.

As shown, both the starburst reticle and target designator box are present. Gun director aiming is readily distinguishable from the other gun modes and the Sidewinder NIRD circle by the shape of the symbology. Gun director mode symbology includes the following:

a. Director Reticle. Only displayed in the A/A gun mode when the radar is in STT and the LCOS option has not been previously selected. The director reticle consists of a series of tic



AHR607-590-1-013

Figure 1-82. Gun Director Reticle

marks equally spaced around a 50 mil diameter perimeter, a 3 mil pipper, a range bar, a computed gun R_{max} indicator, and the AIM-9 R_{min} cue. The reticle represents the lead angle steering command and is positionable over the total HUD FOV. The range bar is displayed around the inside of the tic marks and indicates target linear range from 0 to 23,000 feet (12 tic marks around the circle, i.e., 15,000 feet = full circle + 3 tics). Each tic mark represents 1,000 feet of range. The gun R_{max} indicator is displayed on the outside of the reticle and indicates the effective gun firing range.

b. Sidewinder Minimum Range. This symbol along with the range bar indicates whether minimum Sidewinder range has been exceeded.

c. Target Closing Velocity (V_c). This is the range rate of the target and represents either the target closing velocity when positive or the target opening velocity when negative. V_c is positioned relative to the gun reticle and moves as the reticle moves.

d. Shoot Cue. Displayed steady on the gun director display when the following conditions are satisfied: MASTER ARM selected, target range is less than R_{max}, and the predicted miss distance will be less than 20 feet within the next one-half record (anticipation of SHOOT cue) or the predicted miss distances will remain less than 30 feet (after SHOOT cue present).

e. Target Designator Box. The TD box in the gun mode operates the same as in the missile mode except, when target range is less than 3,000 feet, the TD box is occluded by the gun reticle to reduce clutter.

NOTE

Hot-gun cross occludes when coincident with gun director reticle.

1.5.15.1.3 Gun Director Considerations. The Director mode is the primary gun mode. The Director mode is obtained immediately upon gun selection if the radar is already tracking a target. Valid range, range rate, and angle tracks are required for director mode operation. If the radar is not tracking an airborne target when gun is selected or if radar track is broken, the LCOS mode is utilized until a valid radar track is established.

In the Director mode, once the radar is locked on, the TD box indicates the position of the target being tracked, and target range is displayed as an analog bar on the 50 mil diameter gun reticle along with a maximum firing range cue. Maximum gun firing range will vary depending on attack geometry. For example, maximum firing range is much greater head-on than tail-on. The radar provides target range, range rate, line of sight, velocity, and acceleration data to the MC. In the Director mode, this data is utilized to predict time-of-flight of the bullet to impact and the future position of the target. The system also knows where the gun is actually aimed and uses this information to determine gun aim error. A pipper is then positioned on the HUD relative to the present target position to make gun aim error equal to pipper to target visual error. In order to get the rounds on target the pilot must maneuver to position the pipper over the target. What this maneuvering really does is aim the gun toward the future position of the target in one bullet TOF. Therefore, the pipper "directs" the pilot to aim the gun toward that future target position. As a consequence, the angle observed between the Director mode gun reticle and the target represents the bullet miss distance at impact range. Correct gun aiming is indicated by coincidence of the reticle and the target.

In the Director mode, lead angle requirements due to target motion are derived from radar track data. These parameters (range, range rate, LOS rate, and target g or acceleration) are completely independent of ownship aircraft motion. The use of track data makes the lead angle computation dependent then on target parameters which will change dramatically as a function of attack geometry. Thus, the Director mode allows firing solutions to be obtained very quickly since rapid attitude changes have little short term effect on the required lead angle. As a result, the pilot's task is solely one of flying to aim the gun reticle since the target tracking function is being performed by the radar.

In theory, a Director system should be a pipper on and fire system regardless of target aspect. And, for the most part, this is true. However, there are several minor limitations.

First of all, present state of the art AI radars and weapons computers are not able to instantaneously calculate all of the target parameters required to predict and display the correct LPA (lead prediction angle) after initial radar lock on. It normally takes a short period of time (about a second) to solve the problem. Determining target "g" usually takes the longest. We call this time period settling time. During this settling time a pipper is still displayed but may be indicating an incorrect LPA.

The accuracy of the target parameter data will also effect pipper accuracy. If one or more of the parameters are incorrect then the pipper displayed LPA may also be incorrect. A good example is the problem of radar glint. The closer you get to a large target the more likely the radar is to shift lock from one point on the target to another. Every time this shift occurs the director system interprets it as a shift in target line-of-sight. The system then recomputes the LPA and displays the pipper in a new position. The end result is a pipper that jumps all over the target. If the pilot tries to get in the loop and correct his aim every time the pipper jumps he is making a mistake.

There is also a short settling time associated with the target changing his steady state flight parameters after shooter radar lock on. Normally, this type of settling time is complete within 1/2 second after the target resumes steady state flight. We can define steady state flight as a fixed plane turn: i.e., constant plane-of-motion and constant "g". The Director always assumes the target is in steady state flight and uses this information to determine target future position. It cannot predict the target's correct future position, and thus the correct LPA, if the target does something non-steady state like change his plane-of-motion or substantially change "g". A pipper will still be displayed but it will be inaccurate. An example is attempting to track a target who is in a high "g" spiral down to the deck. You may be able to hold your pipper on him throughout the maneuver but you will probably see your rounds miss off his high or outside wing.

1.5.15.1.4 A/A Gun Summary. As we have seen, one operational advantage of the Director mode is related to its use of tracking data, which makes the LPA dependent only on target motion and the encounter geometry. The computed lead angle is essentially independent of ownship attitude motion, i.e., roll, pitch, and yaw angular rates and accelerations. Thus, the Director mode allows firing solutions to be obtained very quickly since rapid attitude changes have little short term affect on the required lead angle. As a result, the pilot's control task is solely one of flying to aim the gun reticle since the target tracking function is being performed by the radar.

A second operational advantage of the Director mode is its direct indication of bullet miss distance. Since the director lead angle is essentially independent of ownship attitude motion, no sight damping is included and there is no inherent delay in the miss distance indications as a result of ownship motion. Consequently, recognition of current or impending gun solutions is much easier. While there is some lag during and immediately after a transient target maneuver, it is removed within 1 second so that the lead angle is accurate by the time the pilot reacts to the target motion. Depressing the cage/uncage has no affect in the Director mode.

The LCOS mode, while not the primary A/A gun mode, is still a highly effective mode. The LCOS mode is used if the radar is not in STT (i.e., target line-of-sight, velocity, or range data is invalid) or if the pilot has selected the LCOS option on the stores format. In the latter case, even if the radar is in STT with the gun selected, the LCOS gun mode is utilized.

The main difference between the Director and LCOS modes is the source of target data used in the lead angle computations. In the LCOS mode, target body angular rates and accelerations are derived from the ownship INS rather than actually being measured by the radar. The pilot may select either a long (2400 feet) or a short range (1200 feet) target range via the cage/uncage switch. The system initializes to a long range reticle. A hot-gun cross is also displayed. The LCOS mode is dependent on the availability of aircraft body rate and acceleration data. When this data is not available, only the hot-gun cross is displayed at a fixed position on the HUD (i.e., backup mode).

1.6 RADAR PREFLIGHT MANAGEMENT

1.6.1 Air-to-Surface Radar Checklist

1.6.1.1 Preflight Checks

1. RADAR switch - OPR

   Radar initiates 3 minute power-up sequence and self-test (ORT).

2. Radar display selection:

   (a) Select RDR on main MENU (either MPCD).

   -or-

   (b) Slide sensor select switch aft.

   Radar display appears on right MPCD.

3. Radar Channel/Channel Set - SET

4. Left and right MPCD controls - ADJUST BRT/CONT LEVELS

5. Radar BIT - PERFORM

   (a) Select main MENU and BIT

   (b) TEST displayed during ORT/IBIT, then blank (OK), or appropriate WRA fault code (1 to 9).

1.6.1.2 MAP (RBGM) Mode

(1) Master Mode - A/G, NAV, or VSTOL

(2) Sensor select switch - ASSIGN TDC TO RADAR (when required)

(3) Radar parameters - SELECT

   (a) AIR - SELECT
   (when Air radar program desired)

   (b) Range - 160, 80, 40, 20, 10, or 5 nm

   (c) Mode - MAP.
   Upon selection of any surface mode, the video gain (GAIN), antenna elevation and beam (PEN or FAN) are automatically optimized for the selected range and altitude. The parameters can be changed if desired.

   (d) Antenna elevation - AS DESIRED (control on throttle)

   (e) GAIN - AS DESIRED

   (f) Beam - Auto beam selection (PEN or FAN).

   (g) RSET - Returns antenna elevation, GAIN, and Beam selection to auto settings.

   (h) SIL - DESELECTED

(i) REJ - AS DESIRED

(j) Azimuth scan - 120° 90°, 45°, or 20°

(k) ECCM - AS DESIRED
(option on ECM display)

(4) Monitor Radar Video

1.6.1.3 EXPAND MODES EXP1, EXP2, EXP3

1. Master Mode - A/G, NAV, or VSTOL

2. Sensor select switch - ASSIGN TDC TO RADAR (if desired)

3. EXP1, EXP2, or EXP3 - SELECT
(options displayed only in MAP mode)

(a) Undesignated:
EXP corral is superimposed on MAP or previously selected EXP mode map.

POSITION CORRAL OVER DESIRED REGION WITH TDC.

ACTUATE TDC TO ACTION POSITION.

Expanded display of selected region is displayed.

(b) Designated:

EXP display is presented centered about designated point.

(c) FAST - AS DESIRED

1.6.1.4 Radar Search - GMT, SEA

1. Master mode - A/G, NAV, or VSTOL

2. Sensor select switch - ASSIGN TDC TO RADAR (when required)

3. Radar parameters - SELECT

(a) Mode - SEA or GMT

(b) Range -
160 nm range not available in basic SEA 160 nm, and 80 nm range not available in GMT

(c) Azimuth scan -
120° azimuth scan not available in GMT

4. Monitor radar video -
SEA and GMT mode targets are synthetically presented as rectangles on the radar display.

5. IMAP - AS REQUIRED
(GMT and SEA modes only)

(a) Synthetic GMT or SEA targets are overlayed on MAP video when IMAP is selected.

(b) 160 nm range scale available in SEA mode with IMAP selected.

1.6.1.5 Freezing a Radar Display

1. SIL - SELECT

(a) Radar transmissions are inhibited (steady Maltese cross displayed)

(b) FRZ is automatically selected

(c) ACTIVE - SELECT (as required)
Radar transmissions are resumed for one antenna scan when ACTIVE is selected. Updated radar display is again frozen.

-or-

2. FRZ - SELECT

Radar display is frozen, but radar transmissions are not inhibited.

NOTE

Normally, the preferred method for silencing the radar along with the other onboard emitters is via the EMCON button on the UFC. Selecting EMCON will box SIL and FRZ, hence freeze the radar display.

The ACTIVE option is also enabled but is not functional.

1.6.1.6 Radar Track

1. Mode - MAP, EXP1, EXP2, EXP3, SEA, or GMT

2. TDC - ASSIGN TO RADAR

(a) Designated:
Sensor select switch - SLIDE AFT AND HOLD.

In-video cursor replaces stab cue over designated point and may be slewed as required.

TDC - RELEASE (if actuated).

Sensor select switch - RELEASE (radar is commanded to track when switch is released).

Synthetic target symbol appears over tracked aim point (MAP video disappears).

Subsequent actuation of the sensor select switch aft breaks radar track (aim point becomes a radar designation).

(b) Undesignated:

Acquisition cursor - SLEW OVER AIM POINT.
(If the acquisition cursor is outside border, no acquisition is commanded).

Sensor select switch - SLIDE AFT AND HOLD.

In-video cursor replaces acquisition cursor over aim point and may be slewed as required.

TDC - RELEASE (if actuated)

Sensor select switch - RELEASE (radar is commanded to track when switch is released).

Synthetic target symbol appears over tracked aim point (MAP video disappears).

Subsequent actuation of the sensor select switch aft breaks radar track (aim point becomes a radar designation).

NOTE

If track can not be established on selected aim point (undesignated or designated), the aim point becomes a radar designation.

1.6.1.7 Special Measurements

1.6.1.7.1 A/G Ranging - AGR

1. TDC - SLIDE FORWARD
(also selects INS sensor mode and assigns TDC to the HUD)

(a) AGR is commanded along the radar LOS in the following priority:

CCIP cross (A/G gun & rocket reticle)

Designated target

Velocity vector

(b) AGR legend is displayed in HUD when AGR data valid.

(c) AGR display:

AGR display integrated into stores display.

Target slant range (in feet).

Velocity error along AGR LOS.

RANGE and velocity error readouts are blanked if AGR data invalid.

1.6.1.7.2 Precision Velocity Update (PVU)

1. UPDT option (RDR, EHSD, or FLIR display) - SELECT.

2. VEL option on ODU - SELECT.

3. LAND or SEA option on ODU - SELECT (as applicable).

4. Velocity error displayed on scratchpad (bearing and knots). Allow to settle out/converge.

5. ACPT or REJ option on ODU - SELECT.

   If ACPT is selected, radar derived velocities are used for weapon delivery computations for 10 minutes with the correction being phased out over the last 5 minutes.

1.6.1.7.3 Terrain Avoidance (TA)

1. TA - SELECT.

2. MPCD controls (brightness and contrast) - SET.

   Use offset wedges at bottom of display as a reference for setting MPCD controls.

3. 5 or 10 nm range scale - AS DESIRED.

4. Monitor for video returns near ground track.

1.6.1.7.4 Radar Designation

1. Mode - MAP, EXP1, EXP2, EXP3, SEA, or GMT.

2. TDC - ASSIGN TO RADAR.

3. Acquisition cursor - SLEW TO AIM POINT.

4. TDC - PRESS and HOLD (In-video cursor replaces acquisition cursor).

5. In-video cursor - CENTER OVER “LEADING EDGE” CENTER OF AIM POINT.

6. TDC - RELEASE.

7. Stabilized cue (stab cue) appears on aim point.

   (a) MC maintains cue on target.

   (b) To update aim point, bring acquisition cursor into tactical region and depress TDC to reinitialize in video cursor. Slew as required and release TDC.

1.6.1.7.5 Standoff Position Update Utilizing Radar Designation

1. UPDT on EHSD, FLIR or RDR display - SELECT

2. DESG on ODU - SELECT

3. Standoff Position Update using one of 15 stored waypoints:

   WYPT on ODU - SELECT (defaults selected).

   WYPT on EHSD - SELECT (appropriate)

   Perform radar designation on video return of selected waypoint on radar display (i.e., place stab cue on waypoint video return).

   Position error is displayed on scratchpad.

   Error on ODU - ACCEPT OR REJECT

4. Standoff Position Update using landmark on digital map.

   Select an update point which is discernible on both the radar and the digital map.

   Perform radar designation on video return of update point on radar display (disregard position error on scratchpad).

   Select MAP on ODU (TDC assignment will switch to MAP).

   Slew update point (point which corresponds to stab cue on radar display) precisely under cross-hair symbol on EHSD display.

   Position error is displayed on scratchpad. Accept or reject error on ODU.

1.6.1.7.6 Radar Troubleshooting Techniques and Procedures

1. Radar Transmitter Failure

(a) Transmitter Failure Indication:

Maltese cross

Steady indicates normal transmitter termination (i.e., WOW, SIL, EMCON, STBY).

Flashing indicates abnormal operation.

2. Corrective Action Options (abnormal operation):

Quick Start

RADAR switch - OFF

Wait 3 to 5 seconds
(not more than 7 seconds)

RADAR switch - OPR

Cold Start

RADAR switch - OFF

Wait more than 7 seconds

RADAR switch - OPR
(radar will initiate 3 minute self test (ORT)

Cycle MC power switch - OFF THEN AUTO

3. Transmitter Channel Failure

(a) Channel Failure Indication:

CH FAIL legend is displayed to the right of the RF channel indication.

4. Corrective Action Option:

CHAN option - SELECT (CHAN option is replaced with the current channel or channel set and the UPDT option is replaced by the MCHN option).

Auto Channel Control - SELECT (MCHN unboxed) or step through the manual (MCHN boxed) channels to find a clear channel (if possible).

5. Radar Overheat (OVHT)

(a) Radar Overheat Indication:

Flashing OVHT legend is displayed on radar display.
(Radar will shutdown automatically after 30 seconds).

(b) Corrective Action Option:

Place RADAR switch in the EMER position to prevent auto shutdown.

If the OVHT indication is due to a liquid coolant low condition, the radar will not reset.

CAUTION

Operating the radar with the RADAR switch in the EMER position during an overheat condition can damage the radar.

6. Backup Radar Displays (see Figure 1-83) (i.e., MC failure)

(a) Select RDR option on backup EHSD display

Air-to-surface radar display
(fixed parameters):

MAP mode

40 nm range

120° azimuth scan

Auto gain

SITE option

AIR option
(selects fixed air radar display)

Air-to-air radar display
(fixed parameters):

RWS mode

40 nm range

INTL PRF

2 Bar elevation

140° azimuth scan

2 second target aging

SITE option

AIR option
(selects fixed surface radar display)

1.6.2 Air-to-Air Radar Checklist

1.6.2.1 Preflight Checks

1. RADAR switch - OPR or STBY (as appropriate)

   Radar initiates 3 minute power-up sequence and self-test (ORT).

2. Radar display selection:

   (a) Select RDR on main MENU (either MPCD).

   - or -

   (b) Select Sidewinder Boresight or SEAM on A/A weapon select switch.

   Radar display appears on right MPCD.

3. Radar Channel/Channel Set - SET

4. Left and right MPCD controls - ADJUST BRT/CONT LEVELS

5. Radar BIT

   (a) Select main MENU and BIT

   (b) Select AUTO or RDR

   (c) TEST displayed during ORT/IBIT, then blank (OK), or appropriate WRA fault code (1 to 9).

6. SET Option (RWS only)

   (a) Select Sidewinder Boresight mode

NOTE

SEAM set features not available with WOW.

   (b) Select desired radar parameters

   - PRF
   - Azimuth scan
   - Bar scan
   - Range scale
   - Target aging

   (c) Select SET option (boxed for 2 seconds).

1.6.2.2 A/A Weapons Checks (Post Takeoff w/Master Arm-OFF)

1. Select the A/A master mode via AIM-9 SEAM.

2. Select BST, GACQ, or WACQ with wingman in the scan volume.

3. Verify valid STT and attack symbology.

4. Adjust sidewinder tones to highest usable level.

5. Uncage and track with AIM-9 onboard.

6. Cage the missile and break radar track.

7. Program SEA M set, if other than default is desired.

1.6.2.3 Radar Search

1. Master mode- Select A/A Master mode.

   The radar can be used for A/A search in the NAV, VSTOL, and A/G master modes via the AIR option. However, the TDC may not necessarily be assigned to the radar and the A/A weapon attack indications are not provided on the radar display or HUD.

2. Radar parameters - SELECT

   (a) Mode - RWS or VS (TWS mode is discussed later)

   (b) Elevation scan - 1B, 2B, 4B, or 6B

   (c) Target aging - 2, 4, 8, 16, or 32 seconds

   (d) Range scale - 5, 10, 20, 40, 80, or 160 nm

   (e) Silent option - DESELECT (unboxed)

   (f) Reject option - AS DESIRED

   (g) Azimuth scan - 140°, 90°, 45°, or 20°

   When a limited scan is selected, the center of the scan can be manually positioned by holding the TDC action switch pressed after making a HOTAS azimuth selection and applying left-right force to the TDC.

   (h) PRF (VS is always HPRF) - AS DESIRED

   (j) Speed gate option - AS DESIRED (Default - NORM)

   (k) ECCM option - AS DESIRED (Default selected)

3. Antenna elevation - AS DESIRED

4. Detected targets appear as solid rectangles in radar display tactical region.

1.6.2.4 To Maintain Radar Silence

1. Silent option - SELECT (SIL available in RWS and VS)

   SIL legend - Boxed

   Radar operates in a passive only mode

   Maltese cross displayed

NOTE

The preferred method of silencing the radar along with other onboard emitters is via the EMCON button.

The radar SIL option is primarily used in silent attacks when momentary reactivations of the radar may be required.

1.6.2.5 To Momentarily Reactivate Radar Transmissions

1. TDC action switch - ACTUATE (ACQ cursor in tactical region)

   Radar transmissions are resumed for two complete antenna scan frames if INTL PRF is selected and only one frame if MED or HI is selected.

   During active frames, the Maltese cross is removed but SIL remains boxed.

   Detected targets are frozen on the radar display after radar transmissions cease.

1.6.2.6 To Resume Normal Radar Search

1. Silent option - DESELECT

   SIL legend - Unboxed

   Normal radar transmissions resume

   Maltese cross removed

1.6.2.7 Manual Target Acquisition

1. Acquisition cursor - BRACKET TARGET

   Position acquisition cursor over target using TDC.

2. TDC action switch - ACTUATE

Radar lock on is commanded.

3. MPCD and HUD - Attack Display

An attack display is presented on the HUD and MPCD radar display after a successful radar acquisition of the target.

1.6.2.8 To Return to Search

1. TDC action switch or designate button - ACTUATE

1.6.2.9 Automatic Target Acquisition

1. Sensor select switch - VACQ, WACQ, AACQ, or BST

Select appropriate automatic target acquisition mode based on target position.

Selecting the A/A gun selects GACQ mode.

2. Visual target- In Selected FOV

Bring target within the FOV of the selected automatic acquisition mode.

3. MPCD and HUD - Attack Display

An attack display is presented on the HUD and MPCD radar display after successful radar acquisition of the target.

1.6.2.10 If the Desired Target Was Not Acquired in AACQ, VACQ, or BST

1. Sensor select switch - RESELECT AACQ, VACQ, or BST

Radar rejects first target acquired, ignores this target for a period of time (approximately 2 seconds), and searches for another target.

2. MPCD and HUD - Attack Display

When the radar acquires the new target or reacquires the old target after a period of target search, an attack display is presented on the HUD and MPCD radar display.

1.6.2.11 To Return to Search

1. TDC action switch or undesignate button - ACTUATE

1.6.2.12 Single Target Track

1. Attack display - MONITOR

No specific radar control is required of the pilot once the target is acquired other than ensuring that track is maintained and checking for anomalies.

(a) Jamming is indicated by appropriate symbology on HUD and MPCD.

(b) Potential loss of track is indicated by a MEM cue on the MPCD, and flashing TD box on the HUD.

2. Steering dot/reticle - CENTER

Center the steering dot in the ASE circle to follow the pure pursuit course.

Center the reticle on the target for a gun attack.

1.6.2.13 If Multiple Targets Are Suspected in Vicinity of Tracked Target

1. RAID option - ACTUATE

MPCD radar display changes to a range versus range display about the tracked target.

All detected targets in near vicinity of tracked target may be resolved in azimuth, range, and altitude.

1.6.2.14 Track While Scan

1. TWS mode - SELECT

From radar search, the TWS mode is selected with MPCD mode button or via HOTAS.

From STT, the TWS mode is selected by actuating the TWS option on the top row of the MPCD.

2. Radar parameters - SELECT

When the TWS mode is selected, the radar scan centroid is automatically positioned about the STT or L&S target (MAN unboxed). However, other radar scans and parameters can be manually selected.

(a) Elevation scan - 2B, 4B, or 6B

Azimuth scan widths are automatically selected based on the number of elevation bars selected. (2B-80º, 4B-40º, 6B-20º).

(b) Target aging - 2, 4, 8, 16, or 32

Target aging selection applies only to unfiled targets. (Default - 2 seconds)

(c) Range - 5, 10, 20, 40, 80, or 160 nm

(d) Reject option - AS DESIRED

(e) PRF - AS DESIRED

(f) Channel option - AS DESIRED

(g) Speed gate option - AS DESIRED

(h) ECCM option - AS DESIRED

3. Antenna elevation - AS DESIRED

4. Detected targets are prioritized and displayed on the MPCD radar display.

(a) The highest priority target is displayed as an inverted half box symbol labeled with a numeral 1. The radar automatically selects this target as the L&S target for which the MC computes attack displays (launch zones and attack steering). In this case, the numeral 1 is replaced with a star. Other lower priority filed targets can be designated by the pilot as the L&S target.

(b) Filed targets with priority ranking 2 thru 8 are displayed as inverted half box symbols with their respective numerical priority label.

(c) Additional targets are simply displayed as solid rectangles.

1.6.2.15 To Manually Reposition Azimuth Scan Center

1. Manual/Auto Scan Center (MAN) option-MAN boxed

2. Acquisition cursor - On Azimuth Scan Digits.

   Use TDC to place acquisition cursor in azimuth scan HOTAS region.

3. TDC action switch - PRESS and HOLD

   Acquisition cursor repositions to center of MPCD.

4. Acquisition cursor - POSITION AS DESIRED

   Antenna azimuth scan center follows acquisition cursor.

5. TDC action switch - RELEASE

   Release TDC action switch when azimuth scan center is positioned to desired position.

1.6.2.16 To Designate New L&S /Target From Filed Targets Via the Undesignate Button

1. Undesignate button - ACTIATE

   L&S designation shifts down to the next highest filed target. Subsequent actuations sequences the L&S designation down through the track files.

1.6.2.17 To Designate New L&S /Target From Filed Targets Via the TDC

1. Acquisition cursor - ON NEW TARGET

2. TDC action switch - ACTUATE

1.6.2.18 To STT the L&S Target

1. Acquisition cursor - ON L&S TARGET

2. TDC action switch - ACTUATE

1.6.2.19 To STT a Filed Target Other Than the L&S Target

1. Acquisition cursor - ON FILED TARGET
2. TDC action switch - ACTUATE TWICE.

   The first TDC action switch actuation designates target as new L&S target, the second actuation initiates STT.

1.6.2.20 To STT an Unfiled Target

1. Acquisition cursor - ON UNFILED TARGET
2. TDC action switch - ACTUATE

1.6.2.21 Radar Troubleshooting Techniques and Procedure

1. Radar Transmitter Failure

   (a) Transmitter Failure Indication:

   Maltese cross

   Steady indicates normal transmitter termination (i.e., WOW, SIL, EMCON, STBY).

   Flashing indicates abnormal operation.

2. Corrective Action Options (abnormal operation):

   Quick Start

   RADAR switch - OFF

   Wait 3 to 5 seconds (not more than 7 seconds)

   RADAR switch - OPR

   Cold Start

   RADAR switch - OFF

   Wait more than 7 seconds

   RADAR switch - OPR (radar will initiate 3 minute self test (ORT).

   Cycle MC power switch - OFF then back to AUTO.

3. Transmitter Channel Failure

   (a) Channel Failure Indication:

   A CH FAIL legend is displayed to the right of the RF channel indication.

4. Corrective Action Option:

   CHAN option - SELECT (CHAN option is replaced with the current channel or channel set and the UPDT option is replaced by the MCHN option).

   Select auto channel control (MCHN unboxed) or step through the manual (MCHN boxed) channels to find a clear channel (if possible).

5. Radar Overheat (OVHT)

   (a) Radar Overheat Indication:

   Flashing OVHT legend is displayed on radar display. (Radar will shutdown automatically after 30 seconds).

   (b) Corrective Action Option:

   Place RADAR switch in the EMER position to prevent auto shutdown.

   If the OVHT indication is due to a liquid coolant low condition, the radar will not reset.

CAUTION

Operating the radar with the RADAR switch in the EMER position during an overheat condition can damage the radar.

6. Birdies (Ghosts)

Spurious indications (ghosts) may appear on the radar display. These indications can be caused by external sources such as jet engine modulation (JEM) from other aircraft or internal transmitter/receiver noise.

Corrective Action Option:

(1) Mode - SELECT VS

(2) RF channel - Step through channels to find a clear channel, (if possible).

7. Backup radar displays (i.e., MC failure)

(a) Select RDR option on backup EHSD display.

Air-to-surface radar display (fixed parameters):

MAP mode

40 nm range

120° azimuth scan

Auto gain

SITE option

IR option (selects fixed air radar display)

Air-to-air radar display (fixed parameters):

RWS mode

40 nm range

INTL PRF

2 Bar elevation

140° azimuth scan

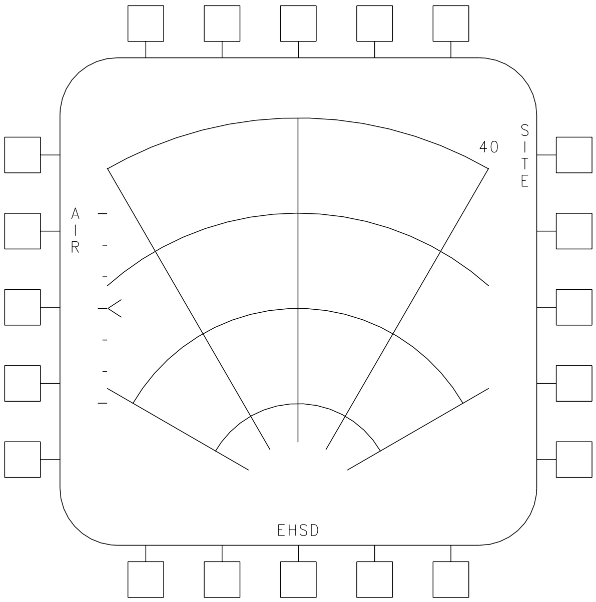
2 second target aging

SITE option

AIR option (selects fixed surface radar display)

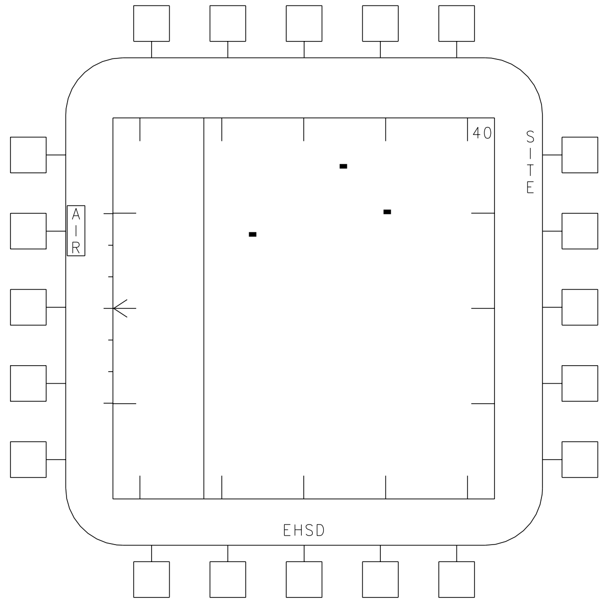
AIR-TO-SURFACE RADAR

BACKUP RADAR DISPLAY



AIR-TO-AIR RADAR

BACKUP RADAR DISPLAY AIR OPTION SELECTED

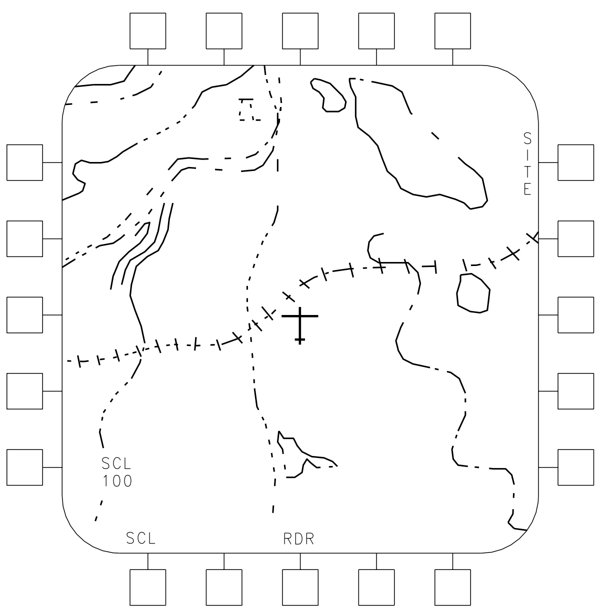


- THE AIR-TO-SURFACE RADAR PROGRAM WILL BE LIMITED TO RBGM WITH A FIXED 40 NM RANGE SCALE, 120 DEGREE SCAN, AND AUTO BEAM.
- THE "AIR" OPTION SELECTS THE BACKUP AIR-TO-AIR RADAR DISPLAY.
- THE "SITE" OPTION ENABLES THE UPFRONT CONTROL TO ALLOW FOR SITE ADJUSTMENTS AND SELECTION.
- THE "EHSD" OPTION SELECTS THE BACKUP COLOR MAP DISPLAY.

- THE AIR-TO-AIR RADAR PROGRAM WILL BE LIMITED TO RWS WITH FIXED 40NM RANGE SCALE, INTL PRF, 2 BAR/140 DEGREE SCAN, AND 2 SECOND TARGET AGING.
- DESELECTION OF THE "AIR" OPTION SELECTS THE BACKUP AIR-TO-SURFACE RADAR DISPLAY.

EHSD

BACKUP DISPLAY



- THE "RDR" OPTION SELECTS THE PREVIOUSLY SELECTED BACKUP RADAR DISPLAY.

AV8BB-TAC-00-(597-1)11-CATI

Figure 1-83. Backup Radar Display

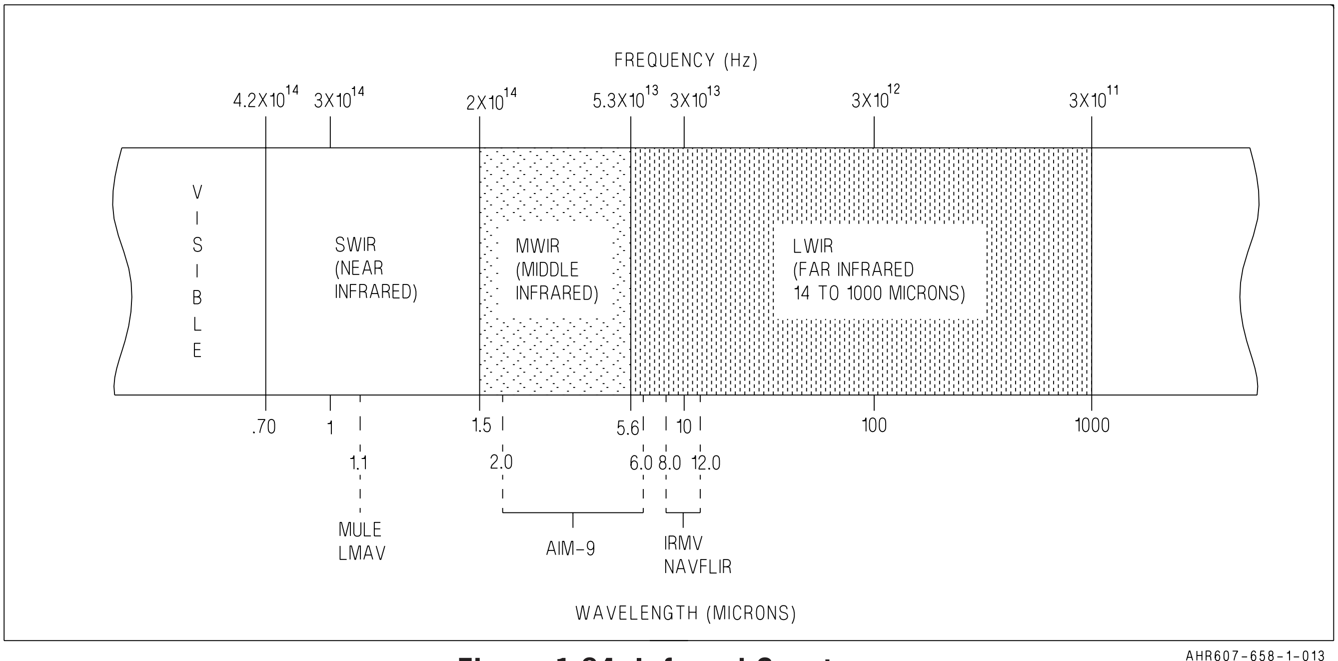


Figure 1-84. Infrared Spectrum

1.7 PRINCIPLES OF INFRARED

1.7.1 Introduction. This section discusses basic IR principles and their applications to AV-8B weapons and sensors. The number of weapons and sensors that use IR energy for guidance continues to grow. Establishing a firm basic knowledge of the fundamentals of IR energy ensures an understanding of the factors which effect IR signatures, target acquisition, and cockpit displays.

1.7.2 Infrared Spectrum. IR radiation is a form of electromagnetic energy. All objects above absolute zero (0 °K = −460 °F or −273 °C) emit some amount of IR radiation. This radiation is emitted over a wide range of wavelengths, but each object's radiation peaks at one particular wavelength, a fact which can be used in military applications. The amount of energy radiated by an object depends on how much solar energy has been absorbed and how much self-generated energy is present from engines, transmissions, exhaust, etc. Detection of an IR target depends on the contrast between the IR energy from the target and the IR energy emitted by the background. A cold object with a warm background may be as good a target as a warm object with a cold background.

The interval between visible light and microwave on the electromagnetic spectrum is known as the IR region. The IR portion of the spectrum starts at the red end of the visible spectrum and extends to the millimeter wave portion of the radio segment. It is customary to refer to wavelength rather than frequency when describing the specification of these waves because the frequencies in the IR spectrum are in the millions of megahertz. The unit of wavelength most commonly used is the micron (μ), which is 10^{-4} cm or 10^{-6} meters in length. In microns, the IR spectrum extends from 0.70 micron to 1,000 microns.

Wavelengths below 1.5 microns are referred to as short wave infrared (SWIR), wavelengths in the range from 1.5 to 5.6 microns are defined as middle wave infrared (MWIR), and wavelengths between 5.6 and 1,000 microns are defined as long wave infrared (LWIR). Given atmospheric absorption effects, references to MWIR for earth applications are generally limited to wavelengths between 3 and 5.6 microns. Likewise, for earth applications LWIR is limited to wavelengths between 7.5 and 14 microns. Wavelengths between 14 and 1,000 microns are only useful for deep space applications, and are referred to as far infrared (FIR), a subset of LWIR.

SURFACE	EMISSIVITY	SURFACE	EMISSIVITY
Ideal blockbody	1.00	Leaves, Plants	0.97
Bare, moist ground	0.96	Water	0.94
Oil base paint (all colors)	0.94	Brick, concrete	0.92
Fresh fallen snow	0.91	Wood, trees, shrubs, grass and desert sand	0.90
Oxidized steel	0.79	Rusted sheet iron	0.69
Aluminum paint	0.49	Polished iron	0.21
Polished aluminum	0.08	Polished steel	0.07

Figure 1-85. Emissivity of Various Surfaces

Although not technically correct, wavelengths between 7.5 and 14 microns are often referred to as FIR for tactical applications. See Figure 1-84. Both the NAVFLIR and the IRMV operate in the 8 to 12 micron region of the LWIR portion of the EM spectrum, while the AIM-9 operates in the 2 to 6 micron MWIR region. The MULE laser designator and the Laser Maverick operate at approximately 1.1 microns.

1.7.3 IR Properties. IR energy is invisible to the human eye and travels in a straight line. It travels in water and air as well as other media. However, it is greatly attenuated by moisture. This energy can be gathered, focused, and changed into an electrical signal using properly designed mirrors, prisms, lenses, and detectors.

1.7.3.1 Absolute Temperature. The absolute temperature of an object is one of two variables which determine the level of energy radiated, the other being emissivity. An object's temperature increases with internal heating, such as a furnace in a building or an engine in a tank. Objects are also heated by direct exposure to the sun and by diffused sunlight on overcast days. Also, an object cooler than the surrounding ground or air is warmed by conduction. An object warmer than another identical object emits more IR energy and appears brighter in the IRMV or white-hot NAVFLIR display, darker on the NAVFLIR black-hot display.

1.7.3.2 Emissivity. The other phenomenon which determines the amount of IR energy an object radiates is emissivity. The emissivity of an object is expressed as the ratio of the IR energy emitted by an object to that emitted by a black body at the same temperature.

Figure 1-85 lists some common target area objects and their emissivities. Note that the emissivities of common backgrounds (i.e., plants, ground, and snow) are nearly the same as common targets (concrete and painted surfaces). Since the amount of IR energy emitted by an object varies as the fourth power of the absolute temperature and directly with emissivity, the temperature difference between an object and it's background has a much greater effect on the emitted IR energy than any differences in their individual emissivities.

For example, consider the case of a tank coated with an oil-based camouflage paint (0.94 emissivity) sitting stationary against a snow background (0.91 emissivity). If the tank engine is not running and the sky is overcast, or it is night, the tank is isothermal with the background. The tank has 3 percent greater emissivity (more IR energy radiated) than the snow background (0.94 − 0.91 = 0.03). Now let's assume the engine is running, and that the heat generated by the engine has increased the temperature of the tank 3 percent relative to the snow background (for a background temperature of 0 °C (273 °K), the tank's temperature is 8 °C (281 °K). The 3 percent difference in emissivity still drives a 3 percent increase in radiated IR energy, plus the 3 percent increase in temperature accounts for an additional 14 percent of radiated IR energy from the tank for a total difference of 18 percent. Because of the dominant effect of absolute temperature, IR seekers may be thought of as temperature difference detectors, but in fact they measure the total amount of IR energy emitted. This simplification is valid except in extreme cases of emissivity differences.

1.7.4 IR Sensor Fundamentals. The AV-8B is currently capable of employing two weapons and one sensor that operate in the IR spectrum; the AGM-65F IR Maverick (IRMV), the AIM-9 Sidewinder, and the Navigational Forward Looking Infrared (NAVFLIR) system. Both IRMV and NAVFLIR present the pilot with a display of the area of interest in the IR spectrum, but there are significant differences in the way these two systems are employed and interpreted. Throughout this TACMAN series the term ″IR sensor″ is used to refer to both IRMV and NAVFLIR as they are employed by the AV-8B.

The IRMV image is displayed to the pilot on the MPCD in either 3° field-of-view (FOV) (wide FOV, 8 × magnification) or 1 1/2° FOV (narrow FOV, 16 × magnification), depending on pilot selection. The thermal image displayed cannot be changed; objects emitting more IR energy (hotter, with higher emissivity) relative to surrounding objects/background are always lighter in color, and objects emitting less IR energy (cooler) are always darker in color. The pilot can select the IRMV to lock onto the relatively cooler or relatively hotter objects by selection of white or black polarity. If white polarity is selected (indicated by white or light green crosshairs on the IRMV display) the IRMV locks onto the hottest (lightest) object within the crosshairs. If black polarity is selected (indicated by black or dark green crosshairs on the IRMV display) the IRMV locks onto the coolest (darkest) object within the crosshairs. If an isothermal environment with no relative temperature difference lies within the crosshairs, the seeker ″superscans″, or searches, until a target with sufficient thermal definition relative to its background is located. Note that by selecting white or black polarity the pilot is selecting the relative temperature for the missile to lock onto, hot or cold, but cannot change the way the IRMV displays the thermal environment on the MPCD. Relatively hot objects always appear lighter and relatively cool objects always appear darker. Also note that the IRMV display of the thermal environment (and the ability of the seeker head to lock onto a target) depends upon the existence of a temperature differential (delta T) within the area of interest. Unless this delta T exists the seeker doesn't differentiate objects for display, and a lock is not possible.

The NAVFLIR display differs from the IRMV display in several important ways. The NAVFLIR display (HUD and/or MPCD) does not provide any magnification. The NAVFLIR display is fixed to HUD FOV, whereas the IRMV can be slewed or slaved to a target of interest. The NAVFLIR display of the thermal scene can be changed by the pilot to optimize the IR presentation for varying thermal environments; the IRMV display cannot. Knowledge, planning, and experience will allow the pilot to optimize each of these IR sensors to maximize their strengths, minimize their weaknesses, and enhance mission capability.

The NAVFLIR provides the ability to display the thermal environment in either ″white hot″ or ″black hot″. With white hot selected the relatively hotter objects in the display are lighter and the cooler objects are darker. White hot is similar to the IRMV display of the thermal scene, though without the magnification. With black hot selected the relatively hotter objects in the display are darker and the cooler objects are lighter. This is the reverse of the IRMVthermal image; a given target with hot delta T would be light colored (white) on the IRMV display and dark on the black hot NAVFLIR display.

Interpreting IR displays requires dedicated training. Proficiency in locating targets on either

SCATTERER	SIZE (MICRONS)	COMMENTS
Haze	0.05 to 0.5	Tiny Dust/Salt Particles
Smoke	0.2 to 2.0	
Fog/Clouds	0.5 to 80	Condensation formed from haze particles; limits visibility to <1 kilometer
Dust	1.0 to 10	
Fumes	Up to 100	
Mist	50 to 100	Visibility < kilometer
Drizzle	100 to 500	Droplet Radius
Rain	500 to 50000	

Figure 1-86. Size of Atmospheric Scatterers

display, IRMV or NAVFLIR, and in determining which targets have sufficient IR signature to make valid IRMV targets, can only come from time spent attacking multiple targets in varying thermal environments. Use the CATM-65F and its video recording system to develop and maintain this perishable skill. Additional information on IRMV and its employment is found in NWP 3-22.5-AV8B, Vol. II, Chapter 2 of this TACMAN series.

1.7.4.1 Atmospheric Effect. The atmosphere is one of the most important factors controlling the performance of IR sensors and weapons. The processes of refraction, scattering, and absorption, all work to attenuate, or weaken, IR energy as it travels from its source through the atmosphere to the IR sensor. The effect of refraction is almost negligible to tactical applications; it mainly applies to orbital applications where the entire depth of the earth's atmosphere must be dealt with.

1.7.4.1.1 Scattering. Scattering is generally less significant than absorption when considering IR sensor performance, but it is sometimes difficult to differentiate between the effects of aerosol scattering and absorption due to water vapor at wavelengths less than 5 microns.

a. Molecular Scattering. Molecular scattering is light scattered by particles which are much smaller than the wavelength of the incident radiation. The primary molecules in the air (nitrogen, oxygen, water vapor, and carbon dioxide) are all much smaller than the wavelengths encountered in tactical applications of IR energy, and thus account for the scattering of this energy. Molecular scattering is negligible when compared to aerosol scattering for wavelengths greater than 1 micron.

b. Aerosol Scattering. Aerosol scattering involves large particles such as dust or smog that scatter incident radiation by reflection. This process is called Mie scattering, and results when the wavelength of the light being scattered is less than or equal to the diameter of the particle. This causes attenuation of the radiation because its energy is redistributed in all directions and lost to the observer. It is the size of these atmospheric particles which determines their effect on IR sensors (see Figure 1-86). For example, fog droplets concentrate in the 5 to 15 micron region where they cause nearly 100 percent scattering of energy received by the NAVFLIR and IRMV, both of which operate in the 8 to 12 micron band. On the other hand, small particles of less than 0.5 microns such as smoke and haze do not affect the NAVFLIR or IRMV nearly as much as they affect light in the visible wavelength region. Thus, IR sensor visibility through artillery impact dust or falling precipitation is significantly reduced, and only the hotter objects may penetrate these obscurants. However, IR sensor visibility through fog, light rain, snow, and dust, while severely degraded, is usually superior to normal unaided

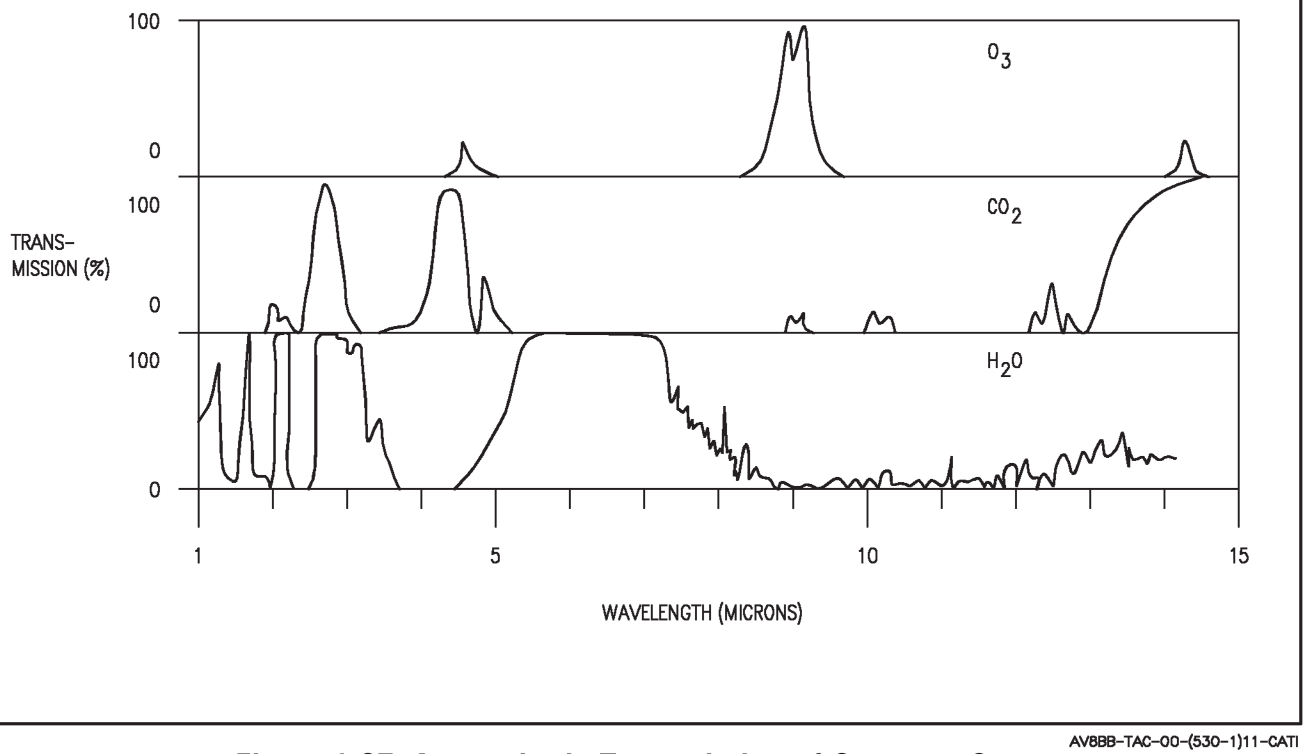


Figure 1-87. Atmospheric Transmission of Common Gases

eye visibility. The IR sensor can be used effectively to supplement and extend eye visibility in daytime fog and dust. IR sensor visibility through diesel fog and smoke is also good compared to the unaided eye. In general, LWIR gives three to five times the visibility through smoke and haze as compared to visible wavelengths (1 mile unaided visibility through smog equates to 3 to 5 mile visibility for NAVFLIR/IRMV in LWIR). MWIR (AIM-9) generally has two to three times the visibility of the unaided eye through smoke and haze.

1.7.4.1.2 Absorption. Absorption is the primary source of atmospheric attenuation, occurring at the molecular level in several narrow absorption bands. The absorption bands of molecules in the far IR region occur at specific wavelengths that correspond to the resonant frequency of each specific type of molecule. When the frequency of the IR energy being transmitted through the atmosphere ″matches″ the natural frequencies of vibration and rotation of the atmospheres molecular compounds, then resonance absorption occurs. These atmospheric molecules can absorb and store discrete amounts of energy by going into large amplitudes of vibration. Once the molecule becomes excited (absorbs energy), it will eventually return to its original state, radiating energy in an arbitrary direction. This radiation of energy in a new direction results in the attenuation of the IR beam as observed along the direction of initial travel.

The three atmospheric molecules that have the most adverse effect on IR sensor performance are water (H_2O), carbon dioxide (CO_2), and ozone (O_3), as shown in Figure 1-87. These molecules have the lowest transmission (most absorption) of energy in the 8 to 12 micron region, which is where both the NAVFLIR and IRMV operate. Other minor constituents which also contribute to atmospheric absorption include nitrous oxide (N_2O), carbon monoxide

TEMP		RELATIVE HUMIDITY									
		10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
°F	°C	ABSOLUTE HUMIDITY									
−13	−25	0.06	0.11	0.17	0.22	0.28	0.34	0.39	0.45	0.5	0.56
− 4	−20	0.09	0.18	0.27	0.36	0.45	0.53	0.62	0.71	0.8	0.89
+ 5	−15	0.14	0.28	0.42	0.56	0.7	0.84	0.98	1.1	1.3	1.5
+14	−10	0.22	0.43	0.65	0.86	1.1	1.3	1.5	1.7	1.9	2.1
+ 23	−5	0.32	0.65	0.97	1.3	1.6	1.9	2.3	2.6	2.9	3.2
+ 32	0	0.48	0.97	1.4	1.9	2.4	2.9	3.4	3.9	4.4	4.8
+ 41	+5	0.68	1.3	2.0	2.7	3.4	4.1	4.7	5.4	6.1	6.8
+ 50	+10	0.93	1.9	2.8	3.7	4.7	5.6	6.5	7.5	8.4	9.3
+ 59	+15	1.3	2.5	3.8	5.1	6.4	7.6	8.9	10	11	13
+ 68	+20	1.7	3.4	5.2	6.9	8.6	10	12	14	16	17
+ 77	+25	2.3	4.6	6.8	9.1	11	14	16	18	21	23
+ 86	+30	3.0	6.0	9.0	12	15	18	21	24	27	30
+ 95	+35	4.0	8.0	12	16	20	24	17	31	35	39
+ 104	+40	4.8	9.6	14	19	24	29	34	38	43	48

Figure 1-88. Absolute Humidity (Grams Per Cubic Meter of Air)

(CO), and methane (CH_4). Because of their relatively low density the concentration and variation of these molecules is considered a constant, and does not appreciably affect performance. Water vapor is the most absorptive of the atmospheric gases, and the most variable. Local humidity conditions can easily double the water vapor content in a matter of hours with a changing weather front. When considering IR sensor performance, absolute humidity is more relevant than relative humidity. Relative humidity expresses the amount of moisture in the air compared to the maximum amount which could be held at that temperature, while absolute humidity is a measure of the actual amount of water vapor in a given area. See paragraph 1.7.4.1.3 for additional information on the effects of humidity on IR sensor performance.

After water vapor, carbon dioxide has the most adverse impact on the transmission of IR energy through the atmosphere. In terms of volume, the vertical distribution of carbon dioxide in the atmosphere is essentially constant. Also, the variations in the amount of carbon dioxide at any altitude are extremely small with respect to time. Thus, a prediction of the amount of absorption due to carbon dioxide at any time is relatively constant (except in urban areas where the concentrations are normally higher and more variable).

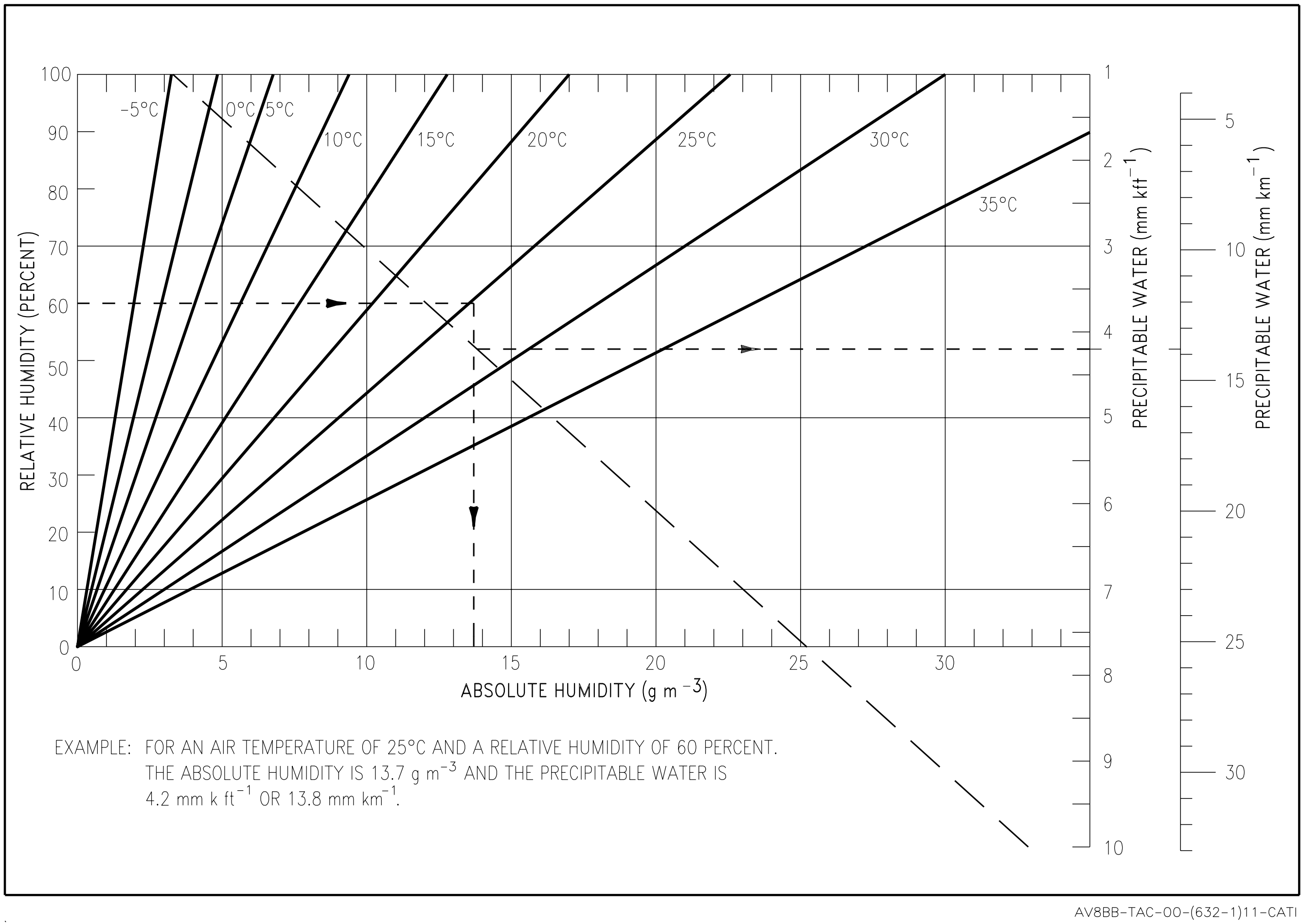


Figure 1-89. Nomograph Relating Absolute and Relative Humidity

Ozone is rarely encountered as it is mainly confined to a layer centered from 25 to 35 kilometers above the earth, though some of it is convected downward by atmospheric turbulence. The total content of natural ozone depends on latitude and season, with higher concentrations occurring at the more northern latitudes. Ozone levels typically peak in the spring and ebb in the summer/autumn time frame. Certain man-made environmental conditions can have an effect on IR sensor performance at tactical altitudes. Significant concentrations of reactive ozone are created in car engines and as a by-product of industry. Large releases of fluorocarbons, industrial pollution, and heavy concentrations of vehicle exhaust can create concentrations of ozone near the ground, which can attenuate the IR signal and thus limit an IR sensors performance.

1.7.4.1.3 Humidity. Humidity warrants a separate discussion because it is a prime cause of both scattering and absorption. Absolute humidity, also known as vapor concentration or vapor density, is the ratio of the mass of water present to the volume occupied by the water, or the density of the water vapor component (see Figure 1-88). Absolute humidity is usually expressed in grams of water vapor per cubic meter (g/m3). Absolute humidity is not commonly used by meteorologists because its measure of atmospheric humidity is not constant with respect to adiabatic expansion or compression. It can be seen from Figure 1-89 that if the temperature remains relatively constant, absolute humidity is directly proportional to relative humidity. Absolute humidity is used in conjunction with relative humidity, temperature, type of terrain, target, historical weather, and various other factors to develop IR sensor performance prediction models, such as the Electro-Optical

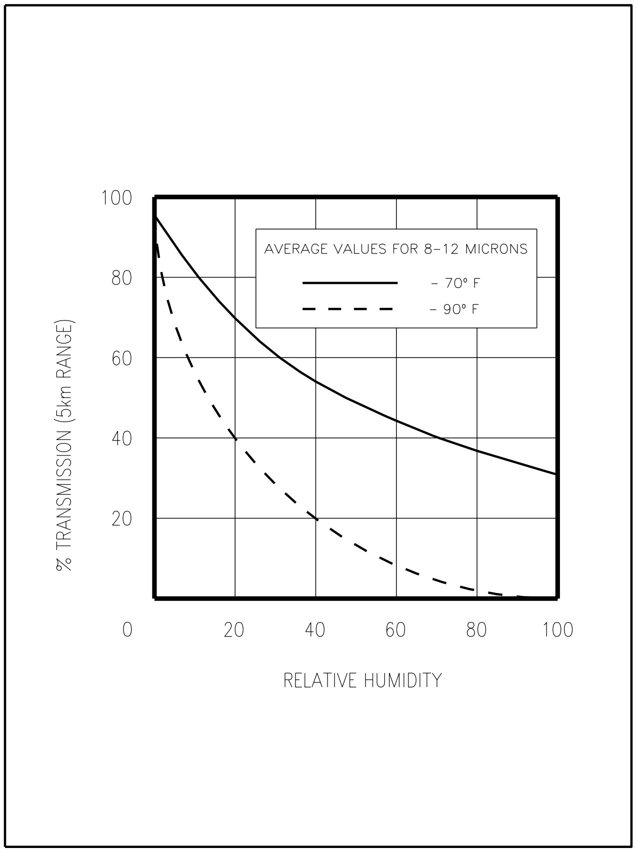


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Figure 1-90. Affect of Water Vapor on Transmission

Tactical Decision Aid (EOTDA) program. These models can be used to develop Predicted Acquisition Ranges (PAR). Note that scattering and absorption do not need to be considered separately, especially when dealing with water vapor in the atmosphere. Large fog particles attenuate the signal mainly by scattering, while particles that are large in comparison to wavelength (raindrops, snow, etc.) absorb as well as scatter radiation.

Absolute humidity is the key factor in determining local atmospheric transmission conditions. A dry mid-latitude winter day, with an absolute humidity of 3.5 g/m3, is almost completely transmissive; a wet tropical atmosphere of 20 g/m3 becomes an effective wall that severely hinders the operational capability of the NAVFLIR and IRMV. Figure 1-90 shows the relative effect of temperature vs. humidity on the transmission of energy. The pilot must realize and plan for the effects of water vapor on IR sensor performance and expect degradation as absolute humidity rises. IR sensor prediction models should be used prior to each mission to help develop proficiency and experience in predicting mission navigation and target acquisition capability.

1.7.4.1.4 Summary of Atmospheric Effects. The ability of an IR sensor to detect IR energy is a function of both atmospheric absorption and atmospheric scattering. The amount of absorption and scattering is a function of the size and concentration of the particles and molecules present. For scattering, as the particles get larger (for instance, from smoke to fog to rain) the less effective the IR sensor becomes. For absorption, higher concentrations of water vapor (absolute humidity) and carbon dioxide result in lower transmission of IR energy from their source (the target) to the IR sensor (NAVFLIR or IRMV). The greatest variant is absolute humidity, since the percentage of carbon dioxide is constant except in urban areas.

Altitude affects IR sensor performance also. Atmospheric pressure and density vary inversely with altitude, so the most significant effect of increasing altitude is to reduce the amount of absorptive atmosphere that the IR sensor must ″see″ through. In general, altitudes below 5,000 feet AGL, where atmospheric density is greatest, represent worst case absorptive effects for IR sensors. Above 5,000 feet AGL absolute humidity approaches zero except in visible moisture. For targets of interest to the IR sensor on the ground, observation grazing angle must be considered. Although in the example presented in Figure 1-91 the slant range to the target is identical in both cases, the percentage of the slant range distance that includes the highly absorptive environment below 5,000 feet AGL is higher in example A. Thus, we would expect the effects of absorption and scattering to have a much greater adverse impact on IR sensor performance in example A than in example B. Lower is not always better.

Example	Aircraft Altitude (AGL)	FPA/Sight Line Depression Angle (Degrees)	Slant Range/Over Ground Distance to Target	Percent Slant Range Below 5000 feet AGL
A	5,000 ft.	0(level)/13.5	21,213 ft/3.5 nm	100 %
B	15,000 ft.	45/45	21,213 ft./2.5 nm	33 %

Figure 1-91. Comparison of IR Sensor Atmospheric Effects at Constant Target Slant Range

1.7.4.2 IR Scene Interpretation. The thermal signature of a specific scene is the product of temperature differences, emissivity differences, and reflected radiation. Objects which have no internal heat supply, such as roads and bridges, are close to the ambient temperature of their surrounding environment. The IR signature of these objects differs from that of their background by virtue of thermal energy absorbed or released (emissivity). For example, since a small surface area per unit mass tends to reduce temperature fluctuation, concrete roads may be expected to be cooler by day and warmer by night than gravel or dust roads. Targets which have an internal heat supply do not necessarily follow this cyclic heating and cooling process; they represent a more consistent thermal scene.

The thermal signature of an object in relation to its background is heavily influenced by cloud cover and the aspect angles between the sensor, the object (target), the sun, and the sky. The cooling rate of objects at night depends on their heat capacity, heat conductivity, thermal contact with the surrounding air, IR emissivity in the 8 to 12 micron band, and present and historical weather conditions. When humidity is high, the sky is cloudy, and the temperature remains constant, then the thermal scene does not vary much from day to night. However, in a dry and clear climate IR energy in the 8 to 12 micron band radiates into the atmosphere and objects cool down quickly after sunset. Vegetation, which is in close contact with the surrounding air, and water surfaces which have large heat capacities (lakes, rivers, and oceans), radiate a fairly consistent amount of IR energy throughout the night. IR contrast between objects on cloudy, rainy days is minimal.

Objects with low emissivity (i.e., polished steel, aluminum, or iron) tend to take on the air temperature with a lag determined by the thermal mass of the object itself. Objects with high emissivity (brick, concrete, or wood) are more likely to have their temperatures influenced by the physical characteristics of the IR background, and the radiation characteristics of the sky and atmosphere.

1.7.4.2.1 IR Signal Diurnal Cycle/Crossover Times. The thermodynamics of the battlefield background can be confusing and cause problems with target recognition. Many of the natural and man-made objects on a typical battlefield undergo continual thermal changes that follow important, predictable trends. For example, natural background objects such as trees, grass, rocks and earth, are heated passively through the absorption of solar energy. Even during overcast days, some solar radiation is absorbed. Daily solar heating begins at sunrise. After midday, the sun declines and the background objects begin to cool. After sunset, the objects cool down to approach the temperature of the surrounding air. This daily two part heating and cooling cycle is called the diurnal cycle. Thus, the IR background is thermally dynamic. During the diurnal cycle, individual background and target objects heat and cool at different rates. Large dense objects, such as medium sized rocks, tree timber, and non-operating armored targets, heat and cool slowly, while lightweight objects, such as grass, tree leaves, bushes and the surface layer of the ground heat and cool quickly. The heavy, dense objects are said to have high thermal mass, while the lightweight objects are said to have low thermal mass. See Figure 1-92.

The pilot should make a note of the fact that there are times during the day and night when

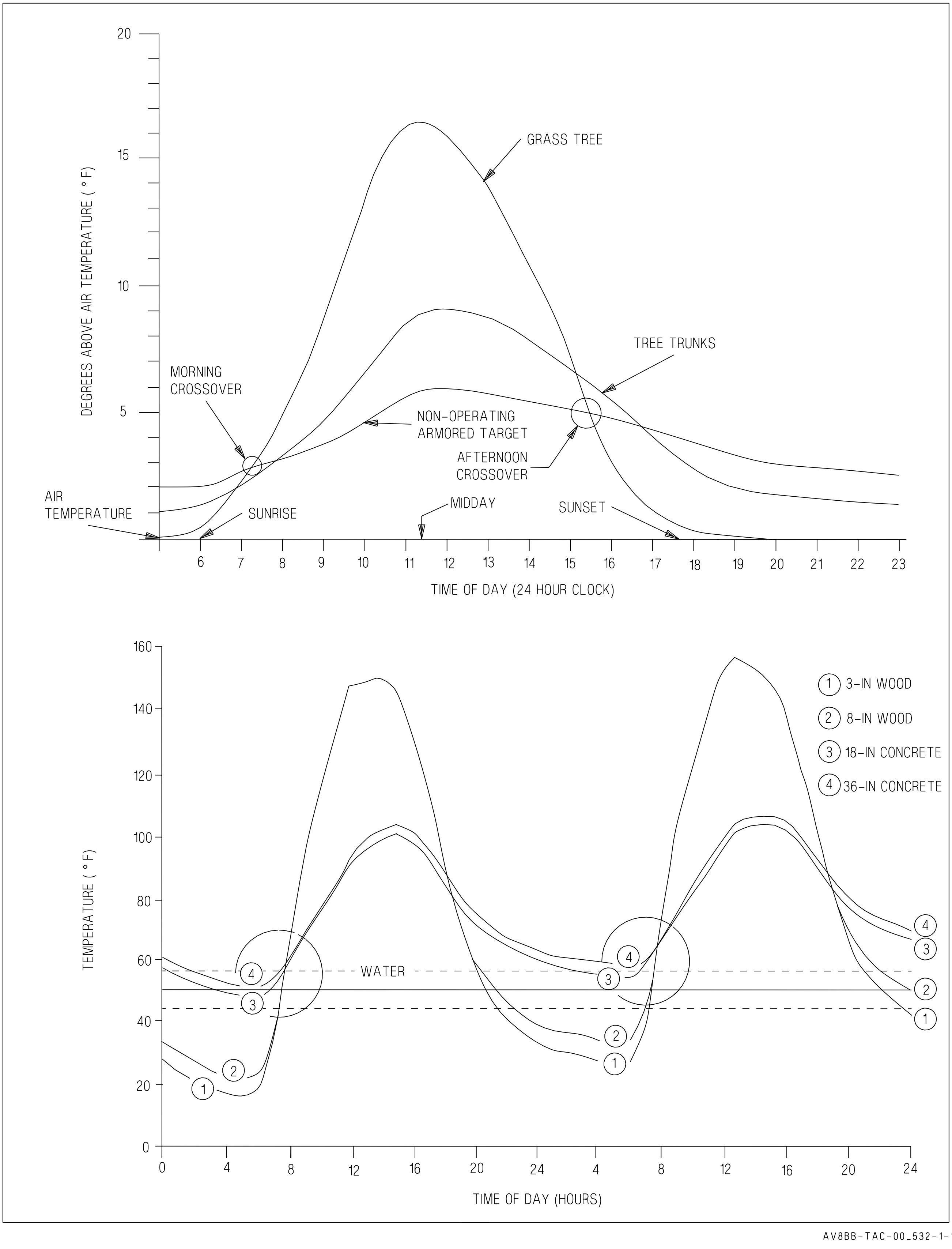

Figure 1-92. Diurnal Cycle/Crossover Times (Sheet 1 of 2)

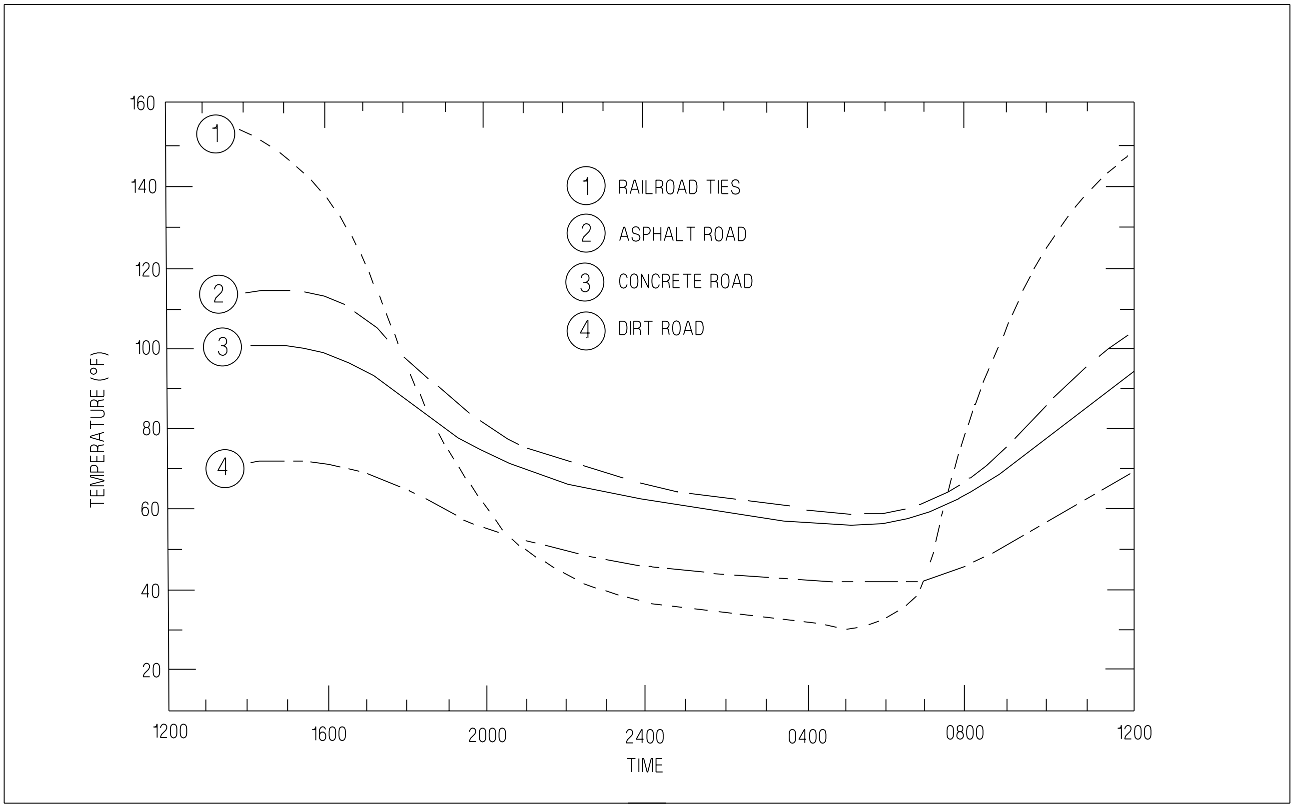

Figure 1-92. Diurnal Cycle/Crossover Times (Sheet 2 of 2)

the spectral radiances of different terrain features are identical so the contrast is minimal. During the night, targets usually do not reach nighttime background temperature before the sun rises once again to restore the heat cycle. After the sun rises the cool background warms up rapidly and at some point exceeds the target temperature. This point, where the background temperature equals the target temperature is called the diurnal crossover. Measurements of crossover times of many different terrain features, considered two by two, have been made and these times have been found to be greatly influenced by environmental factors, and vary widely depending on the objects observed.

1.7.4.2.2 Day Thermal Scene. Day thermal signatures can differ greatly from night signatures. This is especially true for a sunny day followed by a clear night, and less true for rainy, overcast days and nights. The source of the differences is primarily the solar heating effect. Solar heating generates target shape cues that persist into night operations, but make daytime target recognition difficult.

Targets such as tanks, APC's, and vehicles are heated by the sun on warm days to relatively high temperatures. However, the outer hull does not always heat evenly due to shadowing. IR reflections during the daytime can also cause spurious hot spots to appear on the vehicular targets. Daytime target recognition is also complicated by contrast reversal, where the relative temperature of background and other surrounding objects increases display clutter, and target signatures can vary tremendously. This effect causes the most problems from mid-morning through mid-afternoon, where the combination of shadows, reflections, and uneven heating can make daytime target acquisition via IR sensors difficult and confusing. Experiences during IRMV operational tests have shown that in certain daytime desert thermal conditions, even a target with a strong internal heat source (an artificially heated tank) can be difficult or

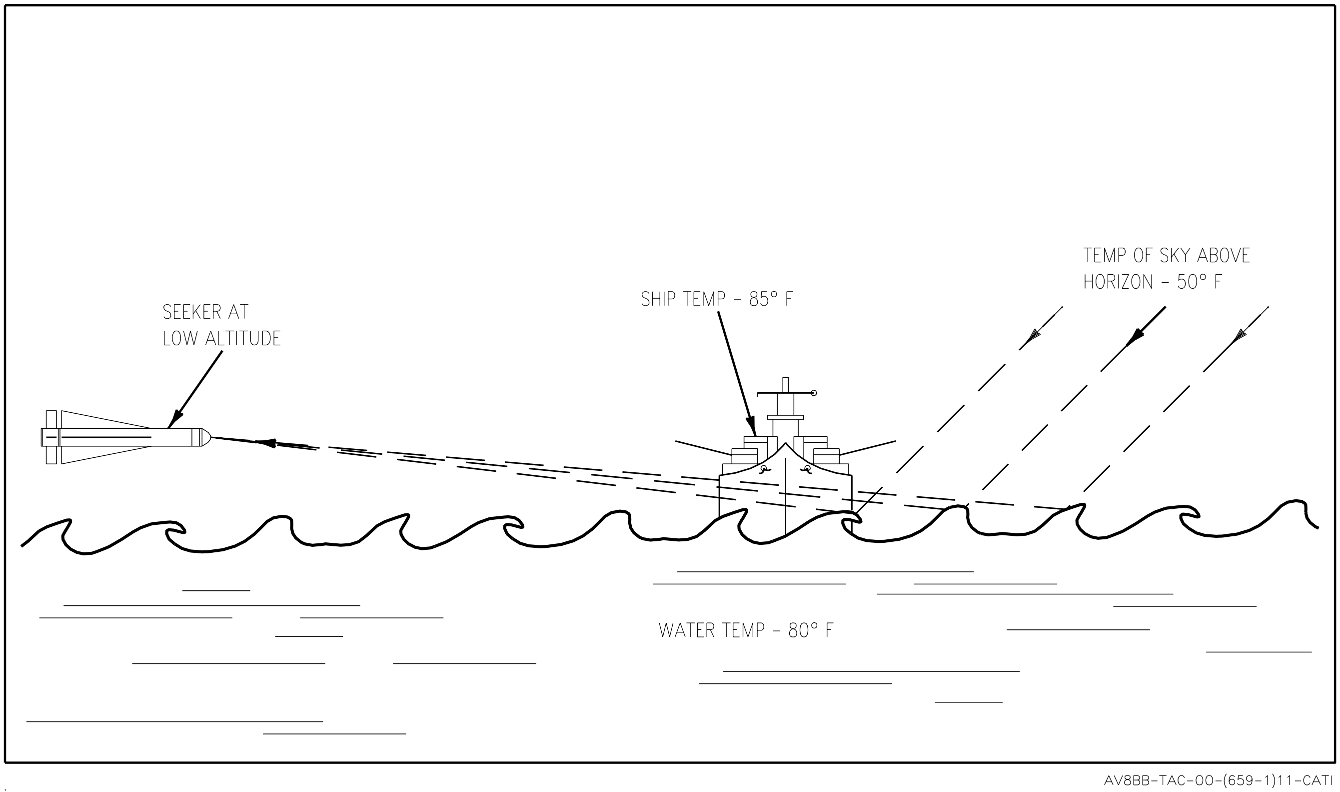

Figure 1-93. Ship Targets

impossible to resolve down to minimum ranges (less than 2 nm) on the IRMV display. The same target later in the day, near or after sunset, becomes easily acquired outside of 8 nm.

The many hot background objects present during these daytime conditions also create problems for the NAVFLIRs thermal cuers, creating a large number of nuisance cues. Thermal cuers that appear on non-tactically significant hot spots are properly referred to as nuisance cues, not false alarms, because these hot spots meet the system requirement for display. A ″false alarm″ is defined as a cuer on the display that was caused by internal system noise.

Rainy day IR signatures are more consistent with expected target acquisition. As the rain cools the background environment, internally heated targets and targets with high thermal mass tend to stand out conspicuously because of their higher thermal contrast in those conditions.

1.7.4.3 Ship Targets. Most IR scenes are created by IR energy emitted directly from an object to the receiving sensor, with IR reflections playing a minor role. A ship at sea represents an exception to this generality. In this case, the thermal energy from the water surrounding the ship does not always come from the water itself, but may be coming from the sky being reflected off the water. This effect is shown in Figure 1-93 for a low altitude attack in a calm warm water, cool air environment. For this example, the ship is only 5 °F hotter than the surrounding ocean. The relatively calm water is a good reflector/poor emitter at low grazing angles. Wave action caused by the ships motion through the water is visible to the IRMV as it comes in at a low grazing angle. This ship-induced wave action reflects the cooler temperatures of the surrounding air, providing a very good delta T between the 85 °F ship and the apparent 50 °F background. This improved delta T results in greater acquisition ranges than would be expected from the 80 °F water. Cloud cover can change this as the reflected temperature would be that of the clouds. Although reflection is generally not an important phenomenon, certain man-made objects (i.e., metal roofs) can reflect enough cold sky at low grazing angles to cause a change of thermal contrast as the IRMV approaches the target and the look angle between the IRMV seeker and the target changes.

1.7.4.4 IR Sensor Predictions. IR predictions are essential tools for missions involving NAV FLIR or IRMV. An accurate IR prediction provides the information necessary to determine if the target can be acquired by the IR sensor at the ranges required, given the forecast thermal environment. The result of the IR prediction may be that a different weapon is selected for the target attack. Much of the target acquisition frustration that is encountered when dealing with IR sensors occurs because the pilot is attempting to do something that is not physically possible; find an object on the MPCD when sufficient delta T does not exist for the IR sensor to display that object. An overview of the requirements for a good IR prediction are provided here, but refer to the current EOTDA program being used by the squadron or MAG for specific details.

The three most important factors to consider in an IR prediction are weather, target, and background. When considering weather, the past is as important as the present (and future). Two hours after sunset following a day of direct sunlight, dark colored metal objects will be warmer than the surrounding environment. Following a cold, cloudy day, the same objects will be cooler than the surrounding environment 2 hours after sunset. Although metal objects may be warmer than foliage or other background material after a day of solar heating, they also radiate energy at night faster than the background. At some point during the night the objects may even become cooler than their background, unless they are internally heated. Surface winds and rain accelerate this cooling process, while cloudy skies at night decrease the rate at which all objects lose IR energy.

The type of target and its composition is another major factor used in an IR prediction. If it is internally heated it has a characteristic IR signal which changes with viewing angle. A target such as a ship or vehicle viewed from the side looks different than one viewed from the rear or front. Warehouses appear different than buildings containing operating machinery. An object's thermal mass must also be considered. If a non-operating tank is left in the open overnight, by early morning it is cooler than its background and remains cooler for some time after starting the engine. Therefore, it is possible to fly up over a ridgeline just before sunrise and see dark objects (cool tanks) moving across a bright IR video display. IR prediction models take the various compositions and heating sources of typical targets into account.

The critical factor that ultimately determines the ranges a target can be acquired at, if at all, is the delta T between the target and its background. While IR predictions enhance the probability of target identification, it is up to the pilot to select the correct polarity for the target area environment. Interpretation of the thermal scene, much like radar display interpretation, requires training and practice. The accuracy of IR predictions is enhanced by experience with IR displays under different weather and atmospheric conditions against a wide variety of targets.

1.7.4.5 IR Sensor Image Considerations. Although the IR sensor image is basically "life-like" and allows the pilot to use normal cues such as size, shape, shadow, surroundings, and tone, for most objects there are special considerations. Thermal radiation can produce some unique signature effects.

1.7.4.5.1 Size and Shape. The true size of an object may not be portrayed on the IR sensor display because the hotter the object relative to its background, the greater the blooming effect. Shape may indicate the type of objects, but hot objects often do not appear in their true shape. Small fires, hot engines and exhaust parts, personnel, and small buildings may be detected as point sources, only if they are warmer or colder than the adjacent surroundings. Therefore, the size of the object is more related to total information than to its actual physical dimensions.

1.7.4.5.2 Shadow. A unique feature of IR sensor imagery is shadow information. Some thermal shadows include the same areas as visible shadow. They are caused by the ground surface temperature being lower in the area shaded from direct radiation, and from reduced amount of near IR radiation reflected from the shaded area. These thermal shadows usually dissipate shortly after the sun sets or when they are obscured by clouds. The rate of dissipation depends on the physical characteristics of the shaded area and upon prevailing meteorological conditions. Other shadows indicate activity, such as the thermal shadow from objects sheltering the background. Often these silhouettes can be detected hours after a vehicle or aircraft has moved. Wind shadows can sometimes be noted in the lee of objects projecting above the surface, and is similar to a thermal wake. Since the wind does not disturb the surface in the lee of objects, this area may be warmer or cooler than the surrounding area, depending upon whether the breeze is warming or cooling the surface over which it is blowing. This phenomenon has limited significance but does point out the protuberance of the object, which is some cases may aid in identification.

1.7.4.5.3 Metal Surfaces. Under normal conditions, horizontal surfaces of (unheated) bare metal appear cold on the IR sensor image, because metals have much lower emissivities than other substances so therefore emit less energy. Although such surfaces are good reflectors and will strongly reflect incident radiation, the intensity of natural radiation at night is quite low, particularly on clear nights, and the reflected component is generally weak. It is also possible, although rare, for metal to reflect the radiation from nearby warm object and thus appear to be warmer than it actually is.

1.7.4.5.4 Pavement. Pavement appears quite warm on the IR sensor image because it has good emissivity and is in good thermal contact with the earth, which acts as a constant heat source. The pavement retains more of the heat received from the sun during the day, because of its high thermal capacity. In late evening it can appear cooler due to a gradual loss of heat which exceeds that of the surrounding area. This is generally true for all types of pavement, including concrete, asphalt, and blacktop. Runways are a very good example of pavement and can normally be seen on the IR sensor display at a much greater range than is possible with the NVG's.

1.7.4.5.5 Soil. Under normal conditions, soil appears quite warm on the IR sensor display. This results from high emissivity, sun heating during the day, and the high heat capacity of the earth.

1.7.4.5.6 Grass. Grass appears very cold on the IR sensor display. Grass is unable to draw heat from the earth because of its poor thermal contact with the ground, and rapidly becomes cold by radiation. For this reason, air temperature at ground level is usually lower at night than that a few feet above ground, a phenomenon known as night inversion of air temperature gradients.

1.7.4.5.7 Trees. Trees appear either cool or warm on the IR sensor display. This is because of the convective warming of the trees by the air, in conjunction with the night inversion of air temperature, although some heating from the life processes in the tree play a role. Indeed, vegetation (leafy trees) is a strong reflector of IR from the so-called chlorophyll effect. Although the process is not fully understood, trees that appear dark (cool) in the visible spectrum, appear light (warm) on the IR sensor display. During daytime the same leaves appear colder than the ground, because the air temperature at tree top height is cooler than at ground level. Shadow areas in the foliage of trees are also cool relative to areas illuminated by the sun.

1.7.4.5.8 Water. The reflectivity and emissivity of a water surface varies greatly with changes in the radiation's angle of incidence on the surface. At shallow angles up to 5°, a calm water surface will reflect most radiation incident on it from the sky or it's surrounding objects. At steeper angles of 30° to 90°, the water's surface will be almost entirely emissive, radiating it's surface temperature. Due to it's limited FOV, an IR sensor display will normally view a water body's surface at very shallow angles (0° to 11° when in level flight), so a calm water body will usually reflect the temperature of the sky or surrounding objects. A large swell in the water surface may be visible because the variations in the incidents angle of the radiation on the surface will be seen as a change in the surface's reflective and emissive radiation. If the surface is not smooth, i.e., roughed up by the wind or an object, this will effectively decrease the proportion of the surface incident at shallower angles. This results in an effective increase in the surface emissivity so the surface appears closer to it's actual temperature. Depending on the temperature differential and wind conditions, a thermal inversion layer normally builds over the water as the evening temperature drops. This inversion layer has been shown to mask the presence of hot objects (boats) on the water, until thermal conditions stabilize. This thermal crossover also occurs over land. Exact timing depends on daytime heating, cloud cover and object characteristics, but in general terms there is a temporary thermal washout in early evening as the more reflective objects transfer from hot to cold.

1.7.4.5.9 Clouds. Clouds can affect the IR sensor image in two important ways: The radiance of clouds due to scattered or emitted radiation can be sufficient to attenuate the signal, and the physical presence of the clouds can mask the radiation from the objects which the system was designed to detect. Beyond four microns, cloud radiation is due to the thermal emission of the cloud itself and to reflected earth radiation. Even thin clouds can cause an appreciable radiation. Measurements made on clouds that were thin enough that they could not be seen visually, showed radiation in the 8 to 13.5 micron region. The IR sensor can detect low lying mist or fog that can not be seen with the NVG's.

1.7.4.5.10 Cloud Cover. Cloud cover reduces nighttime IR contrast between sun-heated surface objects. The cloud cover acts like a blanket over the earth and tends to equalize the temperature of objects on the ground. Total cloud cover lasting several days can degrade the IR sensor image, producing a washout effect. In some cases this washout condition has been found to enhance target acquisition since most natural terrain features blend into a uniform background. Non-natural objects, such as military targets, can stand out sharply against this uniform background if they are internally heated.

1.7.4.5.11 Winds. Winds have different effects on the thermal presentation of targets. The effect of a strong wind is to reduce temperature differential within the scene. In effect, the thermal signature is partially blown away. For example, thermal signatures on a snow covered surface may be erased by a one or two knot wind, while objects such as roads or man made objects may not be affected by winds as high as ten knots. This is because of the higher heat capacity and heat conductivity of those man made objects. The dust kicked up by high winds can block the IR signal and degrade the overall image, but dust kicked up by man made objects such as vehicles can highlight the target.

1.7.4.5.12 Internally Heated Sources. Most of the preceding generalizations assume that targets are not artificially heated, and that all thermal energy involved is the result of solar heating. In the case of solar heating, the best IR sensor image is acquired under clear skies with no wind. Many ground targets, such as buildings, vehicles, and personnel, have an internal heat source so may be much warmer than their surroundings. Within the target itself, significant temperature changes occur. Targets such as tanks, trucks, and APCs have internal temperature variations which form visible patterns that are the fundamental elements of target signature cues. The hottest vehicle parts, such as the engine and exhaust, stand out as bright shapes on the IR sensor display. Medium temperature objects, such as warm tracks and other moving parts, appear medium bright, while the relatively cool hull appears dark. Also, parts of a truck or tank will remain hotter than its surroundings for several hours after use. A factory chimney stack or cooling tower may be a very strong IR source. In all cases however, the emissivity must be considered. Special low-emissivity paints can greatly reduce the radiation from a hot surface of a vehicle or building even though simultaneous camouflage against both visual and IR detection is extremely difficult. Targets with their own heat source, such as a battle tank, are relatively unaffected in tone by meteorological variables

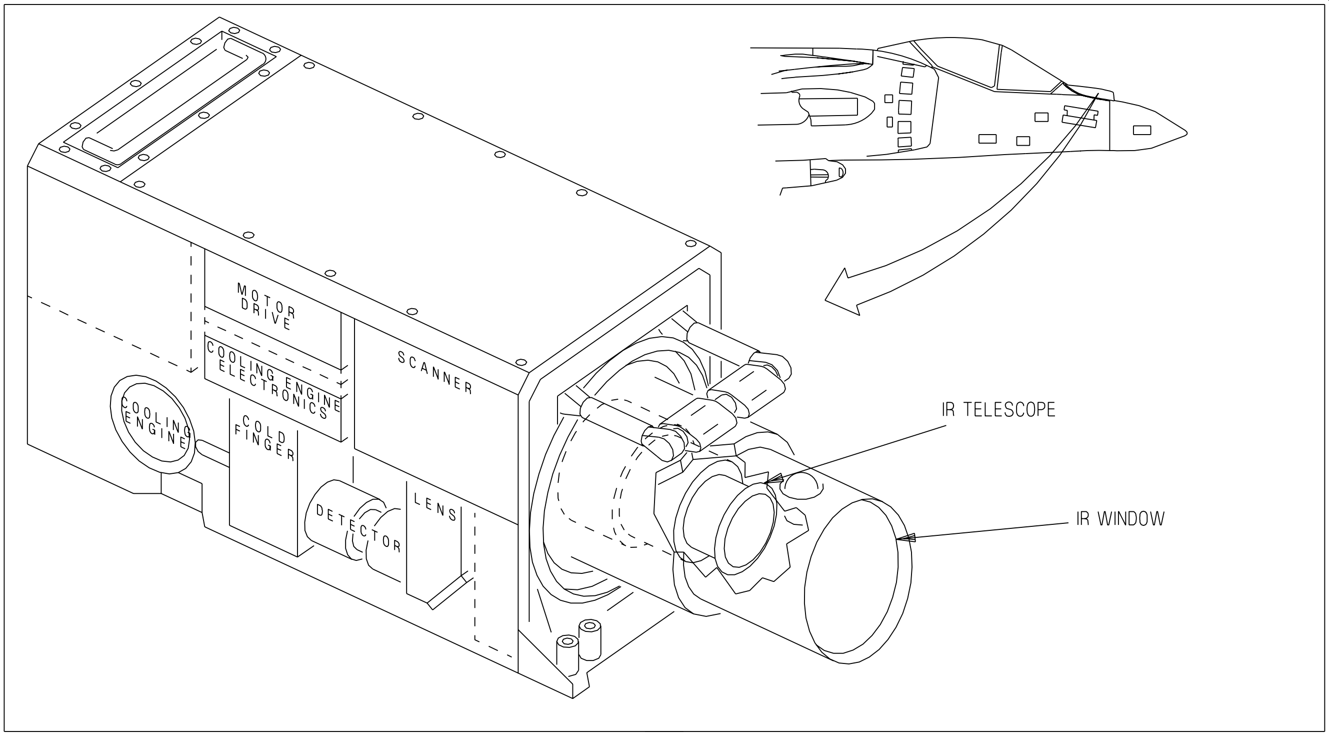

Figure 1-94. NAVFLIR Sensor

assuming a clear line-of-sight. For example, during and after a rainstorm the natural scene tends to become isothermal and exhibit a certain amount of thermal washout. Given this washed out natural scene, a thermally active target, such as a tank, can actually be detected at greater distances, because of its relative heat differential with the background.

1.7.4.5.13 Reflected IR. Certain smooth, glossy surfaces, such as vehicular windshields and glossy painted fenders, can reflect IR radiation which strikes their surfaces from other IR sources. Vehicle windshields often appear cool at night because they reflect the low radiant temperatures of the cool night sky. Similarly, the fenders of a tank appear very cool due to the thermal reflectance of the cool sky. An overcast sky can cause warmer thermal reflections. The thermal radiance from a fire located next to a glossy painted APC could be reflected off the vehicle's flat side surfaces. Only very smooth glossy surfaces are subject to strong reflections.

1.7.5 NAVFLIR

1.7.5.1 NAVFLIR Components. The NAVFLIR system is comprised of two main units (three on radar aircraft): The sensor head and the electronics unit (and the remote power supply on radar aircraft). The NAVFLIR sensor head is mounted directly to a boresight adaptor tray in the upper portion of the nose cone and accounts for the distinctive fairing on the aircraft's nose. The electronics unit is positioned directly beneath the sensor head in the Night Attack aircraft configuration. In conjunction with these two components, the angle rate bombing set (ARBS) receiver processor has been modified to include its own thermal control unit in order to free up additional space in the nose for the NAVFLIR installation. In the radar aircraft the electronics unit was relocated to the aft avionics bay to make room for the APG-65 radar. This required that a third WRA, the remote power supply unit, be added to maintain voltage balance between the electronics unit and the sensor head.

1.7.5.2 Sensor Head. The NAVFLIR sensor head is located in the upper portion of the nose cone in front of the windscreen. See Figure 1-94. The sensor is aircraft referenced but, must be electronically boresighted by the pilot. The top of the NAVFLIR field-of-view (FOV) is fixed at the aircraft waterline and is 2° above the horizon in level flight. NAVFLIR coverage extends 13.4° vertically and 20° in azimuth. The sensor gathers thermal radiation from the scene by scanning it onto a detector array which is cryogenically cooled. There, the IR signal is converted into an electrical signal which provides an analog representation of the IR scene. The signal is then amplified, conditioned and balanced prior to transmission to the NAVFLIR electronics unit.

The radiation first passes through an IR window which must be strong enough to withstand normal flight conditions, yet provide good transmission of IR energy. The IR window is composed of germanium with a high efficiency antireflection coating for durability. Directly behind this window, an IR telescope with a magnification selected to match the HUD FOV ensures a one-to-one registration on the HUD. The IR energy is then focused onto a motor driven scanner assembly which scans the thermal scene through a series of mirrors (optical train) and lenses onto a photoconductive detector array. The detector array is constructed in a vertical arrangement of eight separate elements composed of mercury-cadmium-telluride (HgCdTe). The band gap which causes the detector to be sensitive to energy in the far IR area of the electromagnetic spectrum is a function of the mercury-to-cadmium ratio.

The NAVFLIR image itself is built by controlling the position of the two mirrors in an optical train. This process opto-mechanically scans the detector array across the scene in a series of swathes with each successive swathe scanning the scene immediately below the previous swathe. A total scene area of 13.4° vertical by 20° horizontal is scanned. Because the detector array has eight elements positioned in a vertical line, each swathe scans eight lines of the raster image. This technique of scanning an array is referred to as serial-parallel processing. In serial-parallel processing, each detector element is used to scan a scene line-by-line and element-by-element, so each element constitutes one line of the raster image.

The function of the detector is to convert the IR radiation into a measurable electrical signal. Unlike thermal detectors such as the thermocouples used to measure engine exhaust gas temperatures, the NAVFLIR detector is a quantum detector. Thermal detectors measure a change in the temperature of the detector while a quantum detector measures small increments of radiant energy (photons). The NAVFLIR detector array responds to radiation wavelengths in the far IR area of the light spectrum. The detector material belongs to the semiconductor family. When the IR energy strikes the surface of the detector, IR photons are absorbed at the atomic level which changes charged particles in the detector from the bound state to the conducting state. These charges are carried across the surface of the detector and measured as voltages. The process is therefore an analog one in which the IR signal is represented by continuously variable voltages which form the NAVFLIR image.

In order to be able to detect the small increments of radiant energy absorbed by the detector, it is necessary to reduce the inherent thermal agitation of the detector by coding it so it does not mask the arrival of discrete IR photons. This is the same concept as reducing the temperature of a Sidewinder seeker head. The cooling for a Sidewinder comes from the release of high pressure nitrogen, which is stored in a refillable container. The detector cooling for the NAV FLIR is provided by a cryogenic pump in the form of a cooling engine and cold finger, which is an integral part of the NAVFLIR sensor head. The cooling engine is powered by the aircraft electrical system.

The cooling engine uses a Stirling split-cycle design which has a small piston to alternately compress and release pressure on a volume of air to achieve operational temperatures. An internally sealed cooling engine was selected to eliminate the logistic support and possible contamination associated with a mini-compressor or small air bottle system. As the detector cooling is

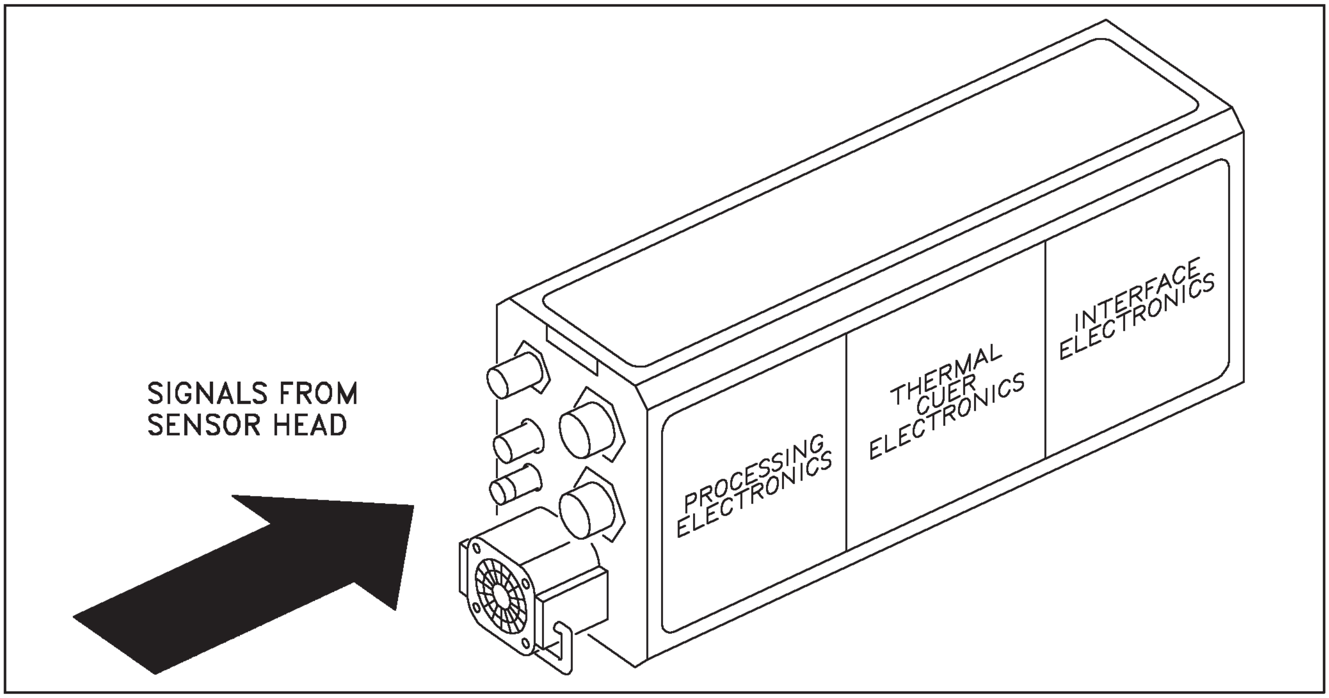

Figure 1-95. NAVFLIR Electronics Unit

provided by a cryogenic pump, cool down time (which normally runs between three and five minutes) is slower than in a Sidewinder missile. The detector array is maintained at a constant temperature of approximately 77 to 80 °K. The NAVFLIR image is available once the detector has reached approximately 100 °K and initialization checks are complete. The best image is available at the optimum operating temperature of 77 to 80 °K, which is obtained soon after the initialization checks are complete

To prevent internal contamination of the optics and scanner, and to cope with pressure changes, the air inside the sensor head is desiccated (dried) and the whole unit is sealed. A humidity indicator on the unit allows maintenance personnel to periodically check to see if the unit needs to be purged.

1.7.5.3 Electronics Unit. The NAVFLIR electronics unit (see Figure 1-95) provides the special signal functions required to stabilize and enhance the quality of the NAVFLIR imagery. An integral component of the electronics unit is the thermal cueing unit, which uses the NAVFLIR signal to detect potential targets and supply their coordinates for display to the pilot. The electronics unit receives the eight parallel IR inputs from the sensor head. It then controls the gain and matching of each channel and converts then into TV signals. An important aspect of the unit is to provide automatic control of gain and offset of the NAVFLIR image, which is important for providing the hands-off operation necessary for the night attack mission. The electronics unit also controls and monitors system operation and modes. The unit is composed of three basic subsystems: the interface electronics, the processing electronics, and the thermal cuer electronics.

a. Interface Electronics. The interface electronics provide the integration link with the night attack avionics system through dual redundant mux bus communications. It performs the functions necessary to operate the NAVFLIR, and has command and control of all NAVFLIR subsystems to include built-in test (BIT), data transfer and power up sequencing.

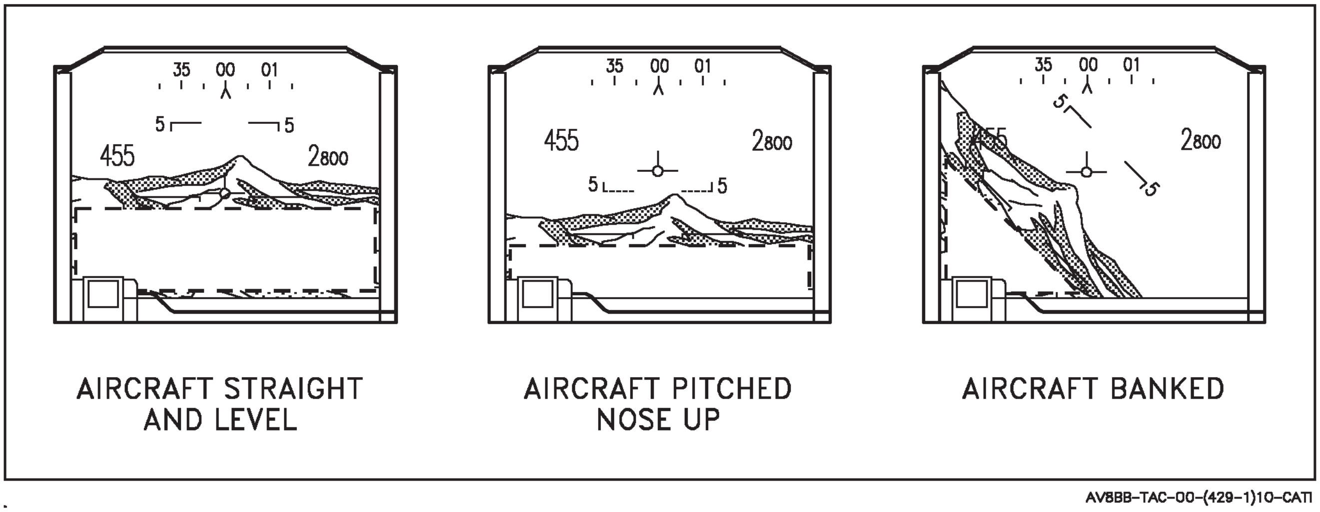

Figure 1-96. Auto Gate Operations

b. Auto Gate. An important feature of the interface electronics is the generation of a ground-stabilized area in the NAVFLIR image referred to as the auto gate. See Figure 1-96. Auto gate generation uses aircraft supplied roll, pitch and height data to determine the auto gate area. The auto gate is used by the automatic gain and offset control to optimize the NAVFLIR image over that area of the image which should be of most interest. The area covered is dynamically controlled, and depends on flight conditions. For example, during straight and level flight the auto gate extends from 0.5° above to 5.0° below the horizon. For nose-up attitudes, such as that required for ridgeline crossings, the top of the auto gate remains locked to 0.5° below the horizon until a preset nose-up attitude of 7.5° is reached. This is done to delay the intrusion of relatively cold sky temperatures into the auto gate area, which can wash out the display and degrade ridgeline contrast. Beyond this point, the auto gate is no longer ground stabilized and will remain fixed in pitch relative to the aircraft roll with the aircraft. With a total INS failure, the gain and offset are determined from a pentagonal-shaped, fixed area in the image FOV. The auto gate generator also generates the cuer capture gate discussed in paragraph 1.7.10.1.1, Target Cuer Operation and Controls.

c. Processing Electronics. The processing electronics controls the functions of the scanner assembly and processes the signal from the sensor head for eventual display to the pilot. It takes the eight parallel IR video inputs from the sensor head, sets the system responsitivity to match that of the sensor head and matches the gain and offset of each channel. Matching improves the image quality by removing the line structure variations between the eight IR video inputs. Poor channel matching is seen on the image as lines at 8-line intervals and is referred to as the "venetian blind" effect; however, software improvements have greatly reduced this effect.

After the signals are matched, they are referenced to an even thermal datum and that portion of the available dynamic range required for display is selected. The range of temperatures that could be viewed by the NAVFLIR can vary from Arctic conditions of –50 °C up to desert conditions of +50 °C. Add to this, man's additional inputs of heating and cooling objects, the range of temperatures viewed by the NAVFLIR can easily span 100 °C. A NAVFLIR must be capable of presenting for display any of these temperatures at some time in it's operation. Conversely, most of the finer details of interest to the pilot for navigation, terrain perception and object recognition needs to be resolved down to temperature differences as low as 0.01 °C. To display all of this information would require a display and human eye with a dynamic range on the order of 10,000:1. In practice, 100:1 is a more

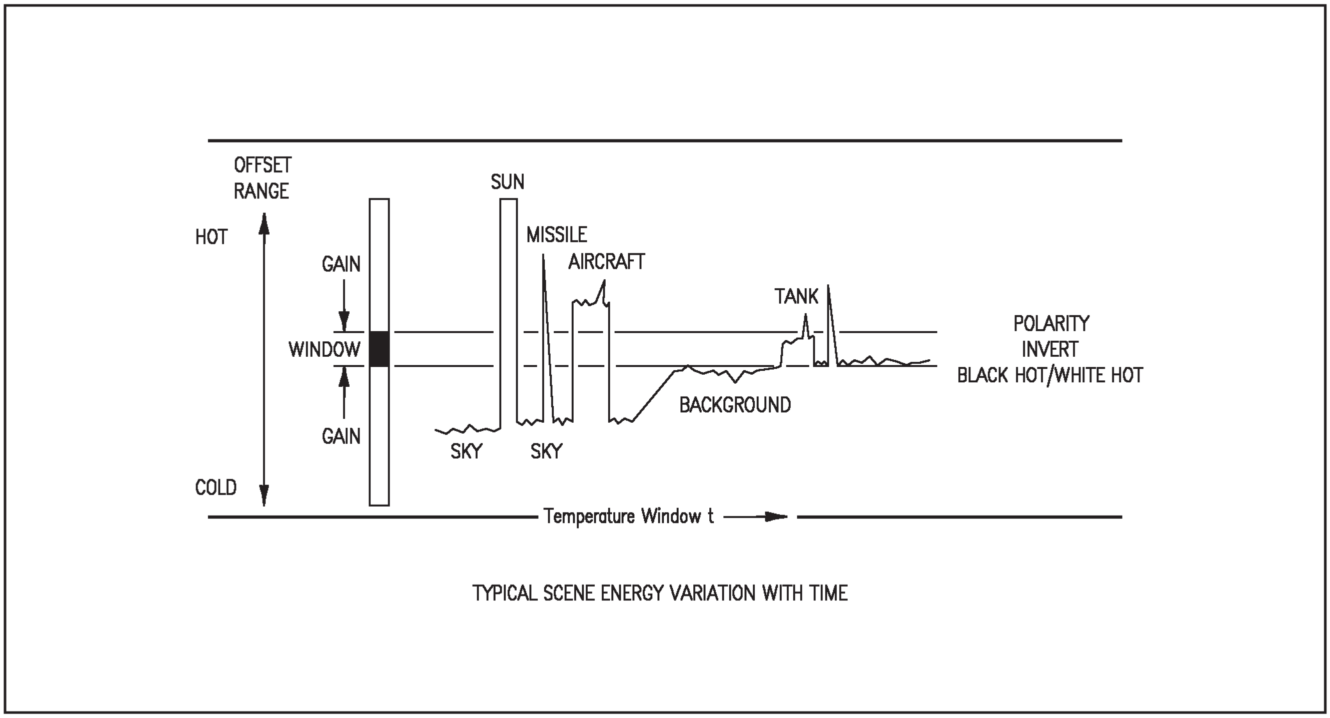

Figure 1-97. NAVFLIR Temperature Window

realistic value for good display and slightly better for the human eye in the right conditions. Fortunately, the real world rarely presents us with single scenes of interest with a total instantaneous temperature range of 100 °C; rather, ranges up to 10 °C or less are more typical.

A temperature window has been incorporated into the NAVFLIR to cover this wide range of temperatures requiring display at various times. See Figure 1-97. Both the position (offset) of the window within the total temperature range, and the temperature window's size (inverse of gain) can be adjusted to select the optimum compromise of resolution of finer details verses the presentation of large features with larger temperature differences. The temperature window can be controlled either manually by the pilot or automatically by the NAVFLIR.

In simple terms, offset determines the temperature that corresponds to black on the display, and gain is the temperature range that corresponds to the displayed dynamic range. Gain and offset are very important to the pilot in terms of NAVFLIR image contrast and detail recognition. The gain (displayed temperature window) can expand or contract depending on the maximum and minimum signal variation in the thermal scene (auto gate). This "stretching" and "crunching" of the gain directly effects image contrast. Every element in the NAVFLIR image is assigned an image intensity (voltage) based on its relative signal strength and the selected gain. Gain and offset are normally automatically controlled by the processing electronics, but a pilot selectable gain bias referred to as *nudge*, as well as full manual control, is available. The nudge (NDG) option on the MPCD (see Figure 1-98) gives the pilot the ability to adjust the image by adding a bias to the auto gain feature, which changes the datum about which the auto gain operates. *Nudging* the NAVFLIR allows the pilot to change the thermal contrast of the image, and therefore, provide a slightly different visual interpretation of the display.

Ridgeline crossings can present a problem to the auto gain circuits. If relatively cold sky temperatures intrude into the auto gate area, the offset is shifted and the gain is "stretched", which can washout scene content. Different terrains can also present significantly different thermal scene content to the auto gain circuits. A

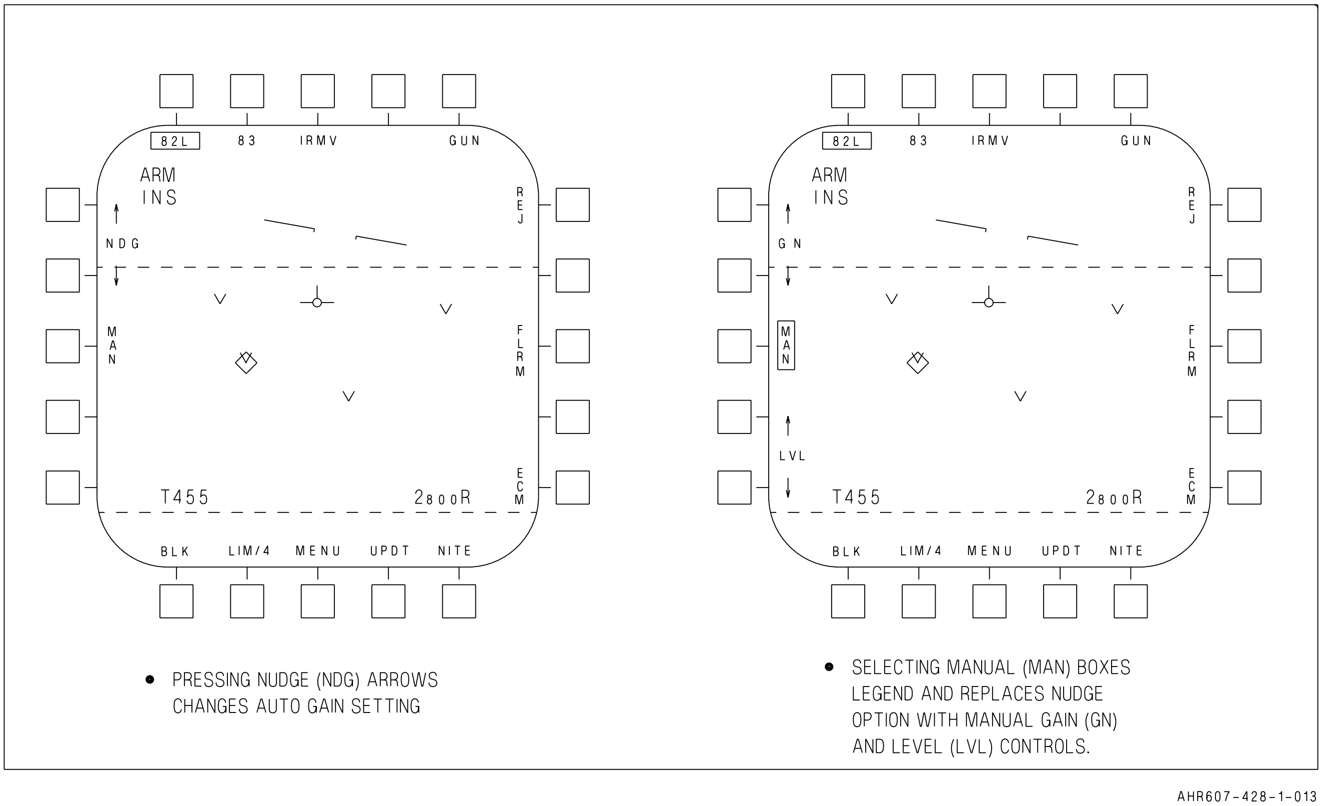

Figure 1-98. Thermal Gain and Offset

heavily vegetated area with gently rolling hills presents a fairly bland thermal scene when compared with an environment like the American high desert, which can present stark thermal contrasts. The gain response must react quickly enough to account for the changing thermal scene, but not so quickly that the image becomes disconcerting or flickers. The optimum auto gain response time was determined by flight test, and is a compromise of all terrain environments.

After selection of a thermal gain and offset, the signal is compressed into scan rates and sent through a TV signal processor which provides several functions. These include black hot/white hot selection, boresight reticle injection, grey scale generation and the detection circuitry used to control the automatic gain and offset of the signal. The processing electronics also contain a BIT module which monitors all pertinent NAVFLIR functions.

(1) Black Hot/White Hot. The black hot/white hot feature is simply an inversion of the gain polarity. See Figure 1-98. The manner in which the pilot uses this feature can enhance target detection and subsequent target recognition. White hot displays a thermal image of the scene in which hot objects are displayed with positive contrast, so appear bright. In white hot, targets such as tanks are given better and more apparent contrast than in black hot, because the bright end of the grey scale is usually more noticeable than the dark end. Since targets are typically warmer than their background, white hot produces bright targets which can generally be detected at greater range.

Target recognition requires more target detail than detection, so more discrimination between adjacent areas of the target is needed. White hot has typically shown less contrast discrimination than black hot. In addition, black hot presents a more natural looking image to the pilot, which enhances target recognition after initial detection. However, experience has shown that the pilot simply uses whichever mode gives the best display at that moment in the mission.

NAVFLIR grey levels are the voltages into which the NAVFLIR image is coded. Images produced by a NAVFLIR consists of between 100 and 200 grey levels. The number of “shades of grey” visible to the pilot is one measure of the capability of the HUD and the MPCD to display these levels. Shades of grey refers to the number of just distinguishable increments in luminance that can be detected on a display. In this context, it refers to all NAVFLIR shades (green) that can be produced on the HUD or MPCD. The available number of shades of grey depends on the contrast between the display image luminance and the background luminance and is a function of the highest total luminance of the display. Each next darker shade is determined by dividing the luminance by the square root of two until the background luminance becomes the limiting factor. According to most human factors references, five shades of grey are the minimum required for sensor imagery. In order to facilitate target recognition by a pilot, at least seven shades of grey are desired.

In order for the pilot to check and adjust the NAVFLIR image for optimum contrast and brilliance, an “eight shades of grey” scale can be selected by the pilot directly from the MPCD FLIR display, for setting up the HUD and MPCD. Although the eight shades of grey scale does not exactly represent the NAVFLIR’s imagery resolution, or match the display’s “shades of grey”, it does provide a standard by which the displays can be adjusted without relying exclusively on the outside scene. To ensure that the HUD and MPCD are set up so that the maximum dynamic range of the NAVFLIR is visible, the displays should be adjusted so that all seven visible steps of the NAVFLIR grey scale can be equally resolved, and the eighth black step is indeed black. Adjusting the intensities initially to the outside scene can result in degraded image contrast if different thermal conditions are encountered later in the flight.

Technically, because it is larger, the HUD should have better resolution capability than the MPCD; however, the intrusion of the outside world with its lights and ambient illumination can reduce the contrast of the HUD NAVFLIR display in comparison to the MPCD. When exposed to sunlight illuminance levels, the displays’ shades of grey capability, and therefore contrast discrimination, is seriously degraded. There are no displays at present which can achieve good contrast in direct sunlight. In fact, the HUD NAVFLIR video is not available using the HUD ″DAY″ setting; it is only available when the ″NIGHT″ setting is used.

d. Thermal Cueing Unit. The thermal cueing subsystem is a vital link in the tactical use of the NAVFLIR system. Its function is to detect and track thermal signals that represent potential targets. There may be many thermally significant objects in any given scene, so the thermal cuer is designed to help focus the pilot’s attention on those thermally significant spots which fit predefined target criteria. The thermal cuer works by analyzing the IR video after it has been matched in the processing electronics and identifying large delta T’s which merit pilot inspection. The cuer uses sophisticated thermal threshold algorithms. These algorithms use commanded target size and position discrimination circuits to cue any object having sufficient delta T within the cuer’s capture gate or area of regard. For example, targets at great range which subtend a very small area on the scene require a higher signal delta T than those near the maximum acceptable target angular coverage. The sensitivity and size of these gates can be preprogrammed by the pilot so that they are optimized for the desired target characteristics.

In addition to delta T, size, and position, the potential targets are time filtered to help reduce the number of spurious or random inputs (nuisance cues). Potential targets are also checked to determine if they remain inside a defined area of movement. The thermally significant spots are then prioritized, tracked, and marked on the HUD and MPCD for pilot inspection.

e. Remote Power Supply Unit. On Radar aircraft a remote power supply unit is installed in the nose landing gear wheelwell. The purpose of the power supply is to ensure adequate power to the FLIR sensor head. The electronics unit which normally supplies power to the sensor head on non-radar aircraft is unable to meet requirements on radar aircraft due to the distance between the two WRAs, approximately fifty feet. On Radar aircraft the electronics unit is located in the aft equipment bay.

1.7.6 NAVFLIR Controls and Indicators. Controls and indicators for the NAVFLIR system include the FLIR power switch, sensor select switch, target designator control (TDC), HUD control panel, and either MPCD. See Figure 1-99.

1.7.6.1 FLIR Power Switch. The FLIR power switch is a two position switch located on the NAVFLIR power panel on Night Attack aircraft or on the miscellaneous control panel on Radar Aircraft. See Figure 1-99. The up position (FLIR on Night Attack aircraft or LST/FLIR on Radar aircraft) applies power to the NAVFLIR sensor and electronics unit. The down (OFF) position removes power. NAVFLIR power is also controlled by these switches with ground power applied and the FWD EQP switch on Night Attack aircraft or the DSP/FLT switch on Radar aircraft in the ON position. When the NAVFLIR power switch is moved to FLIR or LST/FLIR, the NAVFLIR electronics are energized and cool down of the NAVFLIR optical receiver is initiated. The NAVFLIR is operational is less than 5 minutes (typically 3 minutes). Until then, with the FLIR display selected, a NOT RDY legend is displayed on the MPCD. No NAVFLIR control pushbuttons are displayed on the MPCD until mux bus communications to the NAVFLIR are established.

1.7.6.2 Sensor Select Switch. The sensor select switch is a six position (center off) switch. It utilizes five momentary positions, forward, aft, left, right, and down. The forward and aft selections are mutually exclusive but, do not affect selections made with left or right actuations of the switch. However, if a NAVFLIR display was selected on the right MPCD and NITE was not selected from the NAVFLIR EHSD or DMT display, a forward or aft actuation of the sensor select switch will replace the NAVFLIR display with a DMT display (Night Attack aircraft) or a radar display (Radar aircraft).

Sliding the sensor select switch right selects NAVFLIR raster video for display on the right MPCD with previously selected options enabled. Subsequent actuations alternate between white hot and black hot polarity. As previously mentioned, the INS, TV, LST (Night Attack aircraft), RDR (Radar aircraft) or MAP legends appear in the upper left corner of the NAVFLIR display on the MPCD to denote which sensor is assigned to the TDC.

Momentarily pressing the sensor select switch down (HUD scene reject) rejects the NAVFLIR scene on the HUD. Subsequent actuations alternate selection and rejection of video on the HUD.

1.7.7 Target Designator Control (TDC). The TDC is assigned to the NAVFLIR when the FLIR boresight (FBST) option is selected to slew the NAVFLIR scene video imagery or reticle until it matches the actual view seen through the HUD. Refer to the NAVFLIR boresight check, paragraph 1.7.11.5.

1.7.8 HUD Control Panel. NAVFLIR video selection for the HUD and video brightness and contrast control for the HUD are provided by controls and switches on the HUD control panel.

The brightness selector (DAY/NIGHT/AUTO) switch, located in the middle of the panel, must be moved to NIGHT to enable video to be displayed on the HUD.

The adjacent video brightness control (BRT) adjusts the brightness of the HUD raster video. It is also used to set the black reference level for NAVFLIR video. A clockwise rotation increases the brightness. The BRT control has a pushbutton feature which is used for the display alternate toggle (DAT) function. Pressing the BRT control swaps the displays on the two MPCDs.

The video contrast (CONT) control adjusts the contrast of the HUD raster video. A clockwise rotation increases the contrast.

1.7.9 Head-Up Display (HUD). NAVFLIR HUD video provides the pilot with a 1:1 video representation of what is in front of the aircraft within the NAVFLIR FOV. NAVFLIR video can

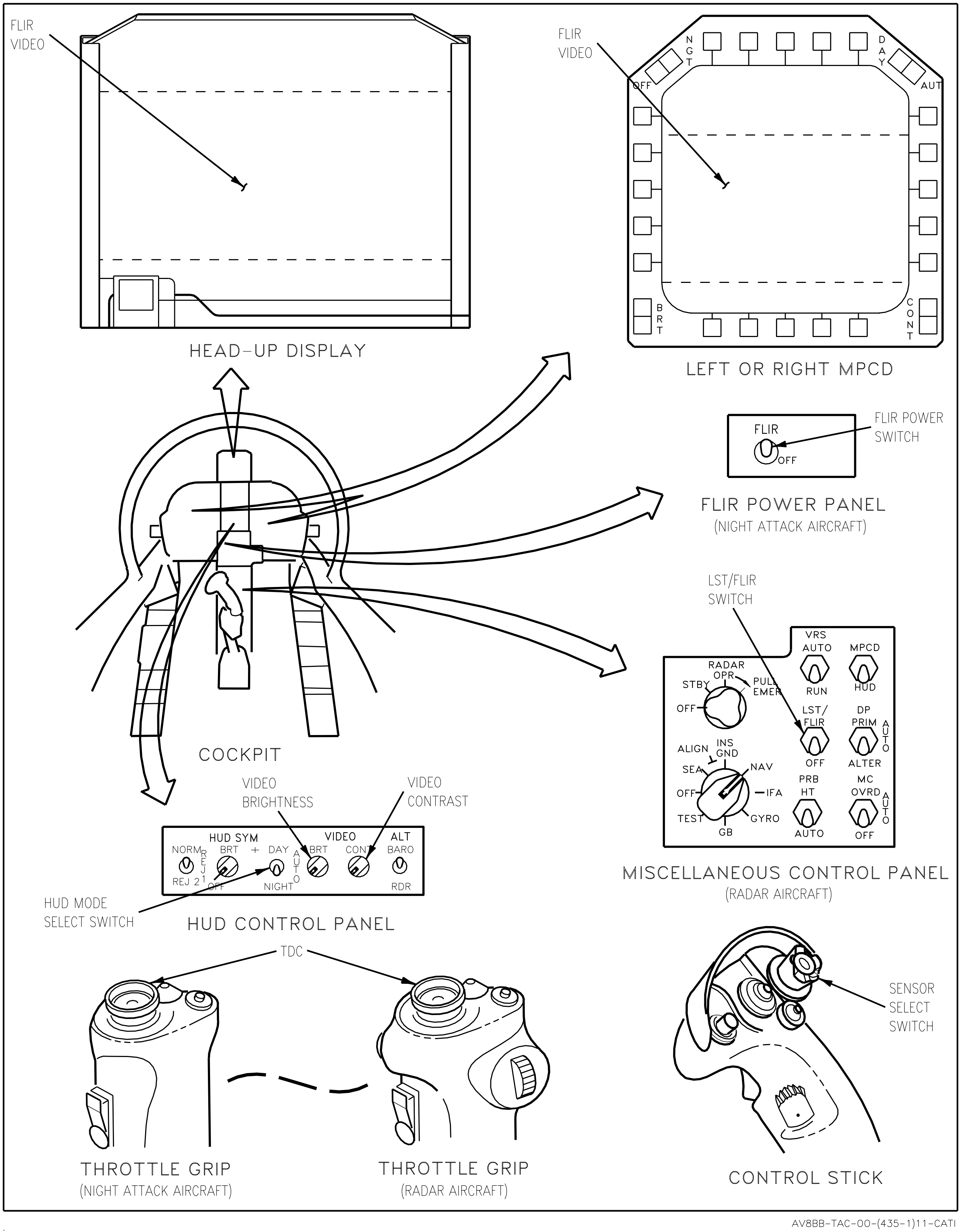

Figure 1-99. NAVFLIR Controls and Indicators

be provided on the HUD if the symbology brightness switch on the HUD control panel is in the NIGHT position. The pilot can toggle the NAVFLIR video on and off the HUD by alternate depressions of the sensor select switch.

NAVFLIR target cue azimuth and elevation values are determined by the NAVFLIR cuer and represent hot spots (V symbols) within the NAVFLIR FOV. If the number of cues requested by the pilot (LIM/0, LIM/4, or LIM/8), via the MPCD NAVFLIR display, exceeds the number of valid cues, the number of cues displayed is the number of valid cues. Otherwise the number of cues displayed is the pilot selected number.

Data on the display is standard HUD symbology, including airspeed, altitude, hot spot cues (V symbol), target designation symbol, velocity vector/attitude reference, horizon line, and break X.

1.7.10 MPCD. The NAVFLIR image can be selected for display on either MPCD directly from MENU by selecting the FLIR option (FLIR boxed). If the FLIR option is not displayed on either MPCD, the pilot can select the FLIR option on the right MPCD by sliding the sensor select switch on the control stick grip to the right.

The MPCD has two rocker switches which may be used to adjust the NAVFLIR scene video. The NAVFLIR display brightness and contrast may be manually adjusted with the BRT and CONT rocker switches.

Data on the display includes airspeed, altitude, hot spots cues (V symbol), target designation symbol, TDC assignment legend, ARM/SAFE legend, velocity vector/attitude reference, horizon line, and break X, when applicable.

Overheat (OVHT) appears in the lower center of the display to indicate that the NAVFLIR is in an overheat condition. This is a warning only and no NAVFLIR functionality is lost . However, there will probably be image degradation. If not required the NAVFLIR should be shut off if the OVHT legend appears.

The NOT RDY advisory appears while the cryogenic motor is cooling the NAVFLIR system. The NAVFLIR image will not be displayed until cool down is complete and the NOT RDY legend is removed. The cool down process is usually complete 3 to 5 minutes after power up.

The HUD NAVFLIR image may be displayed on the MPCD by selecting the HUD option on the MENU display. This display provides the same flight and steering references as on the HUD. If the FLIR display on the right MPCD is replaced by any other display, it can be recalled by pressing the sensor select switch to the right (except in A/A master mode on radar aircraft). The NAVFLIR display recalled is the last selected, either HUD or MPCD NAVFLIR display. If the HUD NAVFLIR scene is rejected, the MPCD NAVFLIR display is always selected for display.

1.7.10.1 MPCD Display Options. Display options for the NAVFLIR video are provided around the periphery of the MPCD and consist of the following; manual (MAN), level/gain control (LVL and GN, available with MAN boxed), nudge (NDG), weapon select options (pushbuttons 6 to 10, across the top), reject (REJ), FLIR menu (FLRM), gray scale (GRAY), ECM, NITE, UPDT, MENU, target cuer quantity (LIM/0/4/8), and black hot/white hot video polarity (BLK). See Figure 1-100.

(1) Manual Gain and Level Control. Pressing the MAN pushbutton (boxing it) selects manual control of the NAVFLIR image and enables the gain (GN) and the level (LVL) pushbuttons. Pressing the GN (up) pushbutton hardens the image contrast and possibly increases the white noise. Pressing the GN (down) pushbutton softens the image contrast. This can bring out details formally saturated into the peak blacks and whites.

With the MAN option selected, the NAVFLIR offset function moves the position of the temperature window over the total temperature range to view hotter and colder scenes. For white hot set up pressing the LVL (up) pushbutton moves the temperature window so to darken the

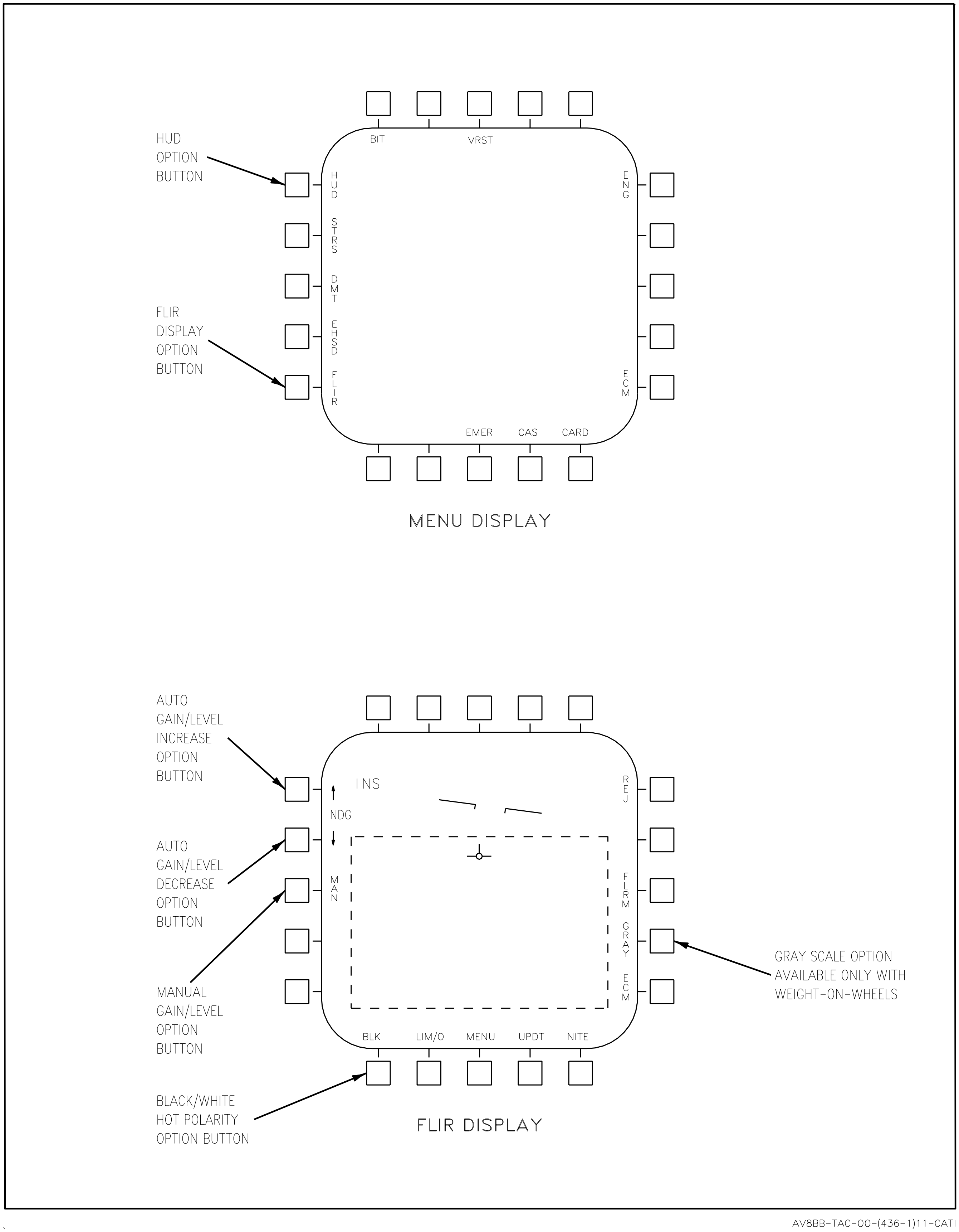

Figure 1-100. FLIR Display Options (Sheet 1 of 3)

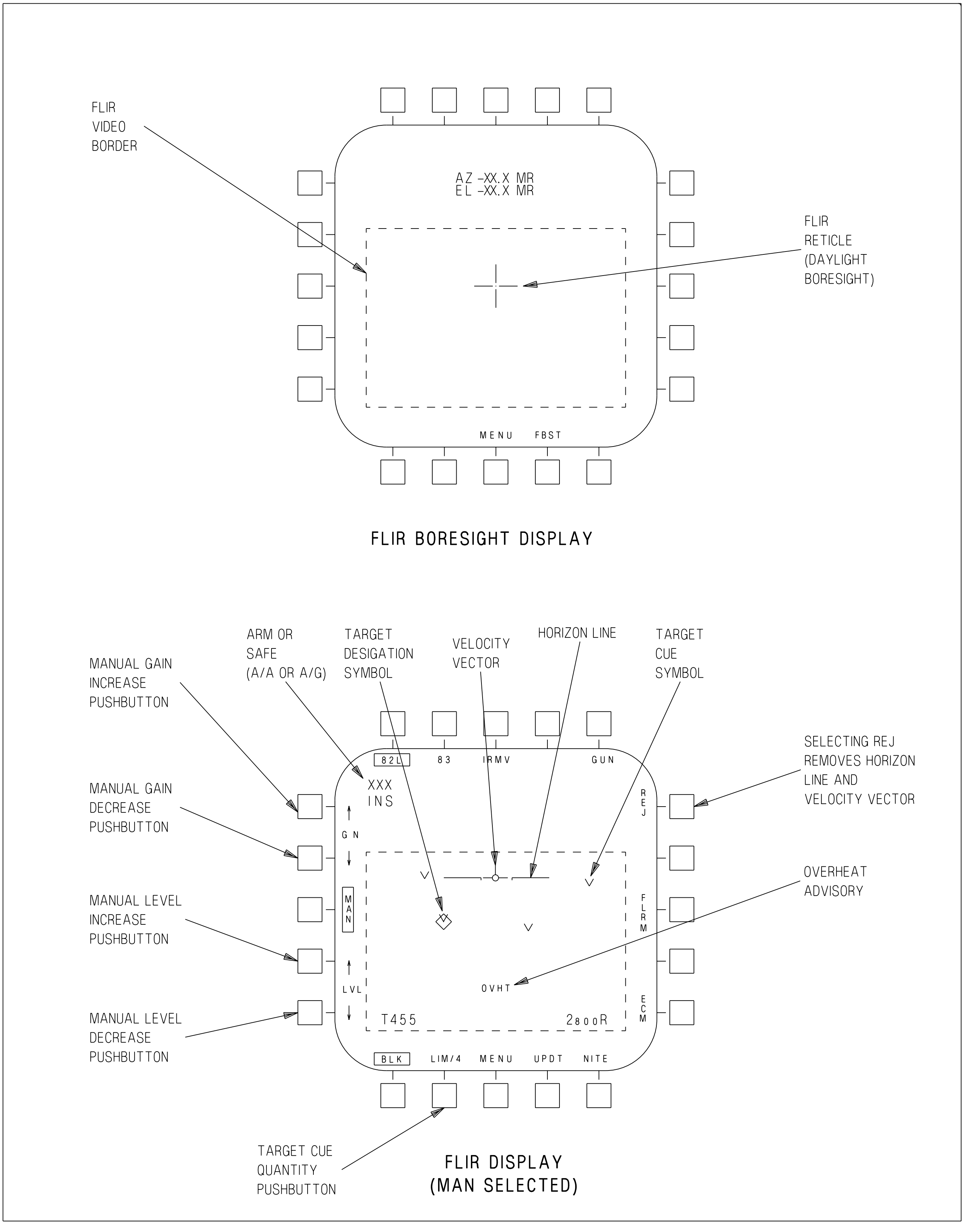

Figure 1-100. FLIR Display Options (Sheet 2 of 3)

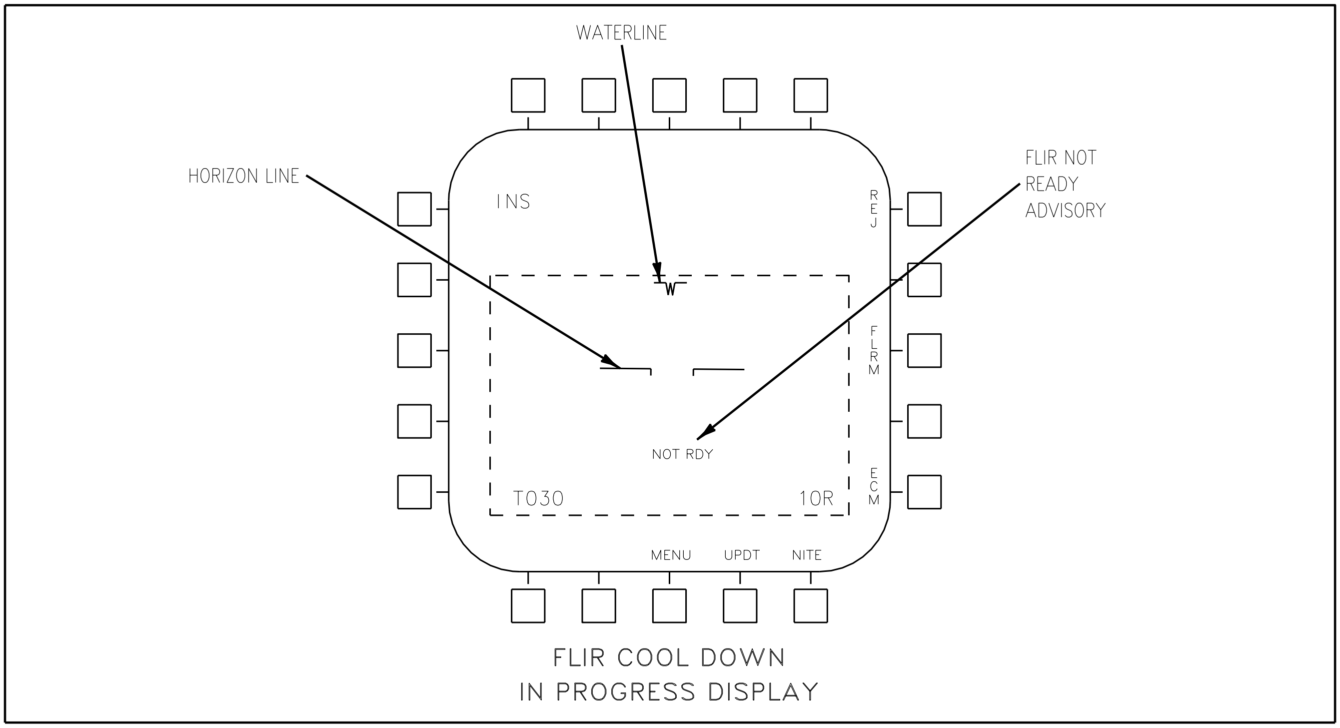

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Figure 1-100. FLIR Display Options (Sheet 3 of 3)

current image and enhance details formerly saturated into whites. Pressing LVL (down) moves the window so to lighten the current image and enhance the details formally saturated into the blacks. For a black hot set up the opposite would be true.

(2) Nudge. An automatic gain and offset function works by monitoring the auto gate and continuously adjusting the gain and offset to attain a preset amount of peak black and peak white in that portion of the image. This function is enabled when the MAN option is not selected on the FLIR display. The automatic gain nudge (NDG) option allows the pilot to make minor adjustments to the programmed settings for gain on both the HUD and MPCD. Nudging demands an increase or decrease in the amount of peak whites and blacks. Nudging up hardens the auto gain image contrast and nudging down softens the image contrast.

(3) Weapon Select Options. Pushbuttons 6 to 10, across the top of the MPCD NAVFLIR display, display the weapons available for selection by the pilot.

(4) Reject. The reject (REJ) option allows the pilot to de-clutter the display by removing the velocity vector or waterline symbol and the horizon line. The limiting of the velocity vector and horizon line on the FLIR display is identical to that on the Radar and DMT displays. REJ is automatically selected with GRAY option selected.

(5) FLIR Menu. The FLIR menu (FLRM) option allows the pilot to program the thermal cueing function to detect the desired target and scene characteristics for a specific mission. The FLIR menu option can be programmed on the AV-8B mission planning system or selected and programmed by the pilot. Options that can be programmed include target size, cuer capture gate/area of regard, and temperature sensitivity.

(6) Temperature Sensitivity. The temperature sensitivity option (TEMP) allows for adjustment of the cuer sensitivity for high (HI), medium (MED), and low (LO) temperature differential. Next to the sensitivity option is a number (1 thru 8) which serves as a sensitivity reference. This number can only be changed via the mission planning system.

(7) Capture Gate/Area of Regard. The capture gate/area of regard option allows for selecting that part of the NAVFLIR image needed for the desired target detection area. Options available are normal (NORM), expanded (EXP), and full (FULL), located at pushbutton 3. The NORM capture gate is designed for the air-to-ground scenario over relatively flat terrain. It covers an area from 2 kilometers slant range from the aircraft to 0.5° above the horizon. The EXP capture gate is optimized for hilly terrain and covers an area from 1 kilometers slant range from the aircraft to 0.5° above the horizon. The FULL capture gate covers the entire NAVFLIR FOV, 1 kilometer slant range from the aircraft to 90° above the aircraft's longitudinal axis, and is designed for A/A conditions.

(8) Target Size. The target size option (TSIZ) allows the pilot to select the category of target as determined by size of the detected heat source and not the physical size of the object. Options include small (SML), medium (MED), and large (LRG).

(9) Gray Scale. The gray (GRAY) scale option is provided on the MPCD display only with aircraft weight-on-wheels. When this option is selected both GRAY and REJ become boxed and an eight segment scale is provided in the bottom center of the FLIR displays to assist the pilot in making adjustments to the HUD and MPCD brightness and contrast settings. The eight shades of gray scale (seven gray and one black) is displayed at the bottom of the MPCD and HUD and should be adjusted for the optimum picture using the MPCD and HUD brightness and contrast controls.

(10) ECM. Selection of the ECM pushbutton displays the ECM page on the MPCD.

(11) NITE. The night (NITE) option retains the MPCD FLIR image whenever the TV image would normally have been selected.

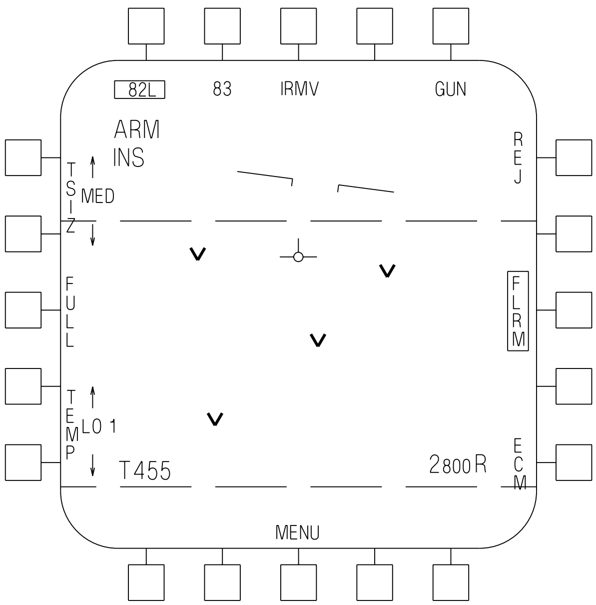
(12) Update. Selection of the UPDT option enables the ODU for available altitude/position updates.

(13) Menu. The menu display contains two options which may be employed with the NAVFLIR system. The FLIR option may be used instead of the sensor select switch to select the NAVFLIR display. The HUD option may be used to select the head-up display with NAVFLIR video on the MPCD.

(14) Limit. The limit (LIM) option allows the pilot to scroll through three target cue quantity selections, zero (LIM/0), four (LIM/4), or eight (LIM/8) maximum possible targets. The target cues are displayed on the HUD and MPCD. This option helps the pilot concentrate on possible target locations and select one for attention. Once a target is selected the pilot must then designate the position denoted by the V shaped display cue symbol to obtain targeting information for an attack. Cues are not displayed on the VSTOL HUD display regardless of LIM selection.

(15) Black Hot/White Hot. The black hot/white hot polarity (BLK legend) option allows the pilot to select whichever polarity provides the best resolution for the tactical situation. For example, a tank might be more easily detected with white hot polarity selected (BLK unboxed) in a forest background or with black hot polarity selected (BLK boxed) in a desert background. The white hot option (BLK unboxed) displays a thermal image of the scene in which white objects are displayed brighter than the background. Since targets are typically warmer than the background, white hot produces bright targets that can generally be detected at greater range. The sensor select switch allows the pilot to toggle between white hot and black hot video polarities by pressing the switch right. This allows the pilot to select the polarity which provides the best resolution for the tactical situation.

1.7.10.1.1 Target Cuer Operation and Controls. Initial target detection is biased towards long range targets in a dynamically controlled region referred to as the ″cuer capture gate″ or ″area-of-regard'. This brings the pilot's attention to any potential target as early as possible, which increases the possibility of detection and ultimate attack. The band covered by



NOTES

- SELECTING FLIR MENU 'FLRM' OPTION BRINGS UP LAST SELECTED FLRM PARAMETERS AND BLANKS 'BLK', 'LIM/X', 'UPDT', AND 'NITE' OPTIONS.
- TARGET SIZE (TSIZ) OPTION CAN BE INCREMENTED/DECREMENTED THRU SMALL (SML), MEDIUM (MED) AND LARGE (LRG).
- TEMPERATURE DELTA (TEMP) OPTION CAN BE INCREMENTED/DECREMENTED THRU MEDIUM (MED), HIGH (HI) AND LOW (LO). THE NUMBER DISPLAYED BESIDE THE 'TEMP' SELECTION CORRESPONDS TO THE SENSITIVITY TABLE SELECTED IN THE FLIR. DELTA TEMPERATURE IS INVERSELY PROPORTIONAL TO SENSITIVITY. THE RANGE IS 1 – 8, 1 REPRESENTING THE LOWEST DELTA TEMPERATURE (HIGHEST SENSITIVITY) TABLE AND 8 REPRESENTING THE HIGHEST DELTA TEMPERATURE (LOWEST SENSITIVITY) TABLE. THE DEFAULTS ARE 'LO 1', 'MED 4', 'HI 8', TO SELECT A TEMPERATURE SENSITIVITY SETTING OTHER THAN DEFAULT (1, 4, OR 8) THE MISSION PLANNING SYSTEM MUST BE USED.
- CUER GATE LOCATION OPTION IS SCROLLABLE THRU NORMAL (NORM), EXPAND (EXP), AND FULL (FULL).
- THE FLIR BREAK X SYMBOL APPEARS IN CENTER OF FLIR VIDEO 2 SECONDS PRIOR TO 4 G PULL–UP MANEUVER AND REMAINS UNTIL UNSAFE CONDITION IS REMOVED.

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Figure 1-101. NAVFLIR Menu

the area-of-regard varies as a function of aircraft supplied height and attitude, and pilot selected cue gate size. Cue gate size selection is dictated by the nature of the terrain and the basic mission. The NAVFLIR will detect and track more cues than are practical for the pilot to handle at one time, so the pilot may select (limit) the maximum number of cues displayed to 8, 4, or 0. This option is selected directly from the MPCD FLIR display. The NAVFLIR then selects which cues are displayed based on the following rules:

1. If the cue is already displayed, then it will continue to be displayed until it ceases to be a valid cue, or progresses inside the minimum range.

2. New cues for display (normally to replace those lost) are chosen from those not displayed (if any) in order of priority.

3. The highest priority cues are those nearest the upper edge of the NAVFLIR's FOV which in up right attitudes results in a cue on the object the farthest away.

The thermal cuer uses a sophisticated algorithm to track 48 thermally significant objects. In order to optimize the cuer electronics for specific mission requirements, the pilot has the option to program the cuer software setup based on mission, target type, terrain and atmospheric conditions. The variables of target size, cue gate size and temperature sensitivity are programmable from a NAVFLIR display (FLRM, see Figure 1-101), and during mission preflight planning with the AV-8B Mission Planning System.

a. Target Size. The target size variable will only cue objects that are equal to or less than the number of milliradians selected. Target size (TSIZ) categories are classified as small (SML), medium (MED), or large (LRG), equating to 2.0, 4.0, or 8.0 milliradians respectively. The small setting is recommended for objects that tend to be taller than they are wide (i.e., smokestacks, bridge abutments, towers, etc.). The medium setting is recommended for targets that tend to have a square-like geometry, such as tanks, APCs, and other vehicles. The large setting is for objects that are wider than they are tall (ships, warehouses, hangars, etc.). However, target size is sensed by the cuer electronics and does not necessarily correspond to the actual size of the detected heat source. A ship or large building may exceed the selected target size, but its associated smokestacks, chimneys, or generators may receive a cuer.

b. Cue Gate Size. The cue gate size selection determines the size of the cuer capture gate, also known as the ″area of regard″. In order to optimize the cuer for terrain and mission requirements, the area the cuer searches can be preprogrammed by the pilot (see Figure 1-102). The NAVFLIR field of view must fall within the selected cuer capture gate field of regard for target detection and cueing to occur. There are three cuer capture gate options available to the pilot:

1. Normal (NORM). The NORM cuer capture gate is designed for the air-to-surface scenario over relatively flat terrain. The actual terrain surface area covered by this cuer capture gate varies as a function of aircraft supplied height and attitude, but encompasses an area which corresponds to two kilometers slant range in front of the aircraft to 0.5° above the horizon.

2. Expanded (EXP). The EXP cuer capture gate is optimized for hilly terrain, or humid environments where atmospheric transmittance reduces thermal contrasts to a point where objects are not getting cued. EXP covers an area from about one kilometer slant range in front of the aircraft to 0.5° above the horizon.

3. Full (FULL). The FULL cuer capture gate covers an area from one kilometer slant range in front of the aircraft to approximately a 90 degree vertical pitch attitude. With FULL selected, the cuer capture gate covers the entire NAVFLIR field of view. This option should be selected if the pilot desires to use a cuer to assist in acquiring airborne targets.

c. Temperature Sensitivity. The final cuer control option is the temperature sensitivity setting. There are eight sensitivity settings (1 thru 8) that may be selected by the pilot during mission planning via the AV-8B mission planning system. Three of these may be selected in-flight via the MPCD (LO, MED, HI). The corresponding sensitivity setting the pilot selected during preflight mission planning will be displayed next to it during flight (i.e., LO 1, MED 5, HI 8). The default settings are 1, 5, and 8. The pilot may tailor this setting to the anticipated mission requirements and environment.

The signal intensity temperature difference ″8″ corresponds to the highest temperature differential. Thus the selection of ″1″ for LO is the most sensitive setting. It is important to note that LO corresponds to low delta T (high sensitivity), NOT low sensitivity, and HI corresponds to high delta T (low sensitivity). These values would typically be characterized as a temperature differential of 1.5 to 5.0 degrees above background with ambient conditions of 60 °F, 25 miles visibility, and 25 percent relative humidity. A HIgh delta T/low sensitivity setting (i.e., ″8″) will produce fewer nuisance cues because it is less sensitive. However, a LOw delta T/high sensitivity setting (i.e., ″1″), may result in numerous nuisance cues. It is recommended that the lowest delta T/highest sensitivity setting feasible be selected until the nuisance cue rate becomes too high. The next higher TEMP setting should then be selected.

The thermal cuer is not a hot spot tracker, but a delta T cuer. Thus, when flying over a coast line or river, one could expect cuers along the beach or riverside where there is a large temperature difference. The thermal cuer does not incorporate any target recognition logic either; thus, any object which meets the preprogrammed target size, falls within the cuer capture gate, and has the required delta T for the TEMP sensitivity setting is a potentially ″cueable″ object. Cattle, trees, and rocks are often cued when not desired. Figure 1-103 provides some general guidance for use in determining TEMP settings. Mission requirements, EOTDA PAR's, and pilot experience must all be considered in order to establish optimal TEMP settings.

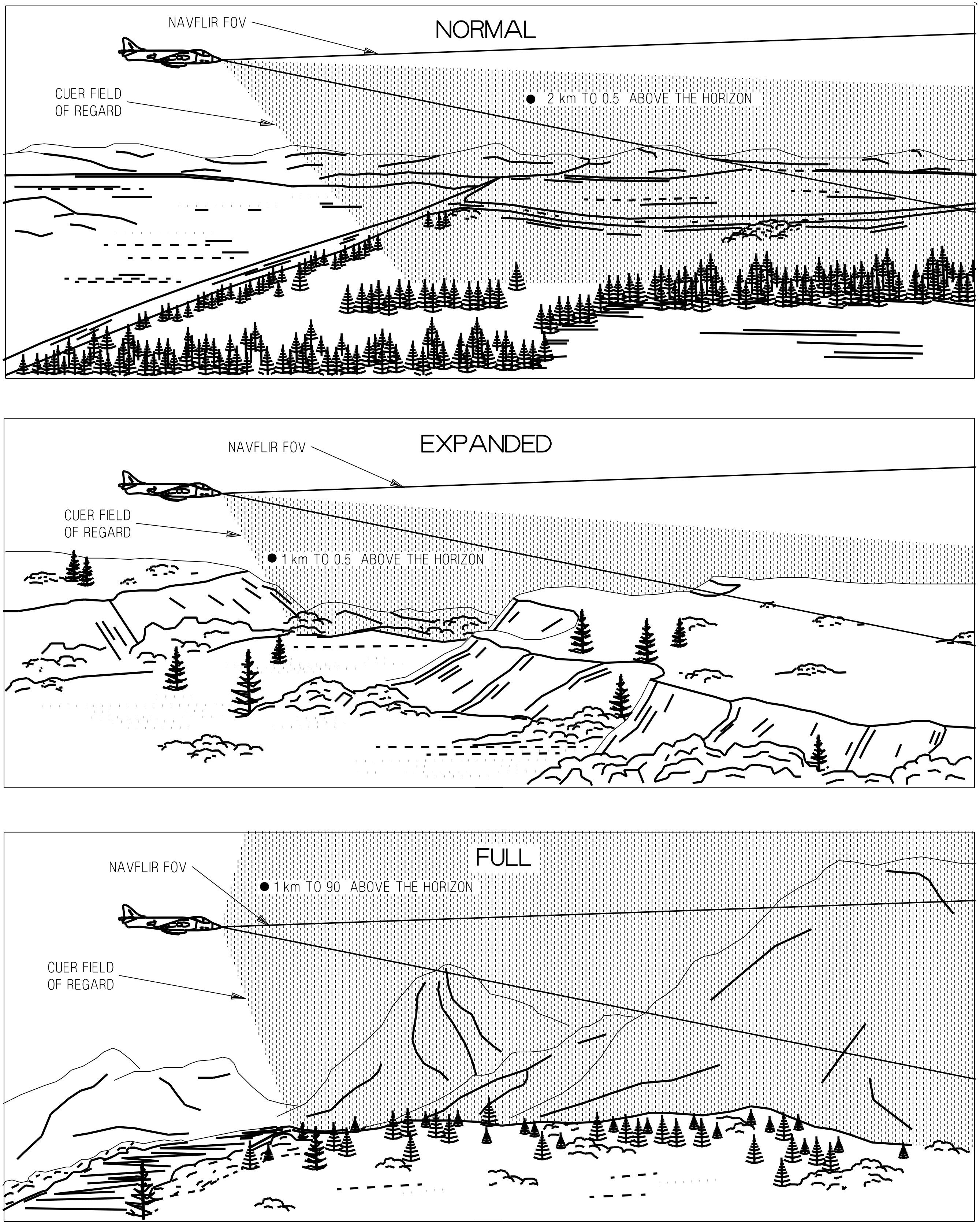

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Figure 1-102. NAVFLIR Cuer Gate

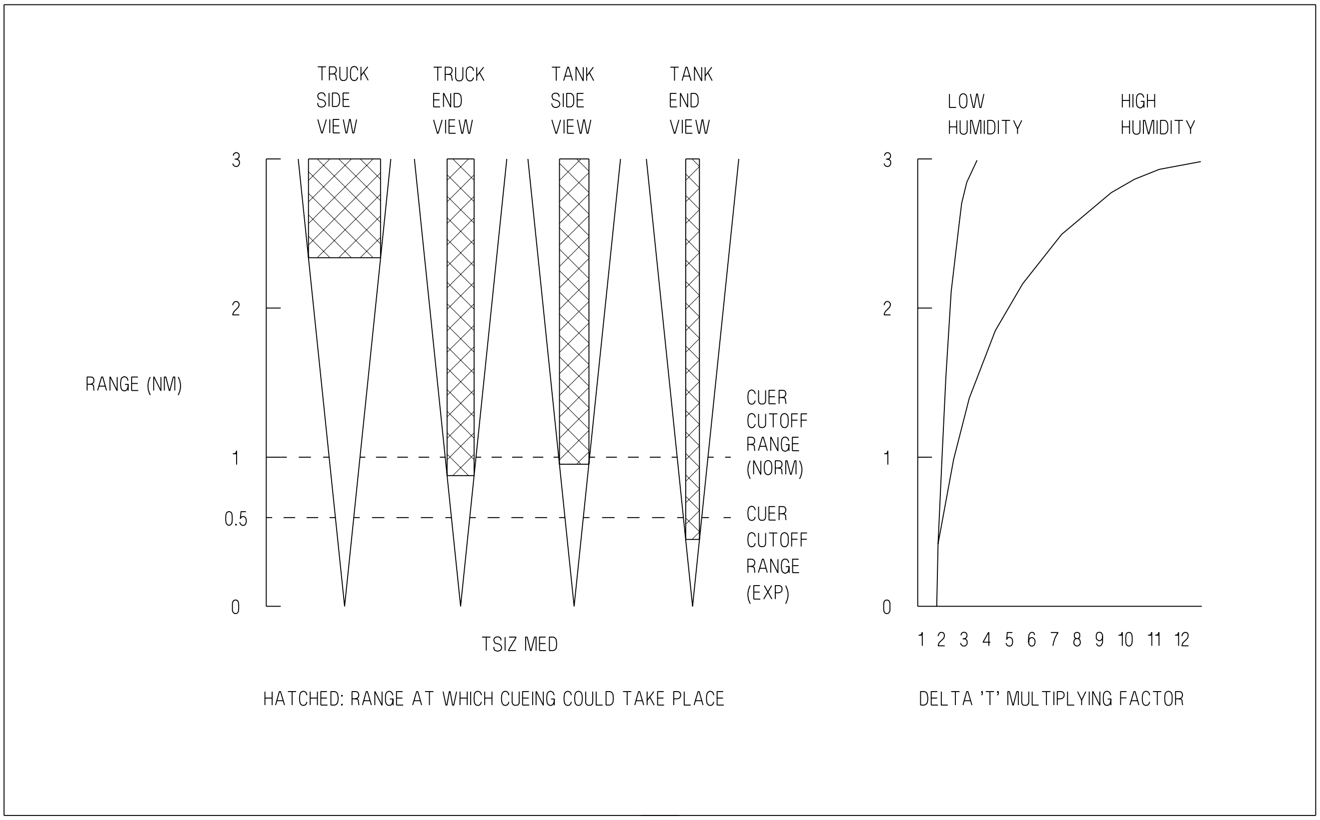


Figure 1-104. Cueable Target Size vs. Temperature Difference

TARGETING	LO	MED	HI
Sea (OAT < 80 ° F)	1	3	5
Sea (OAT ≥ 80 ° F)	2	4	6
Coastline (OAT< 50 ° F)	3	5	7
Coastline (OAT ≥ 50 ° F)	4	6	8
Desert (OAT < 60 ° F)	2	4	6
Desert (OAT ≥ 60 ° F)	3	5	7
Air-to-Air	1	3	5

Figure 1-103. Targeting

d. Cuer Tactical Considerations. The thermal cuer enables the pilot to inspect objects on the HUD or MPCD as potential targets before the would normally be detected with the NAVFLIR or NVGs only. Figure 1-104 demonstrates the nominal range at which the cuer would operate if programmed for a target the size of a battle tank (TEMP LO 3 or MED 4, cuer gate size NORM, TSIZ MED). The graph on the right shows the increasing temperature differential necessary for target cueing as absolute humidity increases.

The very nature of thermal cues provides a certain amount of information as to their validity. Thermal cues which suddenly appear toward the bottom of the display and dance about or flicker are generally random cues. Random cues satisfy cuer gate requirements for such a short time they do not form patterns, nor do they appear as steady as tactically significant cues do. Rocks and scrubbrush heated up during the day can receive numerous cues well into the night. With experience, these nuisance cues can be recognized and ignored in favor of more stable cues. Valid cues normally appear higher in the cuer gate and remain in a relatively fixed ground position as they track down the HUD. The thermal cues are removed as they reach the lower part of the cuer gate. This serves to de-clutter the target for attack, and if the target cannot be seen at that point it is probably too late to attack it on that pass.

The pattern of the thermal cuers can also provide useful information to the pilot. For instance, an organized, symmetrical pattern may indicate vehicles/targets arrayed in a tactical formation. The thermal cuer is an aid which must be used in conjunction with a known probable target position and the nature and context of the cues themselves. It is an educated form of reasonable assurance based on available target information, pilot experience, and cuer patterns. Thermal cueing by itself is not perfect, but experience with the system leads to enhanced target detection and mission success, by day and night.

1.7.11 NAVFLIR Preflight Management.

1.7.11.1 Display Set-up

Set MPCD controls as follows -

1. NGT/OFF or DAY/AUT switch - AS REQ

2. Set BRT control - AS REQ

3. Set CONT control - AS REQ

4. FLIR power switch - ON (up position) (NOT RDY displayed for approximately 3 minutes).

5. Adjust MPCD BRT control up to just see background raster video, then down until the background raster just disappears.

6. Adjust MPCD CONT up until the last two segments are white, then reduce CONT until you can differentiate between these last two white segments.

7. DAT the NAVFLIR display to other MPCD and repeat steps 5 and 6.

8. Select EHSD with MAP video.

9. Adjust MPCD CONT control to give minimum comfortable display.

10. DAT the MAP display on the other MPCD and repeat steps 8 and 9.

Set the HUD controls as follows -

1. Mode select switch - NIGHT

2. HUD SYM BRT control - MIN REQ

3. VIDEO BRT control - MIN REQ

4. VIDEO CONT control - MIN REQ

5. Adjust HUD VIDEO BRT control to just see background raster video, then down till background raster just disappears.

6. Adjust HUD VIDEO CONT up until the last two segments are white, then reduce CONT until you can differentiate between these last two white segments.

7. Adjust the BRT up until the first two black segments separate.

8. All segments of the GRAY scale bar should now be visible. Continue to make minor adjustments to BRT and CONT until all 8 (including the first black tile) are discernible.

9. Adjust HUD SYM BRT control to give comfortable symbology viewing level.

10. Adjust the BRT up until the first two black segments separate.

11. All segments of the GRAY scale bar should now be visible. Continue to make minor adjustments to ″BRT″ and ″CONT″ until all 8 (including the first black tile) are discernible.

12. Turn the NVGs on and verify image acceptability. Repeat steps as necessary.

1.7.11.1.1 Gray Scale Adjustment. The NAVFLIR gray scale must be adjusted during image set-up so that the maximum dynamic range of the NAVFLIR is visible on the HUD and both MPCDs. The display should be adjusted so that all eight visible segments of the

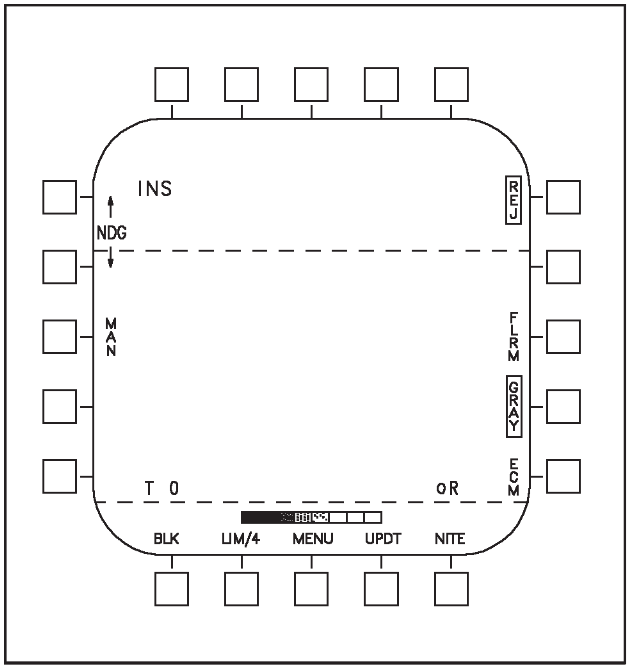


Figure 1-105. NAVFLIR Gray Scale

NAVFLIR gray scale can be equally resolved, with the eighth segment black. The gray scale option is only available with weight-on-wheels. When the GRAY option is selected on the NAVFLIR display, GRAY and REJ legends are boxed, and the horizon line and velocity vector are removed. See Figure 1-105. The shades of gray scale is displayed at the bottom of the MPCD and HUD and should be adjusted for the optimum picture using the brightness and contrast controls.

1.7.11.1.2 NAVFLIR Programming. The FLIR menu display (see Figure 1-100) provides the necessary options required to program the NAVFLIR thermal cueing function. This permits optimizing detection of desired targets and scene characteristics for specific mission. Parameters that can be programmed include target size, capture gate/area of regard, and sensitivity. The FLIR menu display is selected by pressing the FLRM option button on the NAVFLIR display. NAVFLIR parameters can also be set on the AV-8B mission planning system and transferred to the aircraft via the DSU.

a. Temperature Sensitivity Option. The cuer TEMP sensitivity options are high (HI), medium (MED), and low (LO) temperature differential. Next to the sensitivity option is a number (1 thru 8) which serves as a reference to a sensitivity table selected in the NAVFLIR. This number can only be set via the AV-8B mission planning system. Pressing the up arrow or down arrow on the MPCD increments/decrements the selection.

b. Cuer Gate Location Option. The cuer gate option allows for selecting that part of the NAVFLIR image needed for the desired target detection area. The cuer gate is a software generated area; there is no visible indication as to its size and position. It is used for cuer coverage and should not be confused with the auto gate area which is used in determination of gain and offset. Cuer gate (size) options available are normal (NORM), expanded (EXP), and FULL.

c. Target Size Option. The target size option (TSIZ) allows for selecting the category of the target as determined by size of the detected heat source and not the physical size of the object. Options include small (SML), medium (MED), and large (LRG). Pressing the up arrow or down arrow increments/decrements the selection.

1.7.11.2 NAVFLIR BIT Check. To perform an initiated NAVFLIR BIT check, press the BIT pushbutton on the MPCD menu display to call up the BIT display. The NAVFLIR must be turned on before initiated BIT can be run by the pilot. The power-up sequence takes approximately 5 minutes. The NAVFLIR must complete power-up sequence before it responds to initiated BIT. Press the pushbutton adjacent to the FLIR legend to clear the display of any previously set failures and command NAVFLIR initiated BIT. The word TEST will appear next to the FLIR legend in column one while BIT is in progress. After approximately 90 seconds the word TEST disappears and the BIT status will be presented. If the space immediately adjacent to the FLIR legend remains blank no detected failures are indicated. If any numerals appear in this space the NAVFLIR has failed BIT. The appearance of an asterisk identifies the failure as mux bus related.

The NAVFLIR will not prevent the operation of associated equipment during initiated BIT; however, BIT can be terminated by pressing either the STOP or MENU pushbuttons. If STOP is selected, the test ends and the display remains the same with the word TEST removed. If MENU is selected, the test ends and the display reverts to the menu display. NAVFLIR initiated BIT is also performed with AUTO BIT selection.

1.7.11.3 NAVFLIR Boresight Check. A NAV FLIR boresight check may be performed either in the air or on the ground. To perform a NAVFLIR boresight check, first turn on the NAVFLIR and adjust the HUD and MPCD for optimum display. Set the MPCD and HUD controls to the NIGHT position. Select the BIT display on the MPCD and press the FBST option (FBST becomes boxed). See Figure 1-106.

Pressing the FBST option enables the following functions:

1. Brings up the NAVFLIR image on the MPCD displaying the azimuth (AZ) and elevation (EL) boresight corrections.

2. Enables the AZ and EL options on the ODU for updating boresight corrections.

If the boresight corrections are known, they may be entered as follows:

1. Select the AZ option on the ODU and enter the appropriate azimuth boresight correction (–17.1 to +17.1 mR) in milliradians via the upfront control.

2. Select the EL option on the ODU and enter the appropriate elevation boresight correction (–13.1 to +13.1 mR) in milliradians via the upfront control.

The corrections can be verified on the MPCD. If the boresight corrections are correct the pilot simply presses MENU to exit the boresight procedure.

If the NAVFLIR image is not displayed on the HUD, press the sensor select switch on the flight control stick.

Verification of HUD NAVFLIR image boresight requires a thermally and visually significant object at tactical slant range (beyond 7,000 feet). Center the object in HUD FOV; the visual and thermal scene should overlap. If correction is necessary, press the TDC switch and slew the HUD NAVFLIR image over the visual object.

1.7.12 IR Maverick. Refer to NWP 3-22.5-AV8B, Vol II, Chapter 2 for information on the AGM-65F IR Maverick missile.

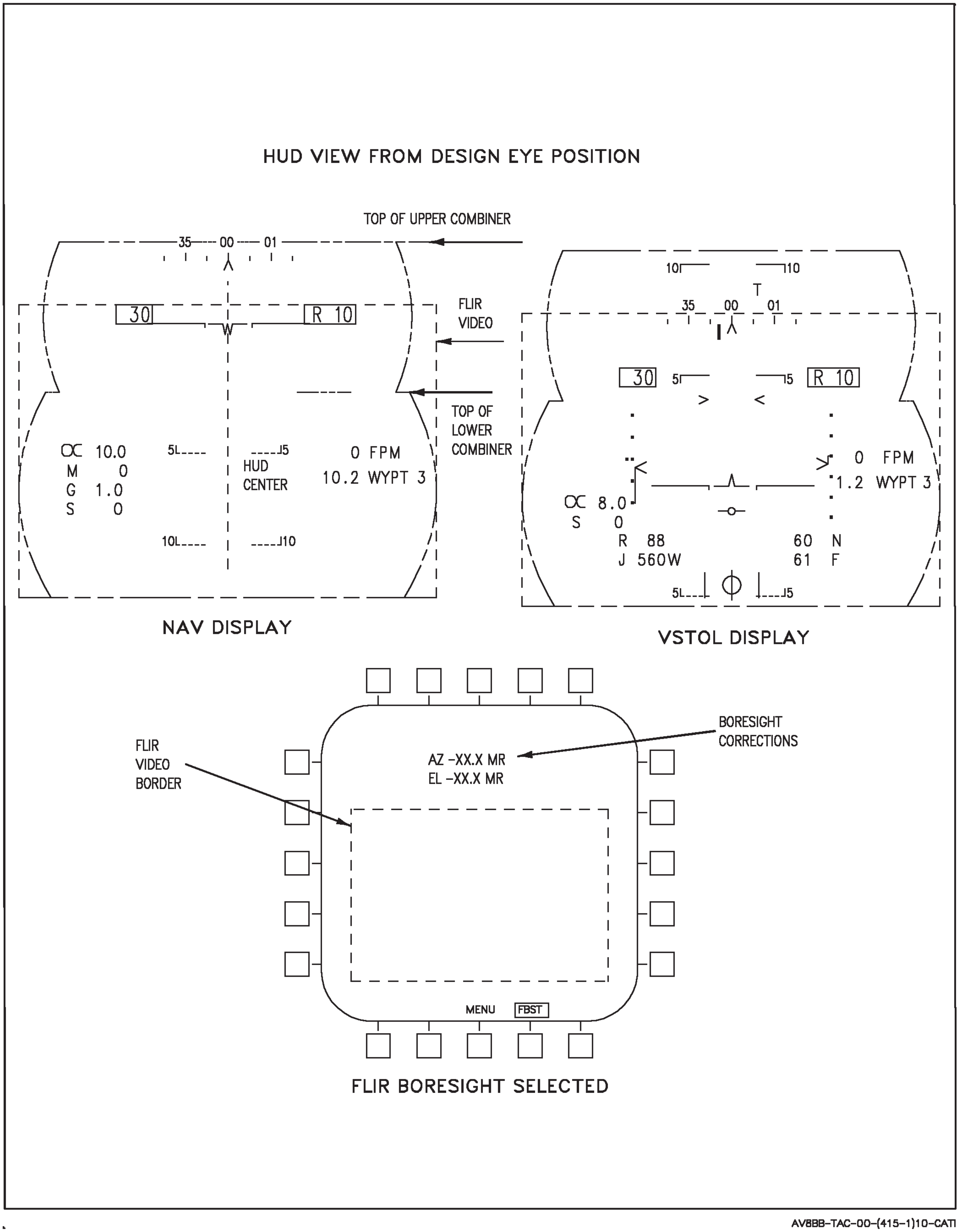
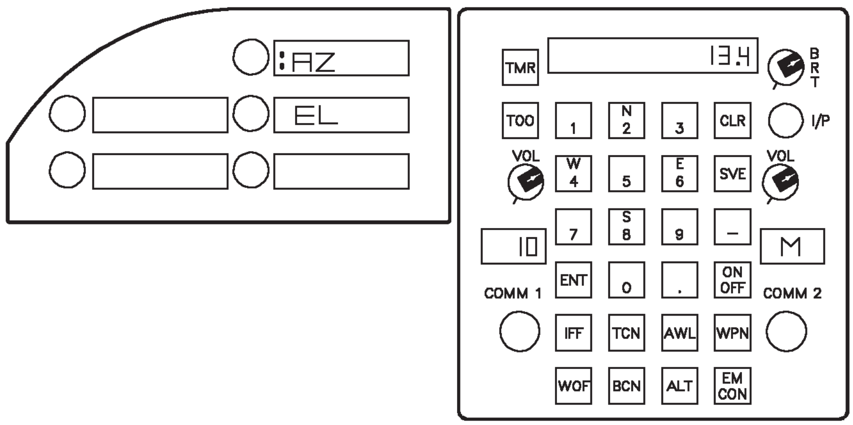
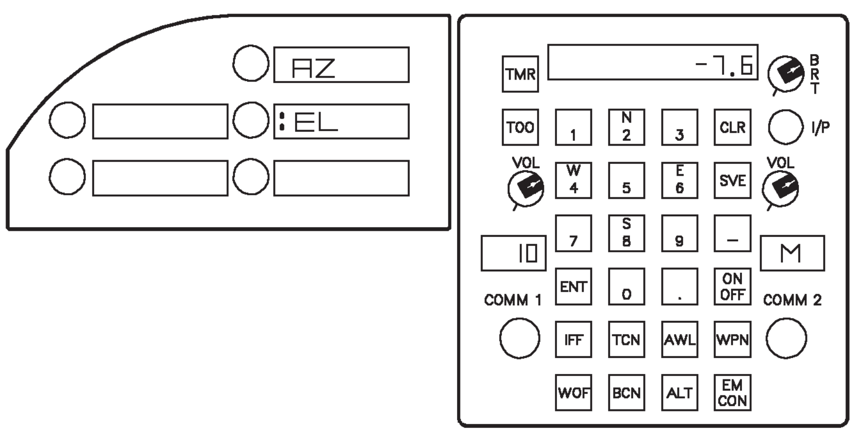


Figure 1-106. NAVFLIR Boresight Data Entry (Sheet 1 of 2)



AZIMUTH SELECTED



ELEVATION SELECTED

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Figure 1-106. NAVFLIR Boresight Data Entry (Sheet 2 of 2)

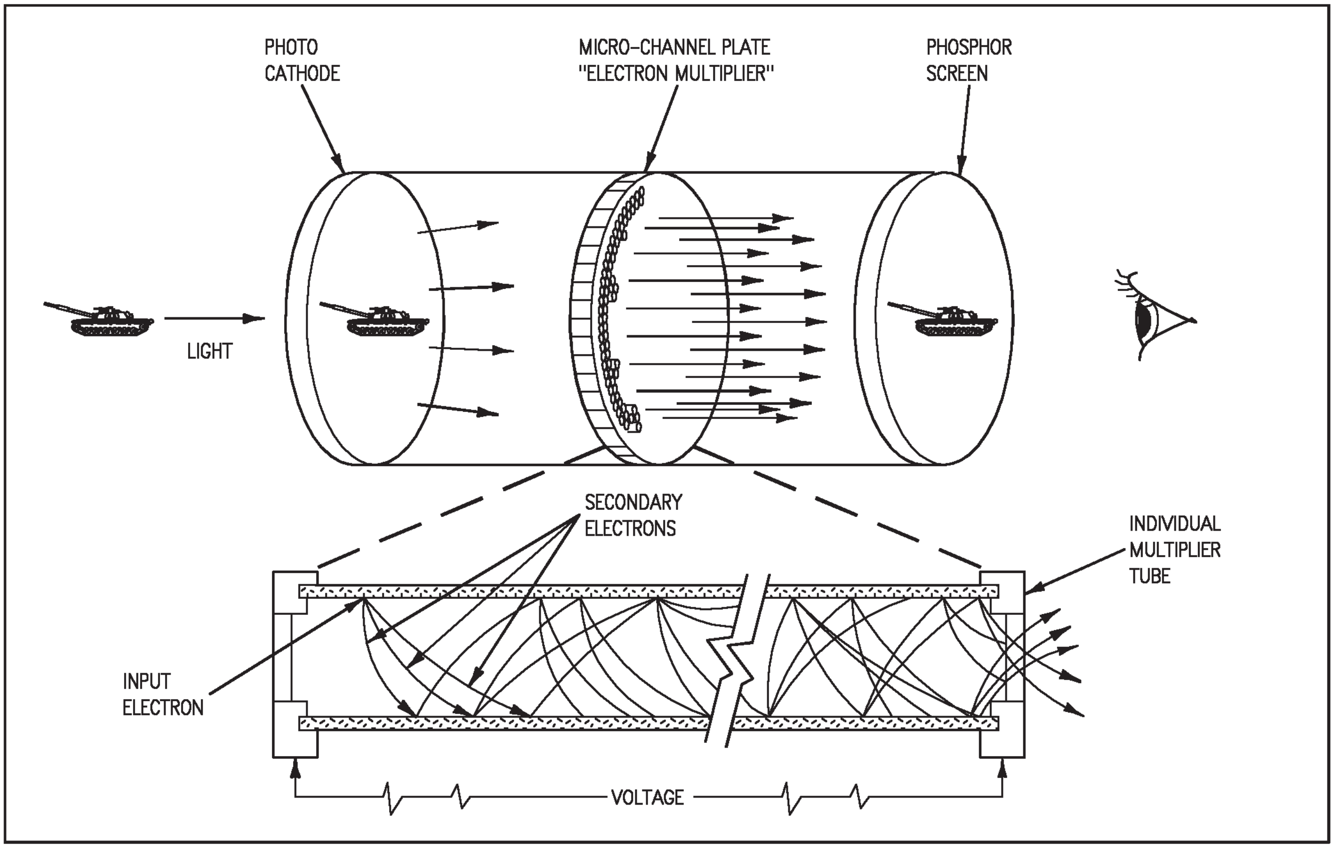

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Figure 1-107. Image Intensifier Tube

1.8 NIGHT VISION GOGGLES (NVG)

NVGs have been in widespread service for years, but only recently, with the advent of the night attack mission, have pilots of high speed tactical aircraft like the AV-8B used NVGs for operational purposes. All NVGs operate on the same basic principles. Image intensified tubes produce a bright monochromatic (green) EO image of the outside world in light conditions too low for normal vision. Unlike the FLIR, however, which uses the far IR area of the light spectrum to create an image based on object temperature and emissivity relative to the surroundings, NVGs use the red and near IR area of the light spectrum to produce their own unique visible image of the world. This image is based on the relationship between the amount of light present, referred to as illuminance, and the amount of light which is reflected from objects in the scene, referred to as luminance or brightness. Under defined luminance conditions, the NVGs provide the primary navigation and terrain avoidance reference for much of the night attack mission. Therefore, understanding the relationship of luminance and illumination, how the NVGs operate and their inherent limitations, is essential in order to perform night LAT effectively and safely.

1.8.1 Image Intensifier Tube. An image intensifier (see Figure 1-107) is an electronic device which amplifies available ambient light reflected from an object. The reflected light enters the goggles and is focused by the objective lens onto the image intensifier's photocathode, which is receptive to both visible and near IR radiation. The photons of light striking the photocathode cause a release of electrons, proportionate in number to the amount of light projected through the lens. The released electrons are then accelerated away from the photocathode surface by an electrical field which is supplied by the device's power source. The released photoelectrons are amplified (increased in number) and accelerated (increased in energy) onto a phosphor screen; the impact causes the screen to glow. The phosphor screen emits an amount of light proportional to both the number and velocity of electrons which strike it. The amount of light amplification produced in an image intensifier tube is referred to as the device's gain. The gain of an image intensifier device is the ratio of the light striking the photocathode to the light delivered by the phosphor screen: output/input.

1.8.1.1 Third Generation Intensifiers. The NVGs for the AV-8B aircraft use third generation intensifier tubes. There are two major differences between the second and third generation tubes, the photocathode of second generation tubes has been replaced by a gallium arsenide photocathode, and a metal oxide film has been applied to the microchannel plate (MCP) located between the photocathode and the phospher screen. This means that third generation tubes are far more sensitive in the region where near IR radiation from the night sky is plentiful, and the 800 to 900 nanometers peak sensitivity range demonstrated by the tube has a five to seven times greater photon rate than in the visible region. This translates directly to increased gains.

Photocathodes are processed or grown by vaporizing several elements in a vacuum chamber, and depositing them on the vacuum side of the intensifier input window before the vacuum seal is made. Photocathode growing is a very delicate process and the quality of the crystals grown in the process directly affects the luminous efficiency and sensitivity of the intensifier tube. It must be noted the quality of the image itself can vary slightly between different sets of goggles because of the difficulty in consistently manufacturing third generation tubes. Indeed, only a certain percentage of the tubes produced meet the specifications established for third generation intensifier tube.

The addition of a metal oxide film to the MCP in third generation tubes greatly extended their service life. As the life of an intensifier tube is largely a function of the life time of the photocathode. End of life for a photocathode is primarily caused by ion bombardment which is given off by the MCP as it is struck by electrons from the photocathode. This bombardment results in a gradual loss of photocathode luminous efficiency. The higher the light input, the more ions are generated, and the shorter the life expectancy of the tube. For this reason the NVGs should never be exposed to any bright light. The film is transparent to electrons so they pass from the photocathode to the MCP but not the ions. The ions are trapped in the metal oxide film and prevented from contaminating the photocathode. A disadvantage of the metal oxide film is an increase in the bias voltage requirement between the photocathode and the MCP. This requires increased spacing between the two components to prevent arcing. Ultimately this spacing results in an increased halo size, as compared to second generation performance, when viewing bright light sources. Depending on light levels encountered during the life of the intensifier, another limiting factor for the lifetime of the tube is a gradual drop in secondary electron emissions through the MCP.

1.8.2 ANVIS. In conventional NVGs, such as the ANVIS 6 , the outside world scene is focused on the intensifier tubes and the resulting EO image is viewed by the pilot directly through the tubes. The NVGs looks like a set of binoculars mounted on the pilot's helmet. See Figure 1-108.

This axial or straight-through design offers a 40° FOV and consistent optical resolution over the entire image but has some major limitations for the AV-8B aircraft. When the HUD FLIR image is viewed directly through the intensifier tubes, the resolution of the HUD image is reduced. This is partly due to the inherently lower resolution of the NVGs compared with the HUD, and partly because the P1 phosphor of the AV-8B HUD image is not optimized for the wavelength sensitivity of third generation NVGs. The only area where the HUD phosphor could actually be detected by the NVGs was the red of the P1 phosphor. This narrow overlap of NVG and HUD sensitivity caused an overlap image on the NVGs.

1.8.3 Cats Eyes NVGs. The Cats Eyes NVGs avoid these limitations by using a see-through

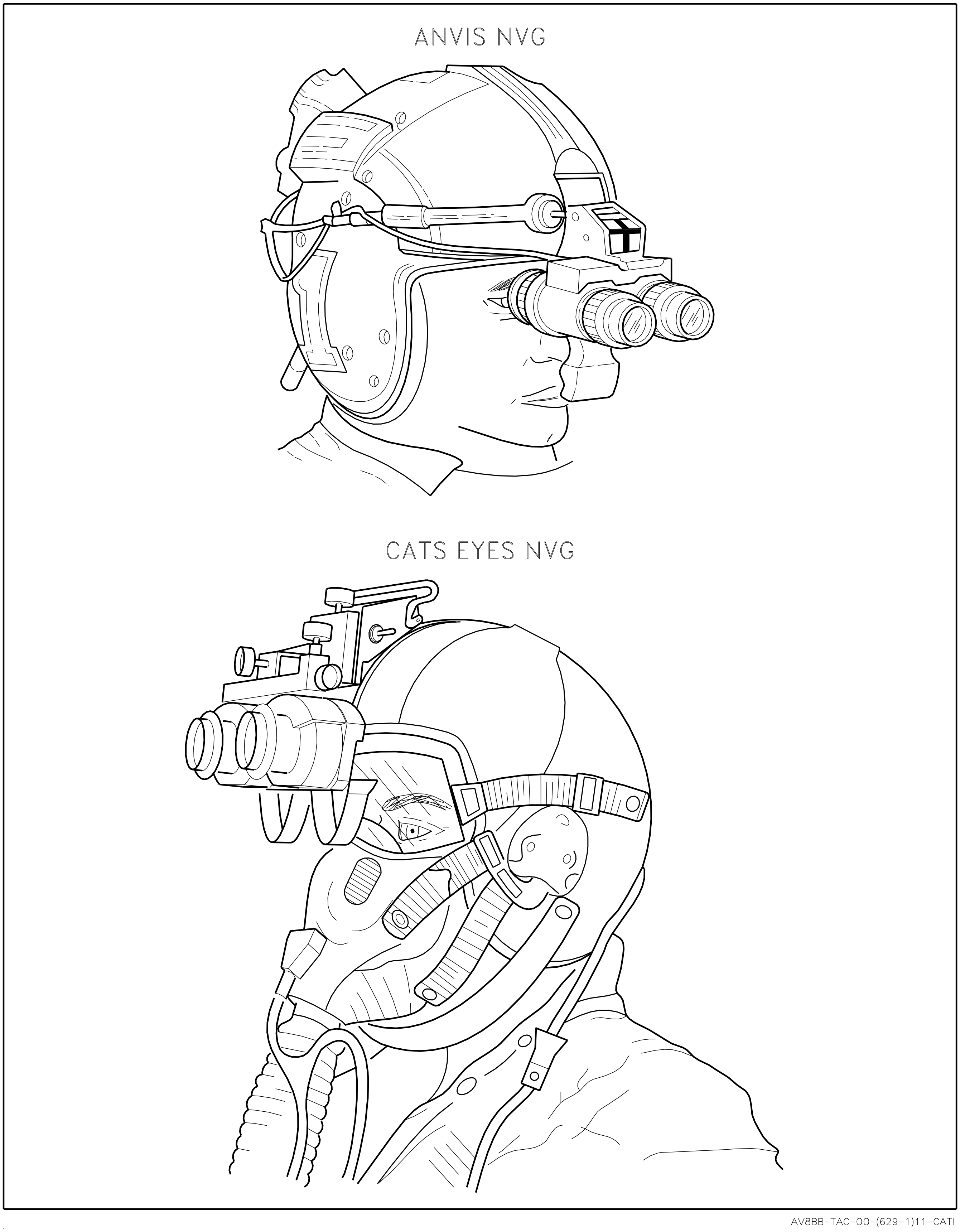

Figure 1-108. Night Vision Goggles (NVGs)

type technology. See Figure 1-110. The see-through design allows the pilot to view the HUD FLIR image without actually intensifying the image through the NVGs, and the HUD and NVG sensitivity overlap is filtered out by increasing the thickness of the 665 filter for production NVGs. The image intensifier tubes are mounted about 1.25 inches above the pilot's line of sight to prevent interference with forward vision. The intensifier tubes used in the Cats Eyes NVGs are third generation tubes with a gain of 30,000. The EO image is turned 90° through an Amici prism and projected into a glass combiner element which turns the intensified image another 90° for display to the pilot.

The image is scaled one-to-one and correctly registered so the pilot sees the intensified image superimposed on the outside world scene. The Cats Eyes have a 30° instantaneous FOV, but because the final image is clipped slightly as it is turned in the Amici prism, the view has the appearance of a modified "baseball diamond."

In addition to avoiding the degrading effects of intensifying the HUD FLIR image, the see-through combiners provided good pilot awareness of the outside world. The ability to scan on either side of the combiners and transversely between the combiners creates a less closed in feeling than straight-through NVGs, which helps in pilot comfort level while improving situational awareness.

A red spectral filter, which severely limits light wavelengths below 665 nanometers from entering the intensifiers, is an integral part of each tube. The filter is designed to maximize the effective range of the goggles by cutting off only as much of the visible light spectrum as necessary to avoid saturating the goggles with inherent cockpit light.

The intended use of the goggles determines the type of phosphor used in an intensifier tube. Persistence is the lingering of an image on the phosphor after the excitation has been removed or changed. A longer persistence can give clearer images, especially in low light conditions, because each picture element is augmented by adjacent ones for a longer time than with shorter persistence phosphors. However, if the objects in a scene are crossing the FOV rapidly, such as in high speed night LAT, too long a persistence can smear and reduce the acuity of the view. This is seen in goggles with a long persistence phosphor as a comet-like tail extending from point light sources when the head is rapidly moved. P-20, which has a short persistence time, is used for the Cats Eyes NVGs.

Electrical power is supplied to the Cats Eyes by two lithium batteries contained in the top of the mount assembly above the tubes. Built-in redundancy is obtained as either battery can power the goggles. Because a total power failure will be highly debilitating, even with this redundancy, close track must be kept of the flight time on the batteries, or new batteries should be used on each flight. A low battery indicator light, consisting of a red LED located on the right intensifier tube, is designed to illuminate and intrude into the pilot's FOV at least five minutes prior to a battery failure.

An automatic scene reject (ASR) detector is attached to the NVGs between the intensifier tubes. The detector gives the pilot the option to automatically shut off the intensifiers when viewing the HUD FLIR display. This may be desirable because the HUD FLIR display is degraded when viewed through the intensifier image on the combiners. The degradation is caused by several factors. One is that the image of the intensified scene on the combiners makes the HUD FLIR image less distinct due to contrast reduction. Another reason is that there is an inherent slight misregistration of the intensified image and the HUD FLIR image. A third factor, identified during flight tests in low light conditions, was caused by the 665 filter in the objective lenses in front of the intensifiers. Although the energy from the HUD was effectively filtered out from being intensified, it created a fluorescing effect on the 665 filter, which produced a random release of photoelectrons into the intensifier tube. This intensification of additional electrons was viewed as an overall brightening effect or "veiling" of the NVG image which served to degrade image contrast. Tests are continuing with the NVGs in an effort to

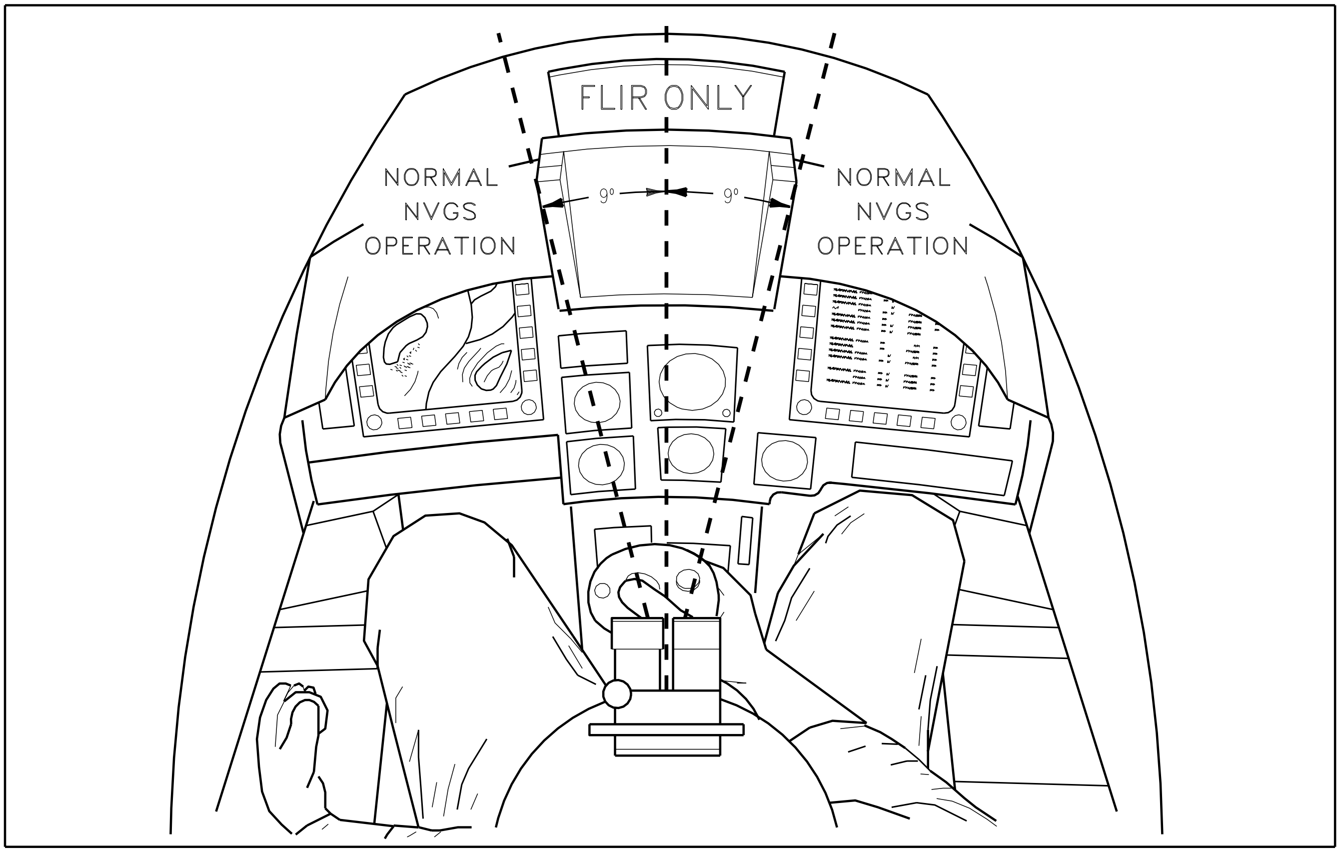

Figure 1-109. ASR Operation.

incorporate an interference filter into the objective lenses to eliminate the fluorescing effect.

The ASR detector acts as a simple angle-sensing device in association with an IR radiator fixed in the cockpit with the HUD. When the NVG power switch is in the ASR/ON position (see Figure 1-109), the system shuts off the intensifiers when the pilot's line of sight is within a few degrees of the HUD central FOV. At greater angles the detector no longer receives the IR energy from the radiator, and the NVGs return to normal operation. This requires precise alignment of the detector on the NVGs. Therefore, the detector is adjustable so that each pilot can align the detector for optimal operation. The IR radiator also operates in conjunction with the HUD FLIR scene reject feature of the sensor select switch. If the pilot decides that flight conditions warrant using HOTAS to kill the HUD FLIR display, the IR radiator will shut down and return the NVGs to normal operation.

1.8.4 Design Eye. Design Eye in the AV-8B is a specific sitting height which places the pilots eyes at the optimum location to view the entire HUD presentation. Design Eye was developed through crew station geometry studies using an average pilot as a model. Design Eye optimizes HUD viewability but does not provide the greatest external field of view. For many pilots, Design Eye seats them lower in the cockpit than they desire. For this reason, pilots may adjust their seats to optimize the external field of view and accept a slight ″Harrier Hunch″ when viewing the HUD. However, when NVG's are donned, the seat must be lowered to Design Eye or HUD information, boresight accuracy, and ultimately bombing accuracy will be adversely affected.

NOTE

Failure to achieve Design Eye while wearing NVGs could result in loss of ASR. Additionally, HUD readings such as airspeed, altitude and heading may not be visible.

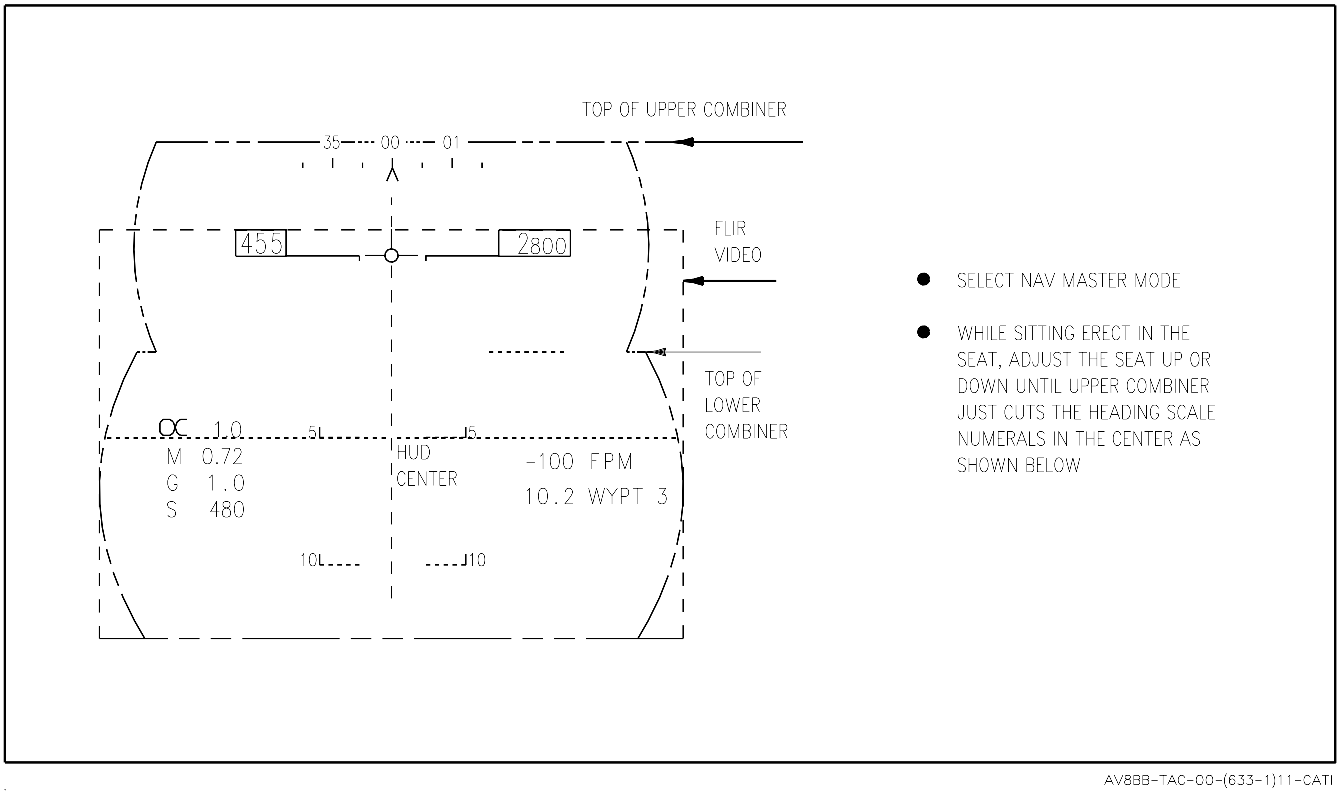

Figure 1-110. Design Eye Position

To locate the Design Eye, select the NAV master mode and sit erect in the seat. Adjust the seat height up or down until the upper HUD combiner glass cuts the Heading numerals in half. See Figure 1-110. HUD FLIR video is designed to fit into the HUD's IFOV, giving the pilot the best presentation of FLIR video with a minimum of head movement.

1.8.5 Cats Eyes Protective Circuits. The Cats Eyes have two protective circuits to guard the intensifier tubes from bright light sources: auto brilliance control (ABC) and bright source protection (BSP). In addition to protection, these circuits also have a direct effect on the performance and resolution of the NVGs. At low light levels, resolution is limited by internal noise, which prevents a clear build-up of the target image and effectively reduces image contrast. The key parameters are photocathode sensitivity and the noise figure for the tube. This noise signal is seen by the pilot as a sparkling effect, referred to as image scintillation. The higher the noise, the lower the resolution. Generally speaking, the higher the photocathode sensitivity the higher the resolution for low light levels. Resolution for the NVGs increases as light level increases until it is limited by the resolution capability of the combiner elements or the contrast transfer function of the NVGs. See Figure 1-111.

1.8.5.1 Auto Brightness Control. At about the same point as the resolution starts to drop off, the Auto Brightness Control (ABC) reduces the MCP voltage in order to keep the MCP-to-phosphor screen current constant. See Figure 1-112. In addition to protecting the NVGs from bright light sources, this creates a plateau which corresponds to a constant output brightness. Since the output brightness is constant, despite input illumination increasing, it follows that the gain of the tube is actually decreasing. It can also be seen that the benefit derived from higher gain intensifier tubes is realized only at low illumination levels, since above a certain light level they are all held constant by the ABC. The level of auto brilliance desired is determined by its overall effect on the pilot's perception of the visual scene, including the HUD. The Cats Eyes' design

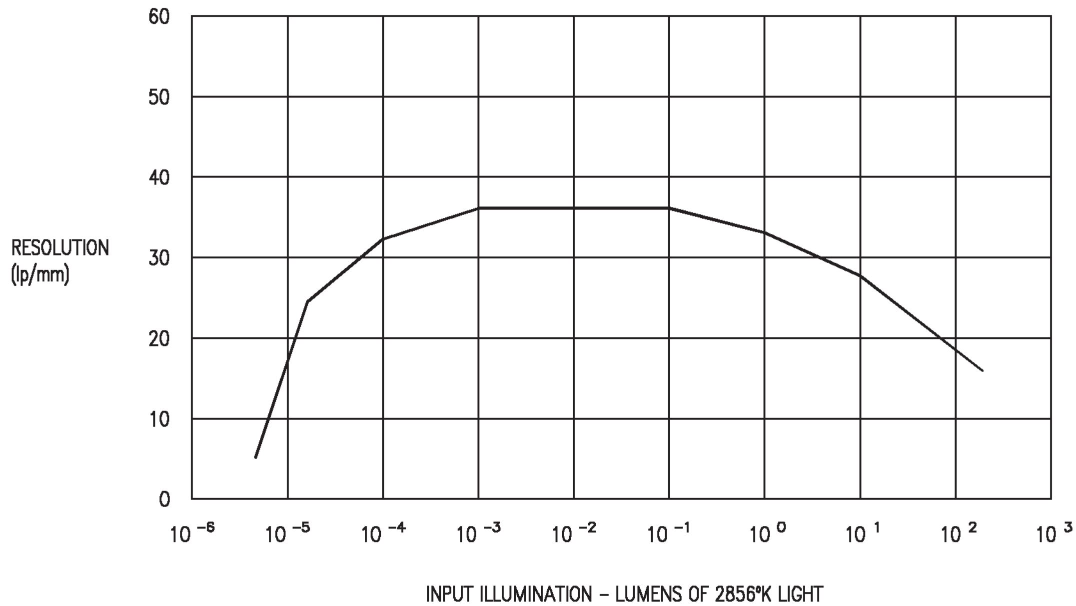

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Figure 1-111. NVG Resolution

requires certain trade-offs in order to allow the pilot to view the intensified image, and at the same time see through the combiner elements and view the HUD FLIR display.

High brightness gain combined with a highly reflective combiner implies low transmission of the HUD image through the combiner. The ASR feature, if used, compensates for this. If the auto brilliance level of the NVGs is high, the HUD FLIR image intensity level must be driven up very high to be viewed. Therefore the NVGs' ABC is set to optimize viewing of the intensified image while allowing transmission of the HUD FLIR image at acceptable HUD intensity levels.

The final intensity of the image viewed by the pilot is also dependent on how much of the intensified image is reflected by the combiner element. If it is desired for the intensified image to be dominant, then multi-layer dichroic coatings are used on the reflective surface of the combiners. Dichroic is a term used to describe the ability of a substance to reflect specific colors or wavelengths. Dichroic coatings are difficult to manufacture, but may be tuned to give high reflection of the tube phosphor, and acceptable transmission of the rest of the visible spectrum. The Cats Eye's combiner elements are optimized by using a neutral density coating, which gives good transmission of the outside scene (i.e., HUD FLIR image), and a more realistic color rendition while having better manufacturing yields. Neutral density coatings attenuate the signal uniformly over a given spectral region, which permits part of the energy to be transmitted and part reflected.

1.8.5.2 Bright Source Protection. The second protective feature, the Bright Source Protection circuit (BSP), guards the life time of the photocathode by limiting the number of electrons leaving the photocathode. See Figure 1-113. This is accomplished by automatically reducing the voltage between the photocathode and the input

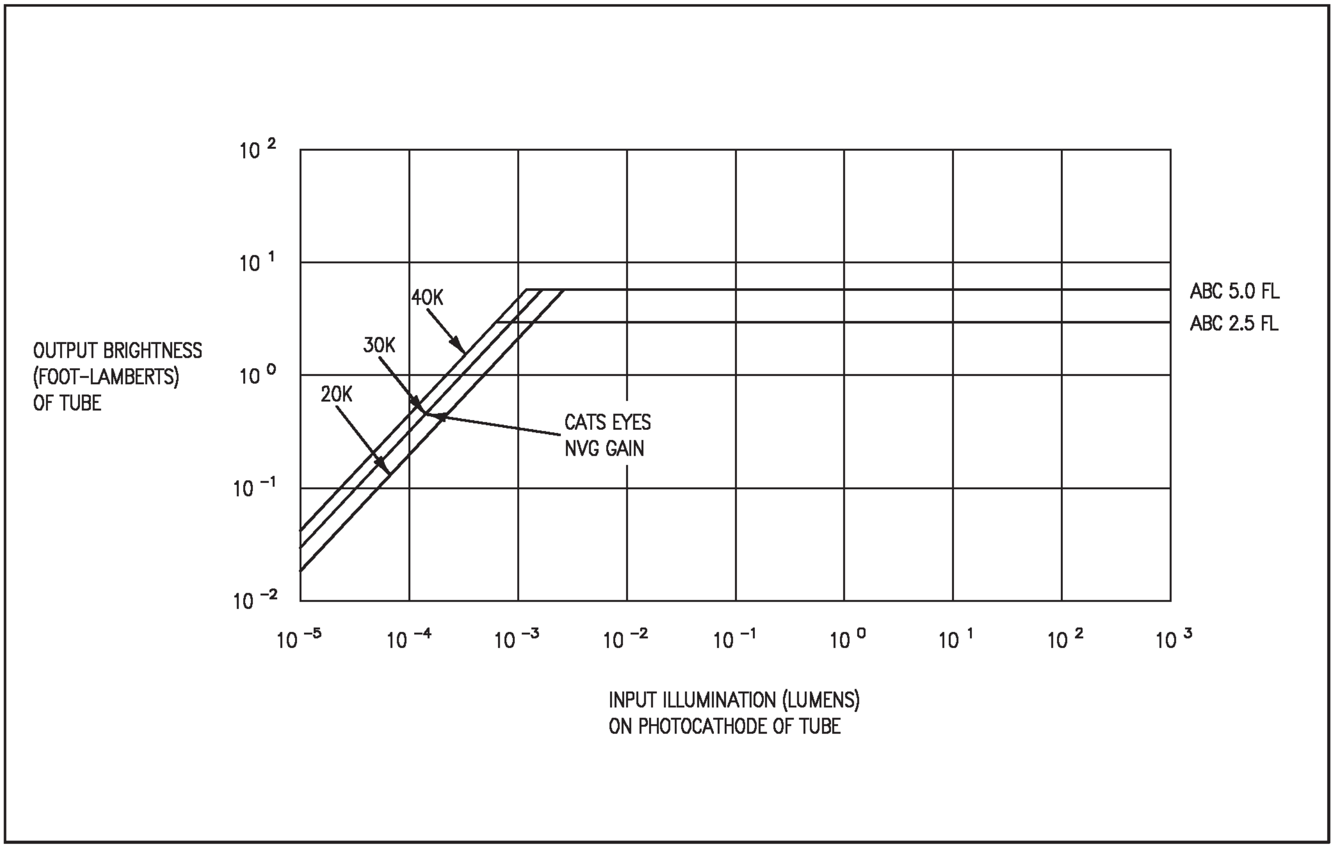

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Figure 1-112. Auto Brightness Control

side of the MCP, when input light levels cause excessive photocathode current to flow.

The BSP circuit actually starts to take effect at fairly low light levels, contributing to tube gain level, and has an increasing effect until the voltage drops to the point needed to ensure that electrons can penetrate the MCP ion film barrier. The intensifier tube would shut down completely if the voltage dropped lower.

1.8.6 Attachments. The NVGs are mounted to the helmet via a permanently attached bracket. The helmet attachment points for the bracket have vertical slots, thereby providing vertical alignment of the bracket. The attachment points on the bracket consist of horizontal slots, which allows the bracket to be positioned horizontally on the helmet. In this manner the helmet bracket can be individually positioned on each pilot's helmet to properly align the NVGs on the pilot's face. After this one-time initial alignment, the pilot uses the NVG adjustment controls to properly position the NVGs.

Another helmet bracket is permanently attached to the right console. This bracket is used when the NVGs are not attached to the pilot's helment.

There have been several instances where NVGs have fallen off the helmet while in flight. Therefore, the pilot must insure the NVGs attach with a "click", and give a gentle tug to check that they are securely attached.

The goggles can be single-handedly removed from the helmet by pulling the release lever on the NVGs which disengages a spring-loaded locking pin on the helmet bracket.

There have been instances where the NVGs would not release from the bracket, and had to be removed from the helmet after flight by unscrewing the helmet bracket from the helmet with NVGs still attached. Therefore, the pilot

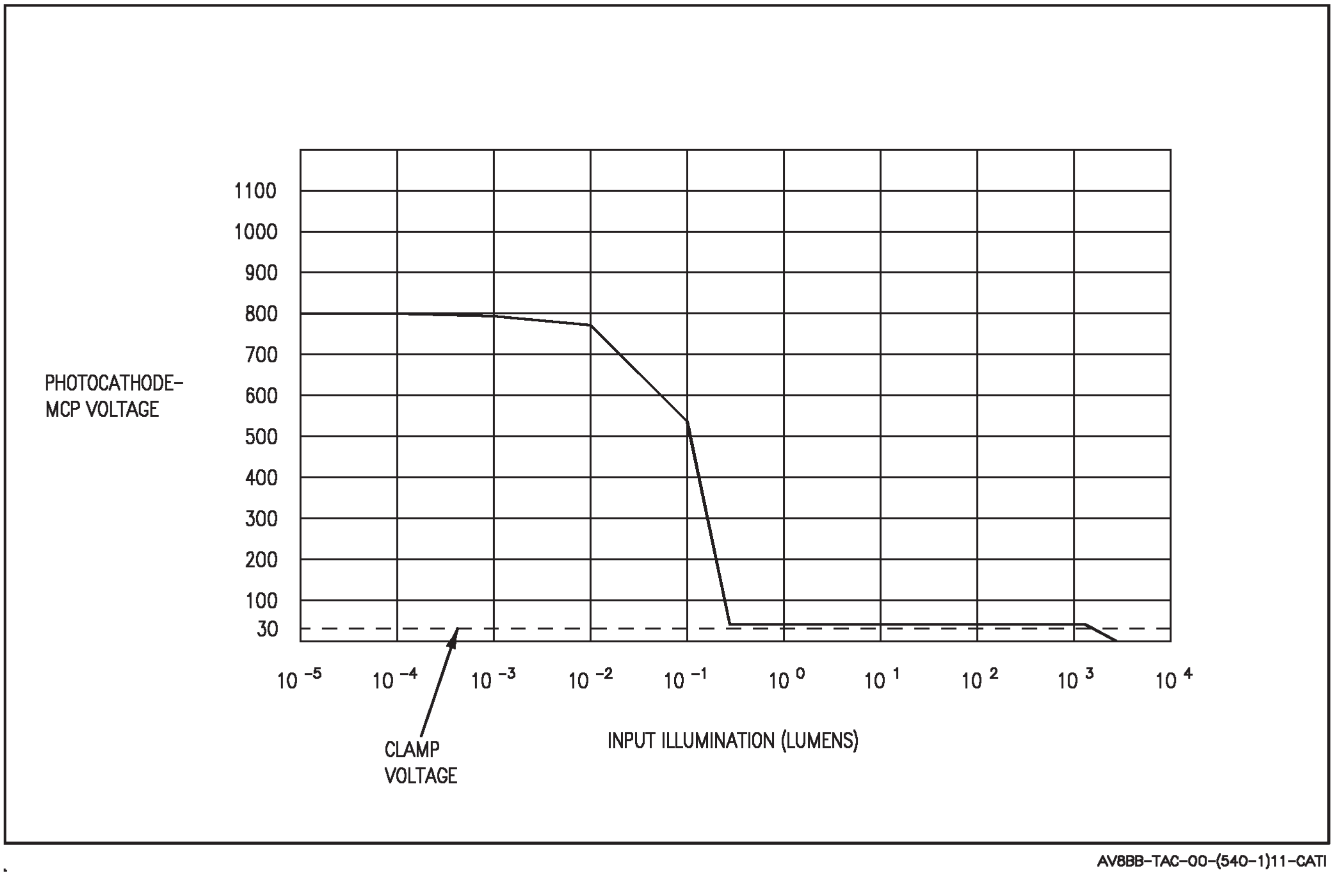


Figure 1-113. Bright Source Protection

should ensure the NVG quick release lever is operating smoothly and correctly prior to man-up. If the attachments tend to stick, a silicone-based lubricant should be applied to connections or a different set of NVGs used.

Ejection with NVGs attached can result in serious injury. Therefore, the release lever is designed so that a quick forward pull immediately releases the goggles.

1.8.7 Controls. All of the controls and adjustments for the NVGs are designed to be operated by the left hand so as to make any necessary adjustments in flight easier. Even so, pilot workload dictates that the goggles should be properly adjusted on the ground. The controls consist of the following:

1. Vertical adjustment
2. Interocular adjustment (distance between the eyes)
3. Fore and aft adjustment
4. Tilt adjustment
5. ASR ON/OFF/ON switch
6. Variable focus

1.8.7.1 Adjustments and Effects. Proper adjustment of the NVGs is extremely important. The very best acuity possible with the NVGs, under laboratory conditions, is about 20/50. Although this is a definite drop from the 20/20 vision possible without goggles under daylight conditions, it is a vast improvement over the unaided eye's capacity at night, which is on the order of 20/400 to 20/200 at best. The 20/50 figure, however gets progressively worse with maladjustment. Studies have shown that even a two to five millimeter maladjustment in the interocular setting (distance between the tubes) can degrade goggle acuity to 20/100.

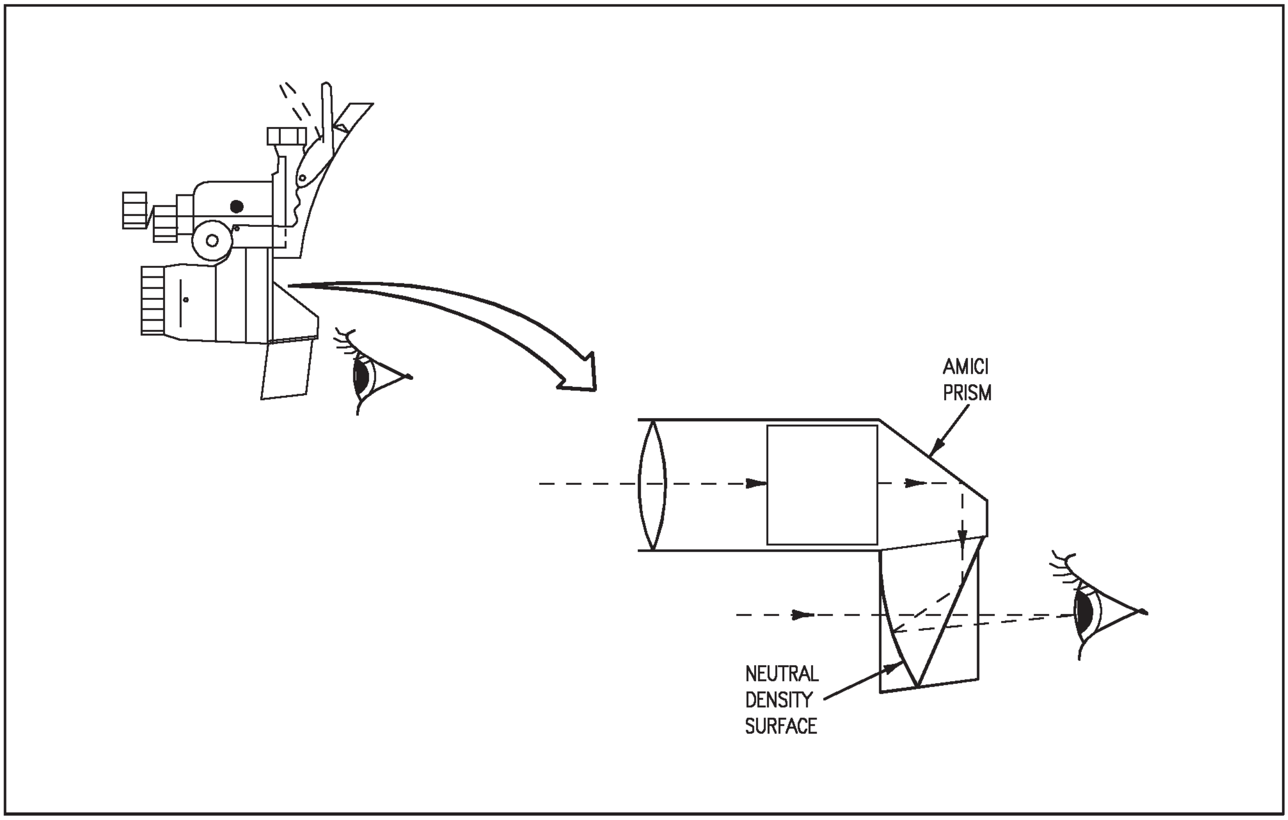


Figure 1-114. NVG Optical Path

The combiner elements of the Cats Eyes NVGs can be thought of as small HUDs, which means that proper eye position is more critical than in conventional NVGs. In addition, being an off-axis system, the Cats Eyes' combiner elements do not have symmetrical resolution characteristics over the entire combiner element. The optical path of the intensified image (see Figure 1-114) requires the light to turn in the Amici prism, then reflect forward off an air gap in the combiner element onto a neutral density reflective coating, before being collimated back into the pilot's eye. Therefore the combiners are an optical compromise, which have been designed with best resolution in the top and central areas to optimize them for distant objects.

In addition to loss of resolution, misalignment can cause pilot accommodative eye fatigue. This fatigue is associated with the eyes continuously and automatically focusing and refocusing to offset binocular maladjustment or differences in monocular resolution. This accommodation can disrupt the natural depth perception of some pilots after flight by temporarily affecting the natural resting position of the eyes.

This interocular adjustment is best made by measuring the distance between the pilot's eyes, adjusting the goggles accordingly, and then noting the scale setting on the goggles. In order to further insure the combiners lineup with the pilot's eyes, the helmet attachment bracket has horizontal adjustment slots for initially aligning the NVGs with each pilot's face. A lot of practice is required to properly make all necessary adjustments. Time spent working with the goggles in front of a mirror, and then in a dark room, pays off in goggle acuity dividends as well as reducing pilot stress. A properly adjusted set of goggles will have the combiners directly in front of the eyes with about one inch eye relief. This allows enough distance for the helmet visor to fit behind the NVG combiners, and still provide the pilot with the full instantaneous 30° FOV. Once the correct setting for each adjustment is determined, the pilot can note the scale setting on each control, and make future attachment quicker and more accurate.

The ASR ON/OFF/ON switch is a three position switch which energizes both the intensifier tubes and the auto scene reject detector in the ASR ON position, or the intensifiers alone in the ON position. The center OFF position shuts power off to both intensifier tubes.

The variable focus control is located on the objective lens in front of each intensifier tube. The range of focus extends from beyond infinity to about 15 feet, which means that anything inside of approximately 15 feet will be out of focus. The intensifier tubes are focused individually. To focus the NVGs to infinity the pilot closes one eye at a time and focuses on any distant object or light source. Light sources are focused by bringing the halo into crisp shape. Focusing in this manner does move the focal point, so visual deficiencies such as myopia (nearsightedness) and hyperopia (farsightedness) can be corrected to a certain extent. Astigmatism is not correctable by the focus adjustment on the NVGs because it causes separate focal points in the eye.

If the pilot is willing to accept a slight blurriness of stars and objects at infinity, the depth of focus of the NVGs can be shifted for night LAT and have a minimal effect on distant objects. If each tube is initially focused on an object under good contrast at about 150 feet, the depth of focus can be brought in far enough to help resolution at more tactical ranges, such as that needed for marking overfly points and detecting small tactical targets. This procedure should cause objects at approximately 100 feet and infinity to be in reasonable focus, and objects from about 130 to 1000 feet to be in sharp focus.

1.8.8 NVG Test Set. The NVGs are an extremely important link in the night attack system. A small hand-held NVG Test Set checks each intensifier tube. Specifically, the test set checks for power, a low battery indication, optical tests, and an ASR test. Just as the night attack pilot would always perform a BIT on the aircraft avionics system, it is just as important that the NVGs be tested.

1.8.8.1 Pilot Considerations. The Cats Eyes goggles were designed to be as compact and light as possible. Even though they only weigh about 28 ounces, the goggles do noticeably shift the center of gravity of the helmet forward, making helmet fit critical. The helmet must fit snug enough to prevent rotation while pulling g’s and help prevent hot spots or pressure points along the crown area of the helmet. It must also allow the goggle to be positioned as close to the eyes as possible. Four types of helmet were evaluated during initial AV-8B Night Attack testing: the standard Navy form fit helmet (HGU-33), the advanced lightweight protective helmet for aircrew (ALPHA) helmet, a Flight Suits Limited custom form fit helmet, and a HGU-65 helmet made by Gentex, which is a modified version of the HGU-55 helmet used by the USAF.

The Gentex HGU-65 was the preferred helmet for meeting night attack requirements. It is made of Kevlar in order to reduce weight, has an integrated chin/nape strap which helps hold the helmet in position, and has an extra one-half inch cutaway at the brow. The higher cutaway allows additional room for proper alignment of the NVGs with the pilot’s eyes. Contrary to popular opinion, birds do fly at night, so there were numerous attempts during the flight test program to find a suitable visor which was compatible with the NVG combiner elements. The final visor configuration selected (see Figure 1-108) fits along the helmet edge roll and is recessed to place it closer to the pilot’s eyes. The visor is attached to the helmet by elastic straps, and when the proper size visor is matched to the helmet, it provides the necessary face protection while still fitting behind the NVGs. The goggles can still produce discomfort and fatigue on long flights but for most flights a properly fitting helmet, in conjunction with having the oxygen mask adjusted snugly, eliminates most problems.

1.8.9 Operational Considerations and Image Deficiencies. The NVGs are a relatively expensive piece of avionics gear whose circuitry and operational mechanisms do not respond well to abuse. The pilot must be careful not to drop the goggles, and never turn them on in a lighted area. Special considerations must be given to protecting the NVGs when operating in sandy or dusty environments, rainy or humid conditions, salt water conditions, and extremely cold temperatures.

If the NVGs are dropped or handled roughly, the MCP can shift and produce conditions known as shading and edge glow. Shading is that condition encountered when a full image cannot be attained in an intensifier tube. This condition will always begin on the edge of the image and move inward. Edge glow, like shading, will appear in the outer portion of the image, appearing as a bright border in a segment of the viewed image. In order to ensure that the bright segment viewed in the image is edge glow and not a result of a bright light in the NVGs FOV, the pilot should cup his hand over the tube to block out all light then determine if the edge flow is still visible. If the pilot encounters either one of these conditions, he should replace the NVGs.

Bright spots (sometimes referred to as white dots) and dark spots are actually two phases of the same condition. The spots occur as a result of irregular emission points on the photocathode of the image intensification tube. In the early stages, characterized by white dots, the spots may appear constant, or occasionally flicker. In time the white dots turn into dark spots as electron saturation literally burns through the photocathode. Neither condition necessarily means that a tube is unusable. As long as the pilot is comfortable with the amount of remaining image in the affected tube, the NVGs are acceptable.

A honeycomb pattern across the tube is not an indication of tube fault, but rather a condition that occurs when too much light enters through the objective lens. The honeycomb pattern is literally a reflection of the MCP. Removing the NVGs from the high light level environment should eliminate this condition.

Flashing, flickering or intermittent operation of the image may reflect an impending failure in the monocular, faulty wiring or impending battery failure. If switching or replacing the battery does not alleviate the condition, the pilot should reject the NVGs, or if already airborne, take appropriate action.

1.8.10 Visible and Near IR Considerations. The two most common terms used when discussing light as it pertains to the NVGs are luminance and illumination. Luminance refers to reflected or emitted light from an object or scene while illumination refers to the light striking the object or scene.

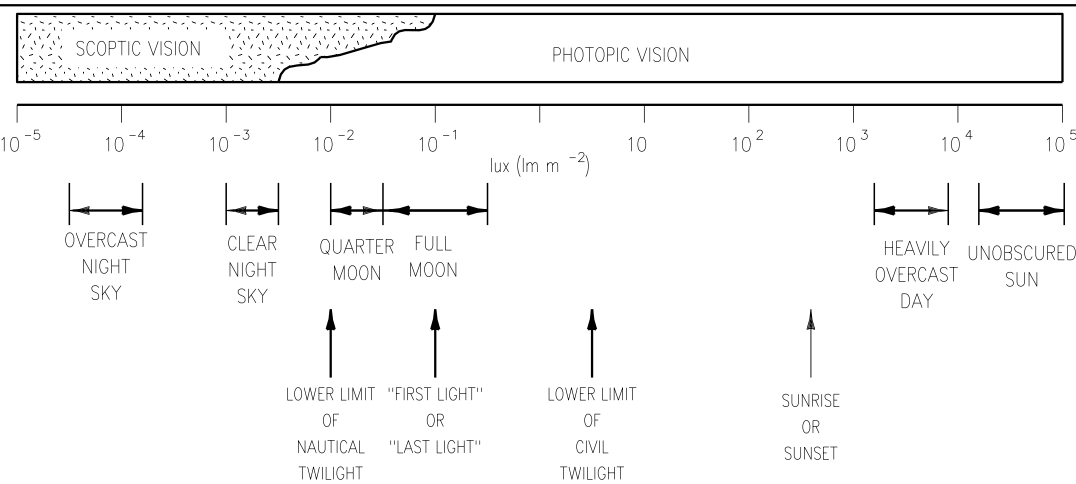
1.8.10.1 Luminance. Luminance, sometime called brightness, is the amount of light reflected or emitted from a surface and is usually expressed in units of foot-lamberts. An example of luminance is the moonlight which is reflected from objects in a given scene. Note that the illumination is the amount of light which strikes the ground and the luminance is the amount of light reflected by objects in the scene. The ratio of illumination (incident radiation) to the luminance (reflected radiation) is called the “albedo”, which varies depending on the composition and condition of the given surface. The albedos for some common surfaces are given in Figure 1-115. Most surfaces have different albedos, so while the illumination from the moon may remain constant, the luminance from the scene shows much variation. This is why the features of a blacktop road are more difficult to see than the features of a light colored concrete road. It is important to note the while ambient light provides the necessary illumination, it is actually the reflected light or luminance that the NVGs detect from objects and the terrain that allow the pilot to see. If all objects had exactly the same albedo then the eye would simply see only a bland scene with no detail. This in fact does happen when flying over a calm sea, or to a lesser extent, when flying over open desert or a snow covered scene with very little density or texture.

SOILS	DRY	WET	WETNESS Unspecified/Indifferent
Dark	0.13	0.08	
Light	0.18	0.10	
Dark - Plowed	0.08	0.06	
Light - Plowed	0.16	0.08	
Clay	0.23	0.16	
Sandy	0.25	0.18	
Sand	0.40	0.20	
White Sand	0.55		
SURFACES			
Asphalt			0.10
Lava			0.10
Tundra			0.20
Steppe			0.20
Concrete			0.30
Stone			0.30
Desert			0.30
Rock	0.35	0.20	
Dirt Road	0.25	0.18	
Clay Road	0.30	0.20	

FIELDS	GROWING	DORMANT	GREENNESS Unspecified/Indifferent
Tall Grass	0.18	0.13	0.16
Mowed Grass	0.26	0.19	0.22
Deciduous Trees	0.18	0.12	0.15
Coniferous Trees	0.14		
Rice	0.12		
Beet, Wheat	0.18		
Potato	0.19		
Rye	0.20		
Cotton	0.21		
Lettuce	0.22		

SNOW		ICE	
Fresh	0.85	White	0.75
Dense	0.75	Gray	0.60
Moist	0.65	Snow & Ice	0.65
Old	0.35	Dark Glass	0.10
Melting	0.35		

Figure 1-115. Albedos for Various Surfaces



SKY CONDITIONS	APPROX. LEVELS OF ILLUMINANCE – LUX (lm m^{-2})
DIRECT SUNLIGHT	1 – 1.3 x 10^5
FULL DAYLIGHT (NOT DIRECT SUNLIGHT)	1 – 2 x 10^4
OVERCAST DAY	10^3
VERY DARK DAY	10^2
TWILIGHT	10
DEEP TWILIGHT	1
FULL MOON	10^{-1}
QUARTER MOON	10^{-2}
MOONLESS, CLEAR NIGHT SKY	10^{-3}
MOONLESS, OVERCAST NIGHT SKY	10^{-4}

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Figure 1-116. Range of Natural Illuminance Levels

1.8.10.2 Illumination. Illumination, sometimes called illuminance (LUX), is the amount of light which strikes an object or surface at some distance from a source. An example is the amount of ambient light which strikes the ground from the moon, although the specific source is not important. A totally overcast night can still provide significant illumination from the reflection of city lights. In order to create a reference point, Figure 1-116 shows the amount of illumination associated with some naturally encountered light levels. There are many sources of ambient illumination which combine to light the night sky. Natural sources include the moon, stars, solar light and other background illumination. There are also artificial sources which include lights from urban areas, automobiles, fires, weapons, searchlights and flares. This illumination supplies ambient light but note that it does not include the reflected light or luminance which results from this light striking objects in the scene.

1.8.11 Lunar Considerations. In areas without cultural lighting, the moon normally provides the highest percentage of natural ambient illumination at night. Moonlight is actually no more than reflected sunlight as it has no sources of internal energy and is, therefore, essentially a dead body. The moon reflects about seven percent of the sun's incident radiation and its albedo changes continually as it arcs across the sky. The moon angle along its arc, changes approximately 15° per hour (1° every four minutes). Obviously ambient lunar light levels vary with these angular changes. Illumination from the moon is at its highest when the moon is at its zenith. The amount of lunar illumination reaching the earth is affected by the lunar phase, variation in earth-moon distance, albedo of the moon's surface and the moon's angular altitude.

1.8.11.1 Lunar Phases. The phase of the moon is determined by its appearance on earth resulting from its relative position referenced to the sun as it revolves around the earth. Note that half of the moon is always in sunlight, just as half of the earth has day while the other has night. Lunar phase only has meaning for an observer on earth. The four lunar phases are new, first quarter, full and last quarter. The rate at which the amount of disk illumination changes is sinusoidal. Hence, the rate of change around a new or full moon is low while the rate of change is high around a quarter moon. Any stage between a new moon and the first quarter or the last quarter and a new moon is called the crescent. Crescent implies that some but less than half of the moon's disk is visible. Physically the moon is located between the earth and the sun during this period. The moon at any stage between a first quarter and a full moon or a full moon and the last quarter is called the gibbous. Gibbous implies that at least half but not all of the moon's disk is visible. Physically the earth is located between the moon and the sun during this period. For night attack planning it is useful to consider the following four stages.

1.8.11.1.1 New Moon Phase. This phase covers the time in which less than one-quarter of the moon's disk is visible and lasts about eight days during the moons 28 day cycle. The new moon phase is characterized by very low light level and limited NVG operational conditions.

1.8.11.1.2 First and Last Quarter Moon Phases. These phases cover the time between one-quarter to three quarters disk illumination, with each phase lasting about six days. These two phases are shorter in duration because of the sinusoidal nature of the rate of change of disk illumination.

1.8.11.1.3 Full Moon Phase. This phase covers the time in which more than three-quarters of the moon's disk is visible and lasts about eight days, as in the new moon. This phase is characterized by very high light level once the moon rises above the horizon. Best conditions for NVG operations are 90 minutes after sunset to 90 min before sunrise.

1.8.11.2 Variation in Earth-Moon Distance. During the lunar cycle, there is a total variation of about 26 percent in the distance between the earth and the moon. Lunar illumination increases as this distance decreases.

1.8.11.3 Albedo of the Moon's Surfaces. Differences in albedo of the different illuminated portions of the moon's surface during the lunar cycle affect the amount of illumination that reaches the earth. The moon is about 20 percent brighter at first quarter (waxing) than at third quarter (waning) due to these differences in the lunar surface.

1.8.11.4 Moon's Angular Altitude. As previously mentioned, the angular altitude of the moon above the earth's horizon significantly effects the level of ambient light received. This effect is shown in Figure 1-117.

1.8.12 Night Sky With No Moon. While NVGs will operate down to starlight-only conditions on clear moonless nights, the stars actually provide only about one fourth of the ambient illumination. The greater portion of the natural light of the night sky comes from an effect called airglow, which accounts for about 40 percent of the night sky illumination. It originates in the upper atmosphere and is caused by solar radiation, which produces emissions from various atoms and molecules. Other minor sources of night illumination include the aurora, which is a luminous phenomenon seen in high latitudes, and zodiacal light, which is the diffused glow seen in the west after twilight, and in the east before dawn. Both the aurora and zodiacal light are caused by the scattering of sunlight from interplanetary particulate matter.

The majority of stars emit radiation that peaks between 0.8 and 1.0 microns (800 to 1000 nanometers). This means that most starlight falls within the response curve of the NVGs while being invisible to the human eye. This is one of the major reasons third generation goggles can be used under starlight-only conditions. The energy received by the NVGs gives many stars a twinkling quality which is poetic but can be confused as aircraft lights. Venus and Mars, which exhibit very definite halos, are especially strong transmitters for the NVGs.

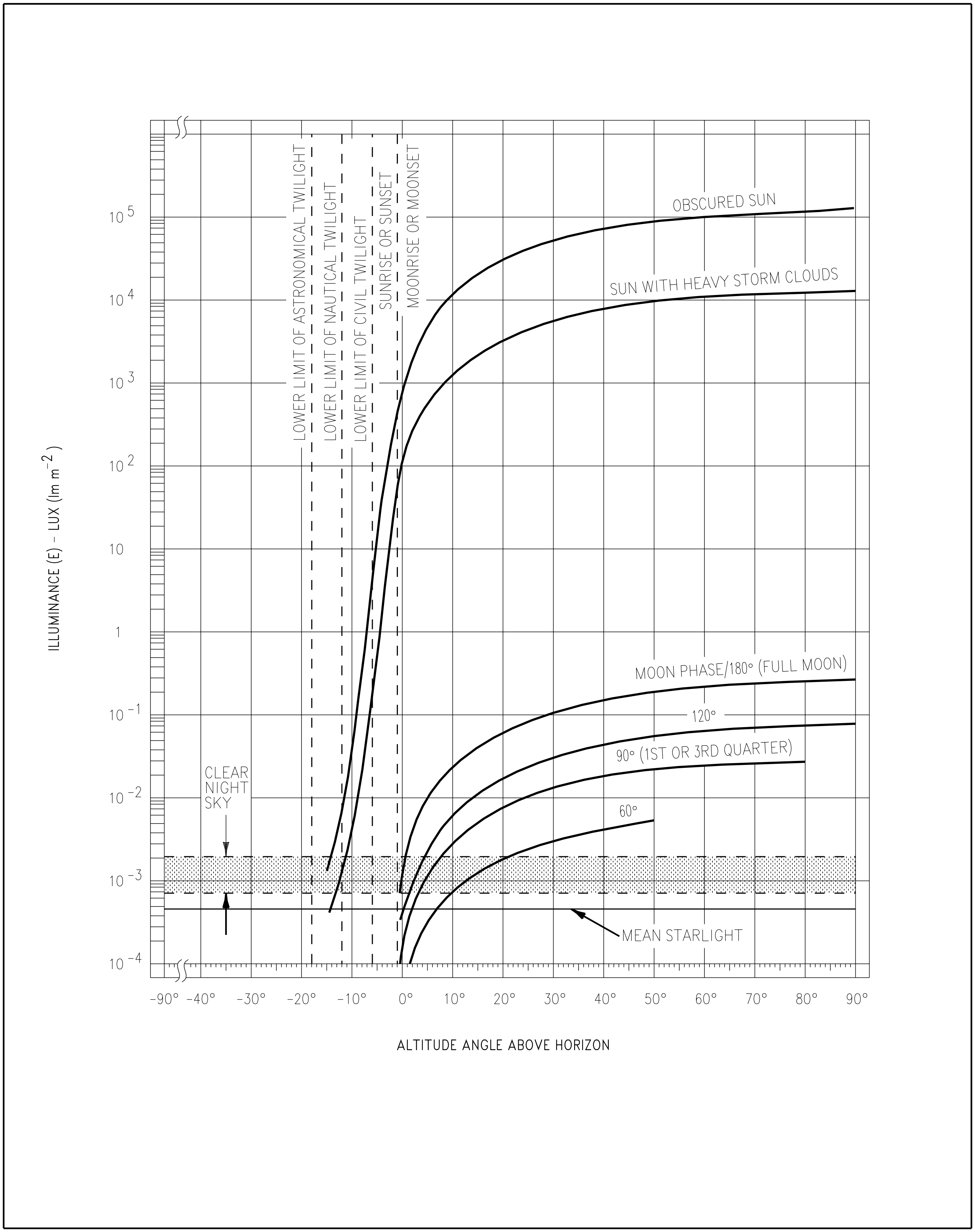

Figure 1-117. Illumination of the Moon

1.8.13 Artificial Light Sources. Highly populated areas can generate very significant levels of ambient light. Many of the discrete artificial sources exhibit overlapping halos which substantially reduces contrast and detail between sources. Although lighted areas can be seen from great distances, specific buildings or objects can not always be distinguished, unless they are recognizable by individual lighting patterns. When associated with an overcast, city lights can be reflected and actually supply increased illumination. Sodium lights on the back of farm houses can make a rural area look like an industrial complex. A baseball field lit up at night can look like a small town. Automobile lights provide excellent cues as to the presence of a road but the direct light from an automobile, especially halogen types, can be very disconcerting at low altitude. Light from weapon flashes, flares, and explosions contain significant levels of near IR light. The red lights on top of radio and microwave towers are visible from 10 to 30 nm, depending on the atmospheric conditions. Indeed, because they are so visible in the NVGs, their range can be hard to judge. Anti-collision lights on other aircraft can be seen at even greater distances than radio tower lights. Weapon flashes, flares, and explosions, which contain significant levels of near IR radiation, are intensified by the NVGs. The light from these sources is most pronounced under overcast conditions.

1.8.14 Weather and Visibility Restrictions. Any condition of the atmosphere which absorbs, scatters, or refracts the night sky's illumination, either before or after it strikes the terrain, will effectively reduce the usable light available to the NVGs. The exact amount of reduction is difficult to predict because a common factor cannot be applied to each condition of cloud or fog coverage. An estimation of light reduction can be made by considering the basic illumination as a starting point, and then knowing the particle size of the atmospheric condition (i.e., clouds or fog) and its density. Knowing the particle size and the density of the coverage is critical in considering the near IR wavelengths that light must pass through to strike the terrain, and be reflected for goggle usage.

Weather and visibility restrictions all serve to reduce either illumination, luminance, or both. Recognition of this reduction in the cockpit is sometimes very difficult. The changes are often very subtle reductions in contrast which are not perceived when viewed through the NVGs. The ABC in the intensifier tubes can hide these subtle changes by attempting to provide a constant image in spite of changing luminance conditions. If cues are perceivable, the pilot will have to be looking for them to catch their significance. Common cues to reductions in ambient illumination due to visibility restrictions include loss of celestial and ground lights; reduced contrast, depth perception/distance estimation and acuity or resolution; and increased graininess (scintillation) and a halo effect around light sources.

1.8.14.1 Clouds. Clouds are very difficult to describe for purposes of calculating attenuating effects because of variability. The problem is exacerbated by the fact that water in low level clouds is found in the gaseous, liquid, and sometimes even solid forms. Water vapor can exists at all temperatures. Because the amount of water vapor a cloud formation can hold increases with temperature, summer clouds generally have higher liquid water contents than winter clouds. These liquid water particles are normally less than 50 microns in diameter, and are general opaque to visible and near IR radiation. For this reason, thick dense clouds can be easily seen with NVGs, especially when silhouetted against the night sky. This also means that thick clouds will reduce the amount of illumination which strikes the ground, and therefore, reduce the available luminance to the NVGs. Thin and wispy clouds have greater space between particles, thus they pass more of the near IR radiation without scattering. Near IR wavelengths have a greater chance of passing through these clouds without being scattered than does the shorter visible wavelength. For this reason it is possible for thin, wispy clouds to be seen by the naked eye (because the visible light is scattered) but be invisible when viewed through the NVGs. This potential invisibility is possible given three conditions:

1. The clouds are thin and wispy, at least on the edges.

2. The clouds are low level and set in against the terrain, vice being silhouetted against the night sky.

3. The ambient illumination is either very high, which degrades NVG resolution, or very low, which causes NVG scintillation.

The invisibility of thin clouds which progress to thicker ones hiding terrain features, can create a severe hazard for NVG operations. Low clouds lying on and between hills present a particularly dangerous situation because of the inability of the pilot to distinguish between the clouds and the terrain. In that regard, a common question occurs: If the cloud is invisible, why can't the pilot see the terrain behind it? The answer is predictably complex. First, the cloud reduces visual and near IR contrasts and detail. This produces a false perception of distance, resulting in a pilot either not seeing the terrain, or thinking it is much farther away than it actually is. Second, the cloud may get progressively thicker, allowing the pilot to progress through the cloud without initially perceiving a cloud wall. If a cloud is perceived, its distance is misjudged as being off at a distance.

Clouds reduce illumination to an extent dependent on the amount of cloud coverage and density, or thickness, of the clouds. For example, a thick, overcast layer of clouds will reduce the ambient light to a much greater degree than will a thin, broken layer of clouds. As stated, clouds obstruct the night sky illumination, but they can reflect and enhance cultural lighting. The pilot must be alert for a gradual reduction in light level, and notice the obstruction of the moon and the stars. The less visible the moon and stars, the heavier the cloud coverage. If the NVG image becomes grainy and begins to scintillate (sparkle), this is an indication that weather may be causing a low ambient light condition. Shadows obscuring the moon's illumination is another indication that clouds are present. These shadows appear as dark areas on the ground, and can be detected by observing the varying levels of ambient light along the route.

1.8.14.2 Fog. The effects of fog on the NVGs are similar to those of clouds. Generally, fog is distinguishable from clouds only in regard to its distance from the ground. Particle size varies from two to 20 microns, which is very similar to a cloud. Typically, fog has fewer particles, and a smaller range of particle size than clouds. Fall is the most likely season, and early morning the most likely time to encounter fog. Urban areas tend to have less fog (probably due to urban heat islands) than rural areas, and mountainous areas tend to have more fog than sites nearer sea level. Chances of fog increase as temperatures decrease, and the dew point spread approaches zero. A decrease in the intensity of ground lights indicates an increase in the moisture content of the air. A halo effect around ground lights, which is more pronounced with NVGs, also indicates that moisture in the air is high and ground fog may be forming. If the size of the halo increases, a weather restriction could be developing and the pilot may be flying into IMC conditions.

1.8.14.3 Rain. Rain, like clouds, is difficult to predict in regard to its effect on the NVGs. Droplet size and density are key ingredients to its visibility or invisibility through the device. Light rains or mists cannot be seen by the NVGs, but will effect contrast, distance estimation, and depth perception. Heavy rains are more easily perceived due to the large droplet formation on the windscreen.

1.8.14.4 Snow. Snow occurs in a wide range of particle sizes and geometries. Snow crystals, while small in size, are generally large in comparison to the wavelength of visible and near IR radiation and will easily block or scatter those wavelengths. However, snow will not normally degrade IR radiation as much as fog and rain due to lower densities. The greatest density condition involving snow will occur during vertical operations or road operations. This can create a condition referred to as white out, which effectively blocks the NVGs.

1.8.14.5 Sand/Dust. The effect of blowing sand or dust on the NVGs is significant because it completely blocks the near IR radiation striking and reflecting from the terrain. This condition is commonly called brown out by the helicopter community, and is especially common during desert landings.

1.8.14.6 Obscurants. Battlefield obscurants, whether smoke or chemical, produce similar effects to those described above. They will be most detrimental to NVG operation if they contain a mixture of small and large particulates, and are fairly dense.

1.8.14.7 Lightning. At least one weather phenomenon increases illumination. Lightning flashes, associated with thunderstorms, have an effect similar to that of a bright flare. The intensity of the illumination depends on proximity to the thunderstorm.

1.8.15 NVG Scene Interpretation. NVG scene interpretation is dependent on many factors, as previously discussed. There are, however, some generalizations which can be made to serve as a baseline.

1.8.15.1 Roads. The surface of some dirt roads provide excellent contrast with surrounding terrain. Roads which cut through heavily forested areas can be recognized if they are visible through the foliage. The light color of concrete highways, normally an excellent reflective surface, is easily identified during most light level conditions. Asphalt roads are usually difficult to identify in a heavily vegetated area, because the dark surface absorbs available light; however, in desert areas the surrounding contrast can make asphalt roads readily detectable. The presence of vehicular lights can be the first identifier of a road. Highways and road bridges that run perpendicular to the flight path can be detected by picking up the moving vehicular lights several miles away.

1.8.15.2 Water. There is very little color contrast between a landmass and a body of water during low light conditions. When viewed through the NVGs, lakes or rivers appear dark gray in color, and basically look like black holes. As the light level increases, the water begins to change color, land-water contrast increases, and reflected moonlight is easily detected. When overflying large open areas of calm water, the light from reflected stars can be disconcerting. When a surface wind exists, the whitecaps can provide contrast to assist in determining AGL, but flight over open water is best performed IFR.

1.8.15.3 Open fields. Contrast is very poor in fields covered with vegetation. Most crops are dark colored and absorb light. During the harvest or the dormant season, the color of the vegetation changes to a lighter color and contrast improves. A freshly plowed field lacks vegetation, but because of the coarse texture of the upturned soil light is absorbed and very little is reflected.

1.8.15.4 Desert. Open desert presents a washed-out image through the NVGs. This is due to the poor contrast offered by the lack of objects in the scene. Military targets such as a battle tank are difficult to detect with the NVGs, even if they are dark and provide good contrast with the desert terrain. Camouflaged military targets have an extremely low probability of detection with the NVGs. Mountain ranges can be easily identified, because of the dark color of barren mountains contrasted against the light color of the desert floor. Low rises in terrain, lying between the aircraft and higher ranges, are difficult to identify, and present real problems.

1.8.15.5 Forested Areas. The NVGs can give a false impression by making tall trees and forests look like bushes. Heavily forested areas do not reflect light efficiently, and solid canopied forest generally appear as dark areas at night. Excellent contrast does exist between deciduous and coniferous trees as well as between open fields, and surrounding forested areas. The forested areas associated with the high mountains of the American west offer very good texture and contrast for the NVGs.

1.8.15.6 Snow. Snow provides the best natural reflectivity as it reflects about 85 percent of its luminance. Under high light levels, this illumination can provide excessive light, which in turn can lower intensifier tube output which degrades esolution. On the other end of the scale, a moonlit night, even over an overcast 3000 feet thick, provides enough light to conduct night LAT. The ability to conduct night LAT under these conditions depends on a sufficient number of objects protruding through the snow for contrast and density. Terrain recognition can be more difficult in a snowy region due to snow obscuration of prominent landmarks.

1.8.16 Night Vision Goggles Flight Preparation. Cats eyes should be checked for proper operation before every flight. Inspect the NVGs in the dark, viewing a plain white scene, for shading, edge glow, bright spots, flashing, flickering, or intermittent operation as follows. See Figure 1-118.

1.8.16.1 Shading. Both intensification tubes should portray a perfect circle. If shading is present, you will not see a fully circular image. Shading always begins on the edge and moves inward. Replace the NVGs if this condition exists.

1.8.16.2 Edge Glow. Edge glow is a bright area in the outer portion of the viewing area. To check for this defect, block out all light by cupping your hand over the lens. Replace the NVG if this condition exists.

1.8.16.3 Bright Spots (White Dot). This condition is caused by a pinhole in the phosphorus screen. Spots may flicker or may appear constant. Check by cupping your hand over the lens to block out all light. If bright spots or white dots are visible, replace the tubes.

NOTE

> If the bright spots or edge glow disappears when the light is blocked out, the binocular may not be bad. Check to make sure the bright spots or edge glow were not simply bright areas on the viewing scene. Shading may also be caused by improper tilt, eye span, or vertical adjustments.

1.8.16.4 Flashing, Flickering, or Intermittent Operation. The NVGs may appear to flicker on and off, or the output may flash. This can occur in one or both tubes. If you see more than one flicker consult Flight Equipment.

1.8.16.5 Dark Spots. Black marks which may look like spots or streaks are acceptable as long as the marks do not interfere with the mission.

1.8.16.6 Fixed Pattern Noise (Honeycomb). A faint honeycomb pattern is prevalent in high light levels, such as those encountered when flying into a rising moon. This condition is acceptable as long as the pattern does not interfere with the mission.

1.8.16.7 Adjustments and Controls. The adjustment mechanisms shown in Figure 1-119 have been designed to be operated by the left hand. The following adjustments and controls are provided.

1.8.16.7.1 Vertical Adjustment. This is achieved by rotating the thumb wheel on the top of the helmet mount. Turning it clockwise as viewed from below moves the NVG down. Adjust the NVGs so the combiners are directly in front of the eyes.

1.8.16.7.2 Inter Pupillary (IPD) Adjustment. This is achieved by rotating the IPD knob on the left side of the cross slide assembly. Turning it clockwise as viewed from the left moves the monoculars closer to each other. This adjustment should be accomplished before mounting the NVG on the helmet. Measure the distance between your pupils and set the eyepieces that distance apart (left side to right side) by the inter pupillary adjustment knob.

1.8.16.7.3 Fore/Aft Adjustment. This is achieved by rotating the forward facing knob at the center of the cross slide. Turning it clockwise as viewed from behind moves the monoculars forward.

1.8.16.7.4 Tilt Adjustment. This is achieved by rotating the forward facing knob at the left side of the cross slide. Turning it clockwise as viewed from behind tilts the line of sight of the monoculars down.

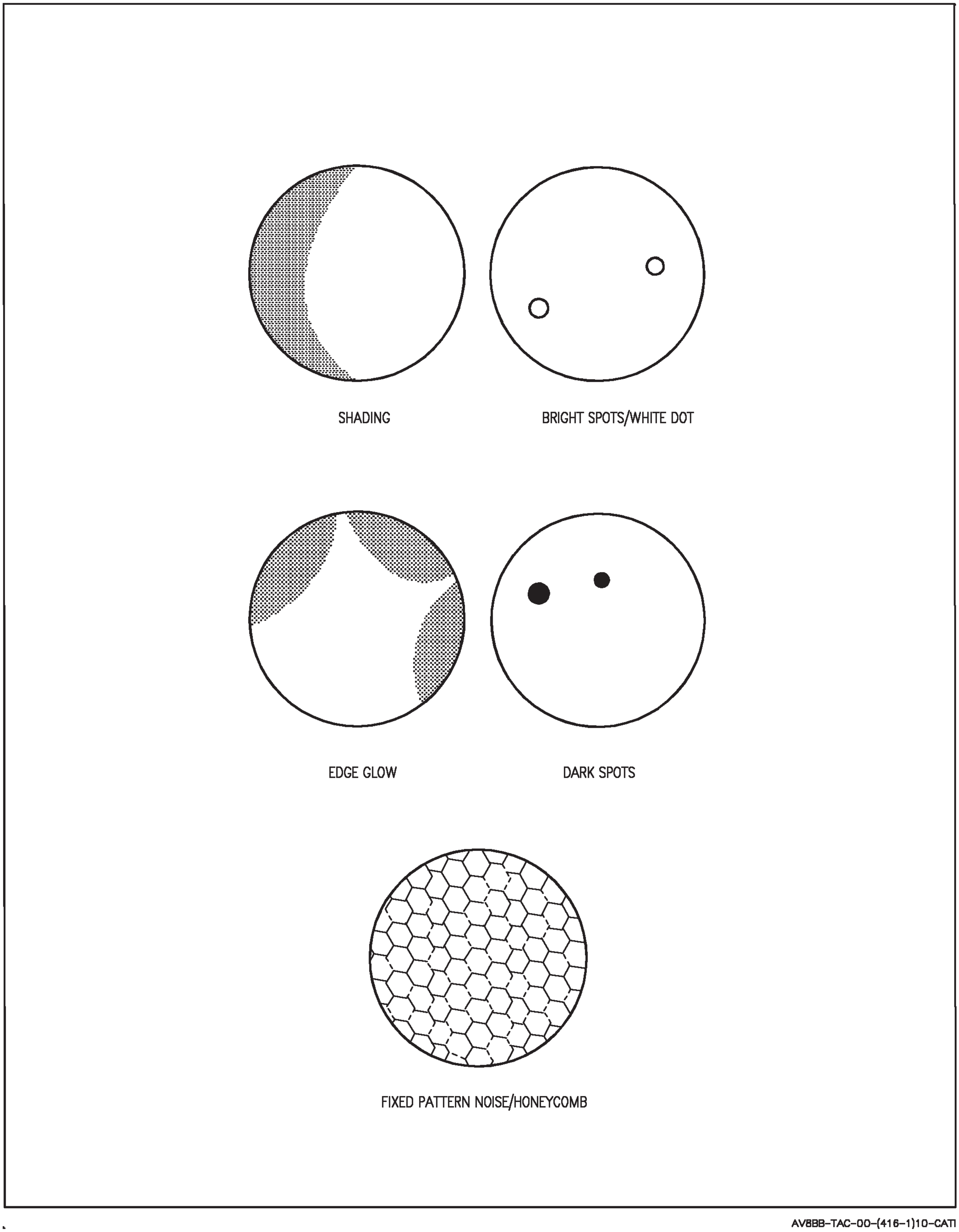

Figure 1-118. NVG Tube Faults

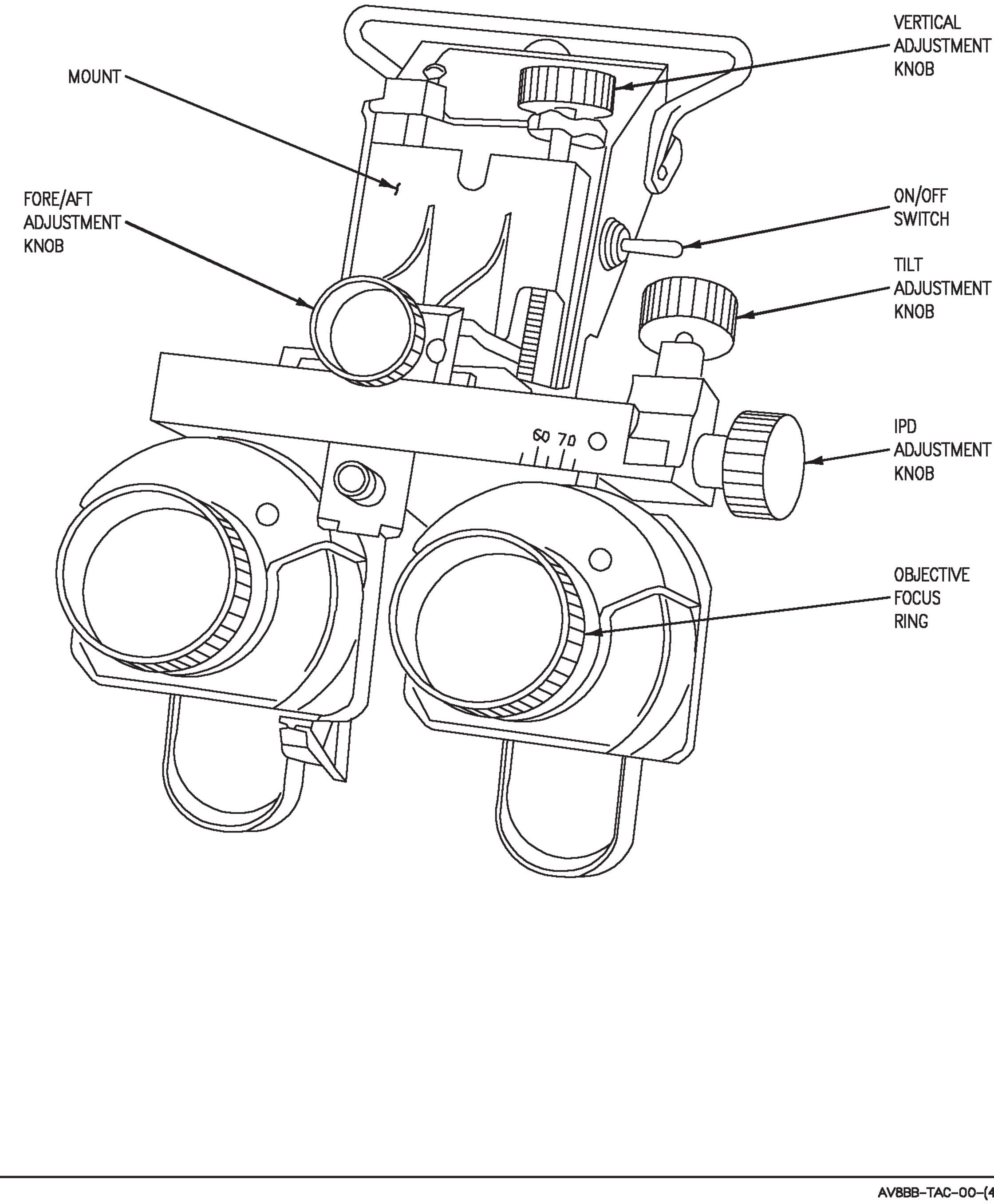

Figure 1-119. NVG Adjustments

1.8.16.7.5 ON/OFF/ON Switch. The switch, on the left side of the mount has three positions:

UP	Switches on both intensifier tubes and activates the auto scene reject facility. Uses the upper battery.
CENTRAL	Switches system OFF.
DOWN	Switches on both intensifier tubes. Auto scene reject is inoperative in this position. Uses the lower battery.

CAUTION

To prevent damage to the image intensifier tubes, operate the NVGs in night time conditions only. DO NOT turn the NVGs on in bright areas unless day filters are attached to the lens.

1.8.17 Attaching to Helmet

1. Put helmet on and fasten chin strap.
2. Grasp NVG by the mount using the thumb and center finger with the eyepiece towards you.
3. Slide the mount up centrally on the helmet plate until the mount hook engages the plate top bar, then rotate NVG down until a positive click is felt. Check for security.
4. Adjust the vertical position of the NVG to place the eyepiece directly in front of the eye.
5. Adjust the fore/aft position to give one inch spacing between the eye and the eyepiece. This is just more than the width of your thumb.
6. If necessary, adjust the tilt to ensure correct line of sight adjustment.

1.8.18 Normal Operation. Turn the NVG on by selecting one of the ON positions. If the UP position is selected, the NVG display will be dimmed to extinction when looking within ±10° of the HUD centerline, and will light when outside this cone. In the DOWN position the NVGs will operate continuously.

1.8.18.1 Auto Scene Reject System. An auto scene reject (ASR) detector is attached to the NVGs between the intensifier tubes. This detector serves to shut off the NVGs when viewing the forward looking infrared (FLIR) image on the HUD. The ASR acts as an angle sensing device in association with a fixed infrared (IR) emitter mounted on the HUD video camera. When ASR and FLIR is selected for display on the HUD, the ASR blanks the NVGs when the pilot's line-of-sight is pointed within ±10° of the HUD centerline. At greater angles the detector no longer detects the IR energy from the emitter and the NVGs return to normal operation. The ASR feature is pilot selectable by the ASR ON/OFF/ON switch on the left side of the NVGs.

1.8.18.2 IR Emitter. An IR emitter mounted on the HUD video camera (see Figure 1-120) provides an IR source for blanking the NVG's when the pilots line-of-sight is pointed within ±10° of the HUD centerline.

1.8.18.2.1 Vertical Adjustment. An adjustment arm on the IR emitter allows for a +12/−10 degree vertical adjustment to position the IR emitter within the range of the ASR adjustment on the night vision goggles. This adjustment arm is normally set to approximately center position and adjusted only when the ASR adjustment on the NVGs will not provide the desired alignment.

1.8.18.3 Battery Power. NVG power is provided by two lithium batteries contained in the top of the mount assembly. The required power can be provided by either battery. Battery life can be as much as 12 hours (3 to 5 hours typical). However, battery life is decreased depending upon storage time and ambient operating temperature.

A red low battery indicator light, located on the right combiner eyepiece, is designed to illuminate at least five minutes prior to a battery

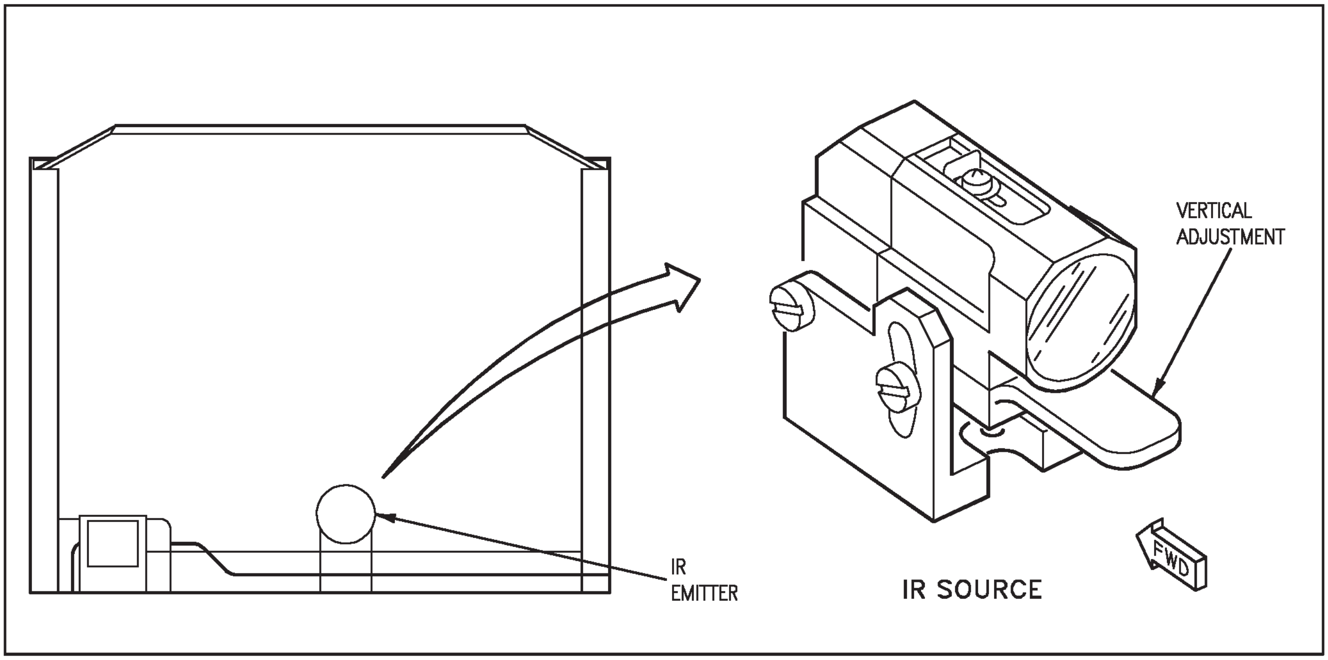

Figure 1-120. IR Emitter Control

failure. This light is located in the pilot's FOV to alert him when to switch batteries.

1.8.19 Removing NVGs

1. Turn system OFF.

2. Grasp the mount with thumb and center finger. With the index finger, pull forward on the release lever, and lift NVGs off in a forward movement.

3. Place NVGs in carrying case or on cockpit hard mounting point.

1.8.19.1 Emergency Removal of NVGs. Grasp the release lever with cupped fingers and pull forward. The NVGs will instantly release.

1.9 LASERS

1.9.1 Principles of Laser. In order to understand the more intricate aspects of the laser energy, one must first have a good basic understanding of what laser energy is, how it is employed, and the conditions that influences its performances.

1.9.1.1 Laser Definition. The term laser is an acronym derived from the term Light Amplification by Stimulated Emission of Radiation. Laser light is coherent light, meaning that the radiated electromagnetic wave trains have a definite relationship with each other and are in phase. This is in contrast to random light that is emitted from an ordinary light bulb or IR energy which is emitted from an IR source. Laser light can be either visible or invisible depending on its wavelength (or frequency). Energy radiated from a military laser is invisible to the human eye.

1.9.2 Laser Energy. Laser energy travels in a straight line. Laser designators transmit coded pulses of this laser energy to be reflected off the target and detected by the Laser Maverick missile. Through the use of mirrors, filters, and detectors, this energy can be gathered, focused, and changed into an electrical signal.

1.9.2.1 Reflectivity of Laser Energy. Laser energy is reflected in various ways, depending on the type of target reflecting surface, the shape of the reflecting surface, and the angle at which the laser energy beam strikes the target surface. This

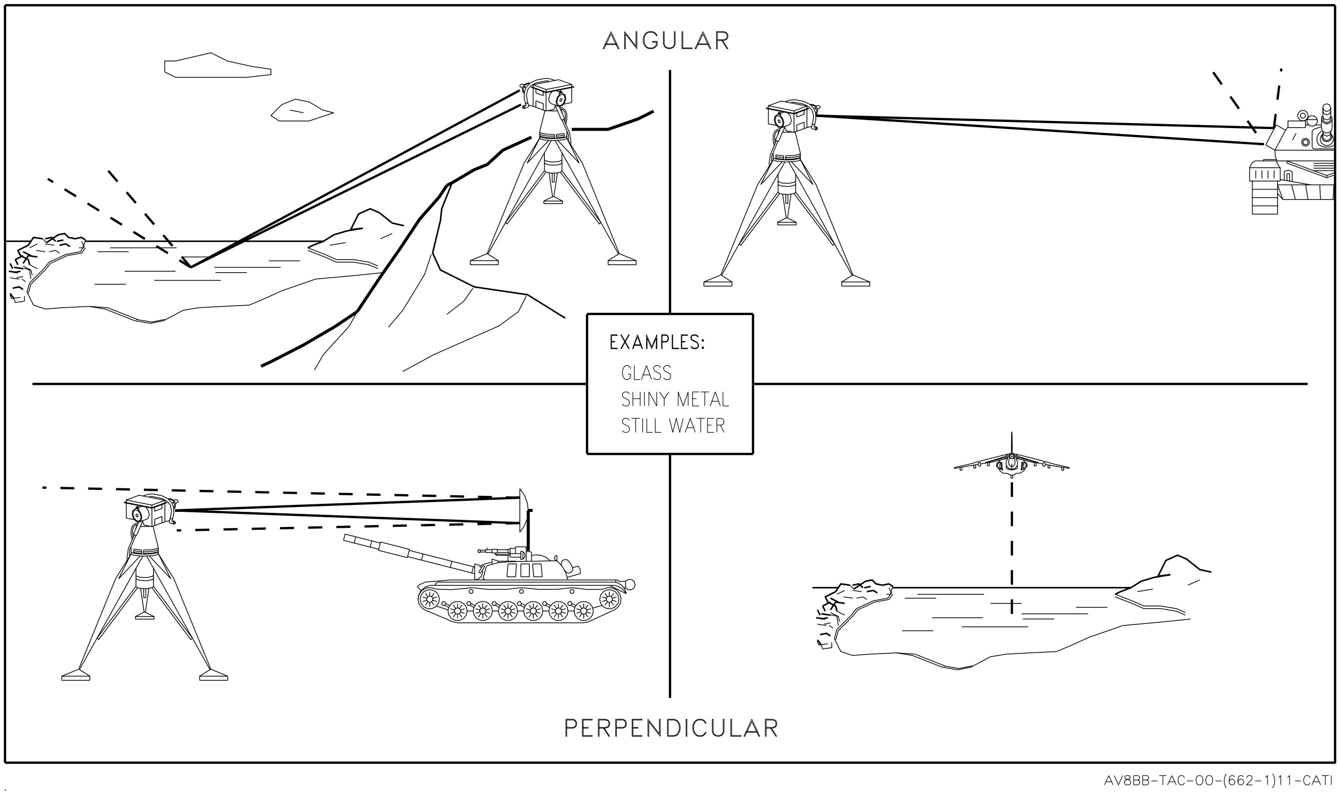

Figure 1-121. Specular Reflection

information is important in determining where the laser seeker needs to be in order to acquire and home on the reflected energy. The following is a brief description of how the beam is reflected from various types of target surfaces.

1.9.2.2 Specular Reflection. The laser energy reflects in a narrow beam from flat bare shiny metal as well as from mirror-like and glass surfaces. Any seeker looking for this laser energy would have to be oriented in this narrow area of reflection to acquire the target. See Figure 1-121 for perpendicular and angular specular reflections.

1.9.2.3 Diffuse Reflection. When laser energy strikes a rougher surface such as a tank, truck, or building it scatters in a larger spherical arc as shown in Figure 1-122.

1.9.2.4 Spillover. Laser energy spillover occurs when the laser spot is larger than the target. Reflections from objects near the target may occur as show in Figure 1-124. When this occurs, the seeker may acquire the wrong spot. This is especially true of trees and other foliage which are excellent laser reflectors.

1.9.2.5 Podium / Blocking Effect. Laser energy reflections can be blocked by intervening objects or by the target itself if the seeker is not in the proper position. This is referred to as the podium or blocking effect. See Figure 1-125.

1.9.3 Material Composition Factors. The laser energy reflected from a target is affected by the target's composition, size, shape, color, and mobility factor. Surface reflectivity is important in determining the amount of laser energy that is reflected to the receiver. Figure 1-123 exemplifies various materials and their associated reflectivity factor.

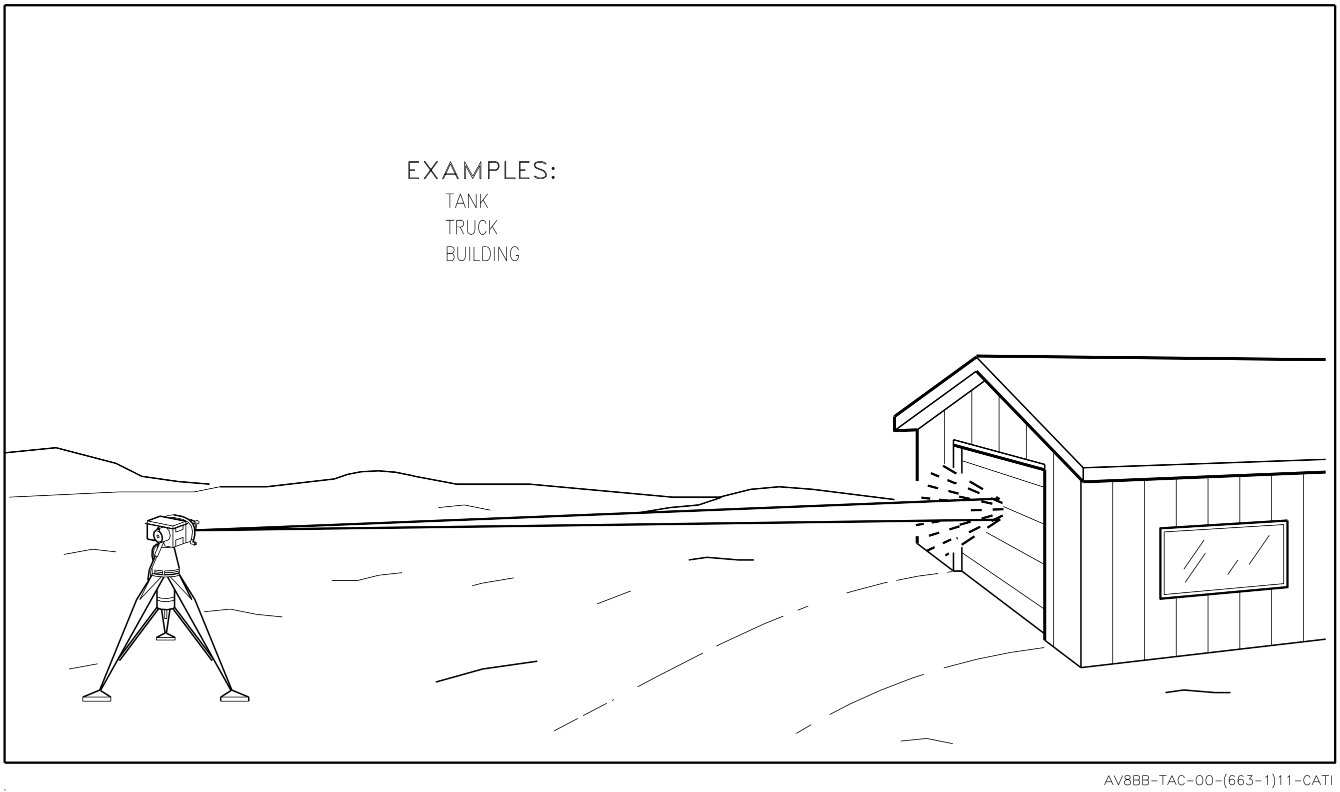

Figure 1-122. Diffuse Reflection

MATERIAL	PERCENT REFLECTIVITY
Brick	55-90
Vegetation	30-70
Unpolished aluminum	55
Olive drab metal (dirty)	2-30
Concrete	10-15
Asphalt	10-25
Water	2

Figure 1-123. Reflectivity Reference

1.9.3.1 Surface Texture Types. The target's surface texture characteristics have a large impact on total reflectivity. There are two types of surface texture characteristics: specular and diffuse.

(a) Specular. Specular reflection is usually caused by smoother surfaces which reflect the beam in a uniform pattern.

(b) Diffuse. Diffuse reflection is usually caused by rougher surfaces which cause the energy to be reflected in all directions. This is usually the most predominant type of reflecting surface on the battlefield.

1.9.4 Atmospheric Effects On Laser Energy. Laser energy will pass through a vacuum with the intensity decreasing inversely with the square of the range. As the distance the energy travels doubles, the intensity decreases by a factor of four. Outside of a vacuum the effects of the atmosphere must also be considered. The effect of atmospheric particles on laser energy is to scatter and absorb some of the

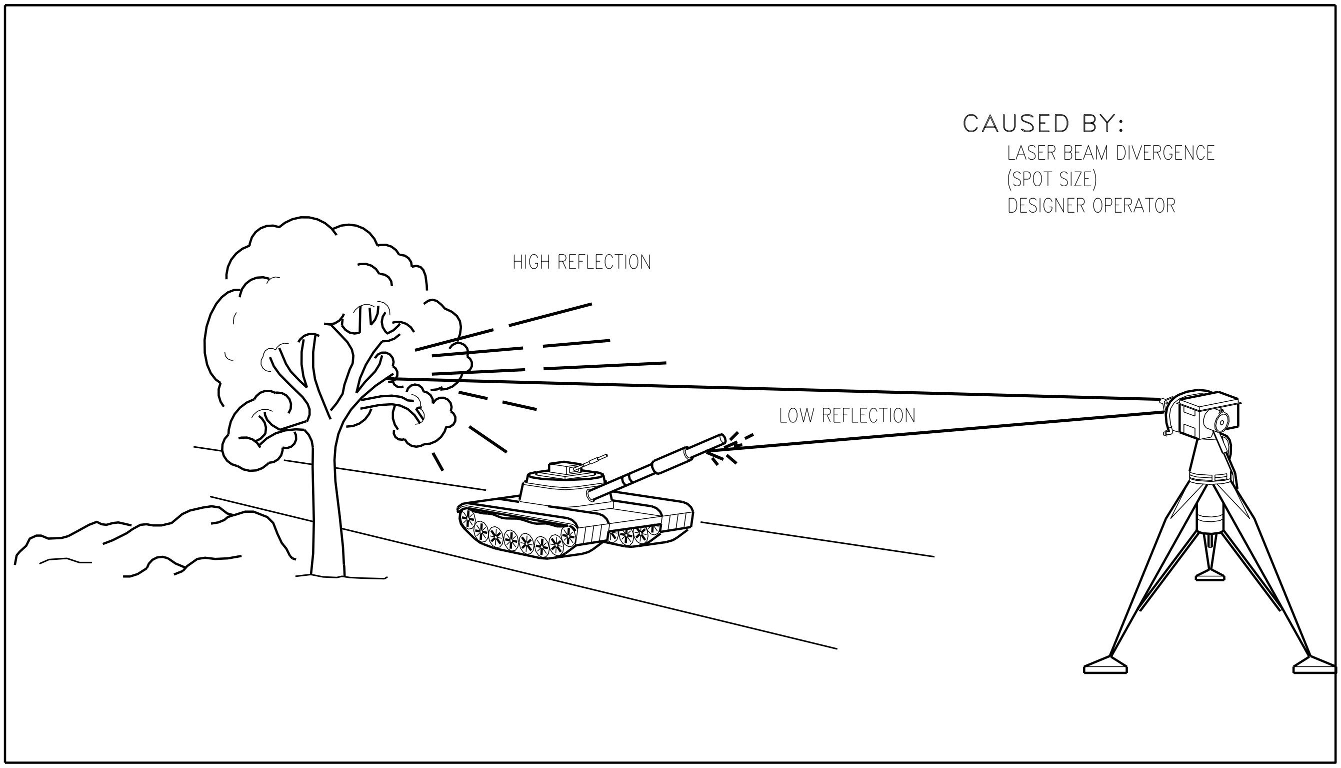

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Figure 1-124. Spillover

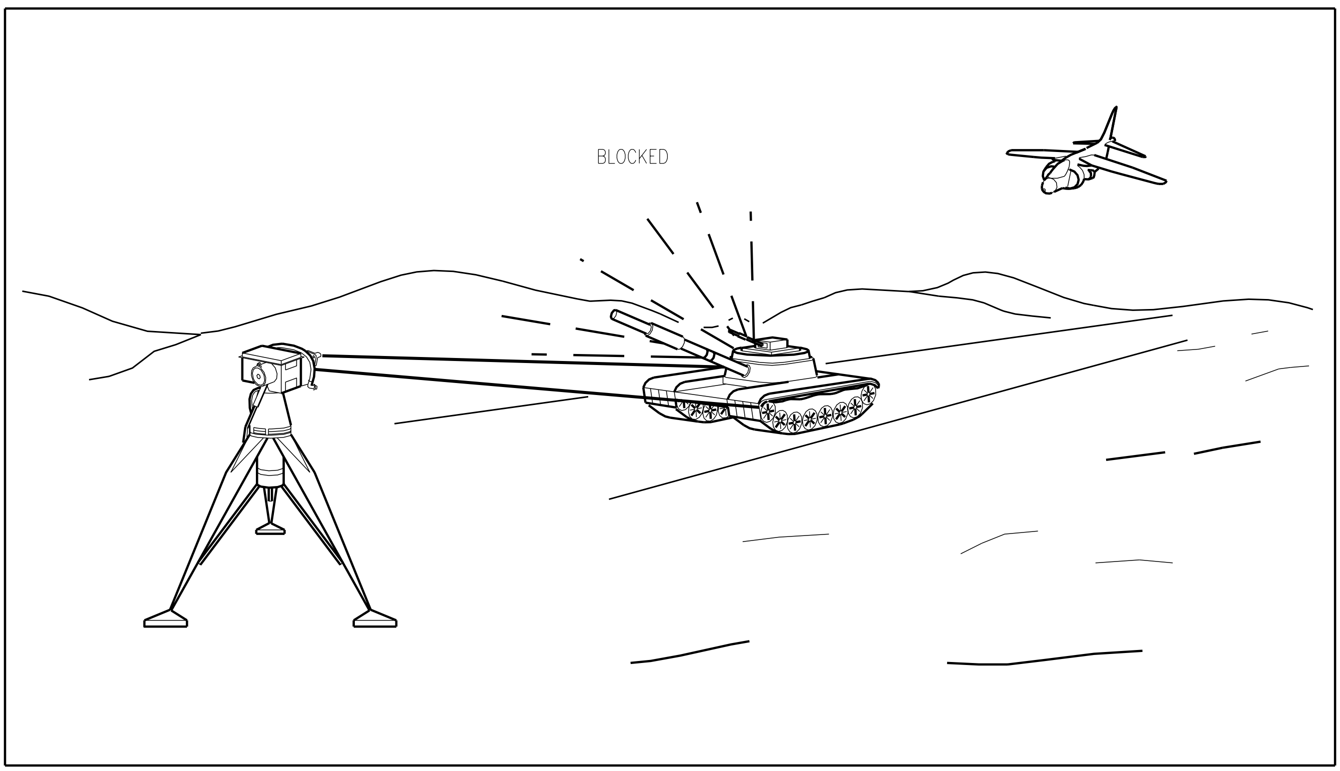

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Figure 1-125. Podium/Blocking Effect

energy that is transmitted. This reduces the amount of energy reaching the target and subsequently reflected to the seeker. Attenuation of laser energy is primarily due to scattering and falls into three loose categories related to the size of the atmospheric particles. The three categories are Rayleigh scattering, Mie scattering and nonselective scattering.

1.9.4.1 Rayleigh Scattering. Rayleigh scattering occurs when the scattering particles (primarily air molecules) are considerable smaller than the wavelength of the laser energy being utilized. On a clear day they are the predominant scattering component in the atmosphere. Rayleigh scattering is responsible for the least amount of laser energy attenuation.

1.9.4.2 Mie Scattering. Mie scattering occurs when the scattering particles are roughly the same size as the wavelength of the laser energy. Smoke, haze, and light fog fall in this category. These particles cause a significant amount of scattering of laser energy.

1.9.4.3 Nonselective Scattering. Nonselective scattering occurs when the scattering particles become much larger than the wavelength of the laser energy and is responsible for the greatest amount of laser energy attenuation within the atmosphere. The major factor in this category is water vapor, although dust can also be a significant contributor. The measure of the amount of water vapor in a unit volume of air is absolute humidity. Absolute humidity is a function of relative humidity and temperature. As relative humidity and temperature increase, absolute humidity also increases. The higher the absolute humidity, the greater the scattering effect and attenuation of laser energy.

Figure 1-126 is a brief breakdown of some common materials and factors which are important as to how reflectivity and atmospheric factors impact laser energy transmission and reflection.

1.9.5 Laser Designators. The Laser Maverick missile acquires, locks-on, and guides to a target using laser energy reflected from a target being illuminated by a laser designator. Laser designators/rangefinders emit discrete pulses of infrared energy which are invisible to the naked eye. The characteristics of these pulses are determined by the pulse repetition frequency (PRF) code of the laser energy beam. The PRF code can be set by a series of switches on the equipment.

To be employed together, designators and Laser Maverick missile seekers must use the same PRF code. Since the Laser Maverick missile seekers have a limited FOV to see the laser energy reflected from a target, their LOS must be toward the target and also must be within the field of energy reflected from the target. The timing of target designation by laser designators is critical to optimize laser-guided munitions terminal guidance.

WARNING

Strict adherence to laser guided weapons employment doctrine and geometry is necessary to prevent inadvertent targeting of air and ground laser designators.

1.9.5.1 Laser Designator Types. The AGM-65E Laser Maverick missile is compatible with standard military ground and airborne laser designators. The military laser is the Neodymium: Yttrium Aluminum Garnet (Nd:YAG) Laser which radiates in the invisible near infrared region at 1.06 microns. The most common ground and airborne designators used in the field are the laser target designator (LTD), modular universal laser equipment (MULE), ground/vehicular laser locator designator (G/VLLD), target recognition attack multisensor (TRAM) (airborne, A-6E), and detecting, ranging, tracking system (DRTS) (airborne, OV-10D). Of the three ground designators, LTD is the smallest, and G/VLLD is the largest.

1.9.5.1.1 Laser Target Designator (LTD). The LTD is a hand held snub-nosed rifle-like laser designator. It is equipped with a telescopic sight for precision aiming, and it can be fitted with an infrared night sight. It can be carried and operated by one man.

Atmospheric Condition	Clear Day	Light Haze	Light Fog
Attenuation Coefficient	0.11	0.36	1.29
Reflective Coefficient Ideal Reflector: 1.00	11 nm	5 nm	2 nm
Vegetation and unpolished aluminum: 0.55	10 nm	5 nm	2 nm
Metal and asphalt: 0.33	9 nm	4 nm	2 nm
Concrete: 0.10	7 nm	3 nm	1 nm
NOTE: The values given for the attenuation coefficient are indicative of an average condition. Light Haze and Light Fog are subjective classifiers and are provided only for the purpose of comparison.			

Figure 1-126. Comparative Effects of Atmosphere

1.9.5.1.2 Modular Universal Laser Equipment (MULE). The MULE is carried into the field by two personnel. Normally, it is tripod mounted for stabilization but can be hand held while operating. The MULE is equipped with a telescopic sight and is night sight capable.

1.9.5.1.3 Ground/Vehicular Laser Locator Designator (G/VLLD). The G/VLLD is carried into the field by two members of a Fire Support team. It can also be installed on specially equipped vehicles. Because of its weight, it must be mounted on either a tripod or vehicle. Its high power sight allows it to track small targets at long ranges. G/VLLD is also night sight capable. The system gains mobility and armor protection when turret-mounted on a fire support team vehicle. Optics and controls can be operated from the vehicle targeting station.

Both the MULE and the G/VLLD are equipped with rangefinders and capable of data link communications with fire direction centers to provide precise target information.

1.10 ANGLE RATE BOMBING SYSTEM (ARBS)

1.10.1 Introduction. On Day and Night Attack aircraft, the Angle Rate Bombing System (ARBS) is a passive system which provides day and night attack capability by using either reflected light images (TV mode) or reflected laser energy (LST mode). The ARBS system provides a flexible, accurate, rapid acquisition, optical, bomb delivery capability to the AV-8B aircraft. The angular rate concept allows for a simple, light weight system by substituting mathematical sophistication for hardware complexity.

1.10.2 Concept. ARBS is a bombing system which utilizes rate of change of the Line of Sight (LOS) Angle between the aircraft and target to compute slant range. When this value has been computed, the system will provide for and automatic weapons release to impact the designated target. This is accomplished through the MC which processes the LOS information along with air data and attitude information from other aircraft sensors to compute this target range. This data in conjunction with ballistics data results in computed weapon release points. An angular rate of change of the sight line to the target, (line of sight rate) referenced to the velocity vector, is required for ARBS deliveries. The pilot can utilize either the ARBS DMT or the INS for designation and tracking of surface targets. The DMT provides both TV and LST sensors to provide LOS angles and angle rates to the MC for computation of target range, height and weapon release solution. The INS mode uses either coordinate position or HUD symbol LOS angles, inertial velocities and either barometric or radar altitudes via the MC to determine the release solution.

1.10.3 ARBS Theory

1.10.3.1 Background. Angle rate bombing provides a simple means to calculate weapons delivery through a sophisticated mathematical process. What we need to know before we can make the necessary calculations are:

1. Range to Target. The primary ranging method is by using ARBS via the DMT. The ARBS, via the DMT, uses target angular motion (in two phases) to kinematically calculate target range and aircraft motion relative to a fixed point in space.

2. Velocity (TAS). The ADC supplies TAS information to the MC. Inputs required are:

   (a) Static pressure

   (b) Dynamic pressure

   (c) Temperature

   The velocity is further refined using inputs from AOA and INS pitch and roll angles to give the direction of the vector.

3. G. The INS sends a signal of the direction and magnitude of the g-force.

4. Groundspeed. During INS computations for navigation purposes, a signal of groundspeed is produced.

5. Target Motion. Target motion can be calculated in CCIP or AUTO when using DMT. The cross track component (y axis) of target motion is perceived by ARBS as a crosswind (+ve or −ve) and is automatically combined with the actual crosswind to give the correct sighting. With dive angles greater than 20°, ARBS calculates range wind (x-axis) and therefore calculates target movement as above. At dive angles less than 20°, the INS supplies range wind and therefore does not take target motion into account. In this case, the along track movement of the target will slightly affect the elevation sight line spin rate which, fortuitously, will account for target motion by approximately 50 percent.

6. Ballistics Information. Ballistics information is stored in the MC. The MC calculates the actual trajectory of the weapon, forward throw, using a second order Runge Kutta integration process. Note that just as with the computation of groundspeed the trajectory must be corrected for wind. The wind correction is not calculated here but as part of the ranging process.

1.10.3.2 Calculations

1. Ballistics Algorithm. Known as the Runge Kutta algorithm, this is the mathematical tool that the MC uses to compute trajectory information. The iteration takes place at 11 Hz although 16 Hz may be possible. The solution must be corrected for wind (INS or ARBS) for weapon release. Impact angle is used to calculate the rate of travel of the impact point over the ground or *miss rate*. This is used to correct for system delays and to convert the required stick spacing (feet) into release interval (ms).

2. Ranging Method DMT. With the DMT locked to the target (TV or LST), the elevation and azimuth gimbal angles, combined INS pitch and roll angles are resolved to produce a LOS angle. From this, the range to the target can be calculated. The ARBS range solution is only accurate at sight line spin rates greater than 2 mr/sec. In the same way, by using azimuth angle rate and TAS the ARBS crosswind can be calculated. At dive angles less than 20°, the along track wind is calculated from INS groundspeed and TAS. At dive angles greater than 20°, the ARBS calculates along track winds. The cross wind value is compared to the cross track range of the target and the difference is used to produce the azimuth steering symbol.

3. Ranging Methods INS/WOF

   (a) INS designation. Using the INS TD LOS angle and elevation (Baro or RadAlt), the range (Rs) to the target is calculated. This is resolved into the X, Y and Z planes. INS output along the X, Y and Z axis are subtracted from Rs ranges as the aircraft progresses towards the release point predicted from the Runge Kutta output. A TV picture of the target is available but this is not involved in the calculation. *Sweetening* the shot by using the TDC will renew the Rs value and improve accuracy. Allow enough time for the sight to settle after sweetening. Although less accurate, this method is useful for targets with low contrast or low light conditions.

(b) WOF designation. Present position coordinates from the INS and target coordinates from the WOF data are compared to arrive at the weapon release point. Both of the above methods rely on Baro/RadAlt height inputs and suffer from accuracy.

1.10.4 ARBS Components. The angle rate bombing set consists of the following components:

1. Dual mode tracker (DMT)
2. Air data computer (ADC)
3. Inertial navigation system (INS)
4. Stores management system (SMS)
   Stores management computer (SMC)
   Armament control panel (ACP)
   Stores station controllers (SSC)

The above components supply inputs to the mission computer which processes the information received from each source in order to calculate weapon's delivery parameters.

1.10.4.1 Dual Mode Tracker. The dual mode tracker is the heart of the AV-8B's angle rate bombing set. It is located in the nose of the aircraft and is capable of tracking both TV (contrast) and laser designated targets. It affords the pilot a 6:1 magnified image of the target and provides the mission computer with line of sight (LOS) angles and angular rates which the mission computer uses, along with air data and attitude information, to compute target range and weapon data.

The DMT consist of the following components:

1. Receiver/processor
2. Signal data converter
3. Heat exchange unit

1.10.4.1.1 Receiver/Processor. The receiver/processor contains a TV vidicon and laser detection circuitry which share a common optics system. It also incorporates sun shutters and colored filters. The optics section contains components to receive, focus, magnify, and direct refracted light images onto the vidicon target plate or to receive and divert laser energy onto the laser sensors. The components are arranged using a dichromatic beam splitter which separates reflected light and laser energy and sends them to their respective sensors by allowing visible light to pass through and reflecting laser energy onto the laser detectors.

Prior to reaching the vidicon, the incoming light passes through either a red or yellow filter. The red filter used for high ambient light conditions is normally selected. The pilot has the option of selecting the yellow filter by boxing the filter option on the DDI. This filter may be more desirable in low light conditions.

In order to protect the vidicon from being damaged by direct sunlight, the receiver/processor incorporations a sun shutter. Two sun sensors are mounted on top and bottom of the input lens. The sun sensor sends an output signal to a sensor driver that closes the shutter before the vidicon can be damaged by excessive light. If this happens and a target has been designated, the designation automatically reverts to an INS designation.

The receiver/processor assembly sits on a stabilized platform which is isolated from aircraft motion by a three gimbaled system. This gives the receiver/processor freedom of motion in roll, azimuth and yaw. The platform provides ±450° stabilization in roll, + 15° and – 70° in elevation, and ±35° in azimuth. The optics are roll stabilized in the air-to-ground mode from roll signals from the INS. In the air-to-air mode, the platform is fixed to the aircraft axis.

a. TV. Using the TV mode, the vidicon converts reflected light images into an analog video signal for development and transfer. The optics provide a focused optical image on the target plate of the vidicon. This produces a charged density pattern formed by photo conduction on the target plate. An electron beam converts the charged pattern into an electrical signal. This signal is amplified and sent to the signal data converter where it is amplified and processed. Video is processed and supplied to the DDI at 6:1 power magnification via the DMT optics.

b. LST. Using the laser spot tracker, the laser energy passes through the lenses but is reflected by the beam splitter onto the four quadrant laser detectors. Each quadrant of the sensor provides an output signal proportional to the amount of laser energy it is receiving. These signals are also amplified and sent to the signal data converter where it is processed. Video is again supplied to the DDI at 6:1 power magnification.

1.10.4.1.2 Signal Data Converter. The signal data converter is the brain of the dual mode tracker. It contains the TV and LST acquisition and tracking circuitry and provides the information to the MC for weapons delivery and aircraft steering computations.

The TV processing section provides aperture control to the receiver/processor and adjust the raw video to the 6:1 picture displayed on the DDI. The signal data converter also combines the video with crosshair symbology. The automatic target control circuitry controls the video level. When commanded, the signal data converter will lock on to the highest area of contrast in the large TV acquisition gate. The larger acquisition gate collapses to a smaller tracking gate during the acquisition period, which is 160 ms. The signal data converter then converts the tracking video signals from frequency data to voltage data which is applied to the receiver processor gimbal platform torque motors to track the target.

The laser processing section takes the signal from the four laser detection quadrants and sends them to amplifiers where automatic gain control is applied to aid in the processing of a wide range of laser signal levels. The frequency of the received laser energy is then matched with the pre-entered code. If three consecutive pulses of the correct code are received, the signal data converter commands the receiver/processor gimbal torque motor to track the target and tracking video appears. In the LST mode, acquisition and track are automatic, the pilot is only required to select the correct LST code and scan pattern. The signal data converter will attempt to keep the target in the center of the small tracking gate. When the target appears to move within the gate, signals are sent to the receiver processor gimbal torque motors which adjust the receiver processor to re-center the target.

Since the TV and laser sensors share the same optics, the TV picture of the target is available and automatically appears on the DDI after lock on. The LST legend on the HUD flashes for five seconds to indicate that laser energy is being received. The legend will always flash regardless of mode when valid laser energy is received, provided that the DMT is on.

The signal data converter also receives roll signals form SAAHS which are used to stabilize the receiver/processor roll gimbal and thus the ground scene. However, because of mechanical constraints, the DMT is limited to 450° of roll. If the aircraft is rolled beyond these limits, the DMT will gimbal and break lock. Therefore when the DMT is operating, aircraft roll should be held below 450°. If the DMT is rolled over (exceeds 450°), the pilot can *undesignate* (using nosewheel steering switch on the stick grip), which commands the DMT to reset to *zero* in roll. The target can then be redesignated.

1.10.4.1.3 Heat Exchange Unit. The heat exchange unit controls the receiver/processor temperature by providing conditioned dry air to the receiver/processor. This is accomplished through the use of a desiccant which dries the incoming ambient air. When receiver/processor temperature is below 40 °F, the heater turns on to warm the cooling air. If the receiver/processor temperature rises above 185 °F, power is disconnected. During extreme cold conditions, the DMT may require up to 17 minutes to warm up. The DMT will not operate until receiver/processor temperature exceeds 10 °F. System operation is also inhibited for approximately 30 seconds after power up to allow temperature and operating voltages to stabilize.

1.10.5 ARBS Management. Mode selection is made using the sensor select switch on the control stick. See Figure 1-127. ARBS and INS modes are mutually exclusive. The mode last selected by the pilot operates until deselected. The sensor select switch utilizes two of the five momentary positions, forward and aft, and a center off position. Pushing the switch forward selects INS. Successive actuations aft alternates between the ARBS/LST and ARBS/TV sensor modes of the DMT. The ARBS/LST sensor mode is always called up first if a valid laser code has been entered. The ARBS/LST sensor mode is not available if a valid laser code has not been entered. Mode selection is indicated by INS, TV or LST legends in the upper left corner of the DDI DMT display. ARBS/TV and ARBS/LST sensor modes will automatically revert to INS sensor mode if the target is outside the DMT gimbal limits (± 35° Az, +15° to –70° ELEV).

Since the TV and LST share the same optics, the LST designated target can be transferred to a TV designated target any time after lock on. The designation may also be transferred to the INS mode; however, a short time must be allowed to develop an angular rate for delivery computations. If the DMT gimbal limits are exceeded at any time, the INS mode is automatically selected in either TV or LST modes.

The DMT also provides a NITE option which, when selected, disables the DDI video to avoid blinding the pilot at night and during Sidewinder lock on in the air-to-air mode.

When sidewinder lock on occurs in air-to-air mode, the DMT video is available for display, (rock back on sensor select switch) to aid in target identification. In this mode, the DMT is slaved to the aircraft axis vice being roll stabilized.

The DMT switch on the miscellaneous control panel controls 28vdc power from the main 28vdc bus to the SDC (signal data converter). This activates power to the DMT by applying 115vac power from the main 115vac power bus. When the DMT switch is off, the gimbals are not mechanically caged and the system relies on balance and soft mechanical stops for protection against vibrations and aircraft movement. It is therefore desirable to have the DMT on during aircraft operations though not required.

1.10.5.1 ARBS/LST Designation. ARBS/LST is the only designation that is automatic; however, it requires external laser illumination of the target. LST mode selection is inhibited until a valid laser code has been entered (using the UFC). The LST laser code is the same for both the LST and Laser Maverick and needs to be entered only once. A laser code must be entered if the ARBS/LST sensor is needed in flight since the code is zeroed at transition of weight-off-wheels to weight-on-wheels. To enter the laser code, a CODE option pushbutton is provided on the DMT Display.

Select the DMT display on the DDI (selected automatically when the ARBS/LST sensor mode is selected); then box the code option. The previous code, if any, will be displayed on the scratch pad and the UFC will be enabled for new code entry (for 30 seconds). Type in the new 4-digit code and press ENT. Valid laser codes have a first digit of 1, second digit of 1 thru 7, and third and fourth digit of 1 thru 8. This code corresponds to the pulse repetition frequency (PRF) of the expected laser designation. Laser code is automatically zeroed 5 seconds after weight on wheels.

NOTE

The C option that appears on the ODU is not used. It is a growth capability for possible laser counter-countermeasures.

The LST mode has three scan patterns, wide, narrow, and HUD. The wide scan FOV is 68° wide. The narrow scan is 24° wide. Scan patterns are selected on the DDI, and are used to search for laser illuminated targets. The LST mode will always initialize to the last selected scan pattern. All scan patterns are computer controlled and in narrow or wide scan at a rate of 20° per second. The centroid of the scan pattern is positioned 5 nm ahead of the aircraft if no target is designated. If the target is designated, the centroid of the scan pattern is positioned abeam the target

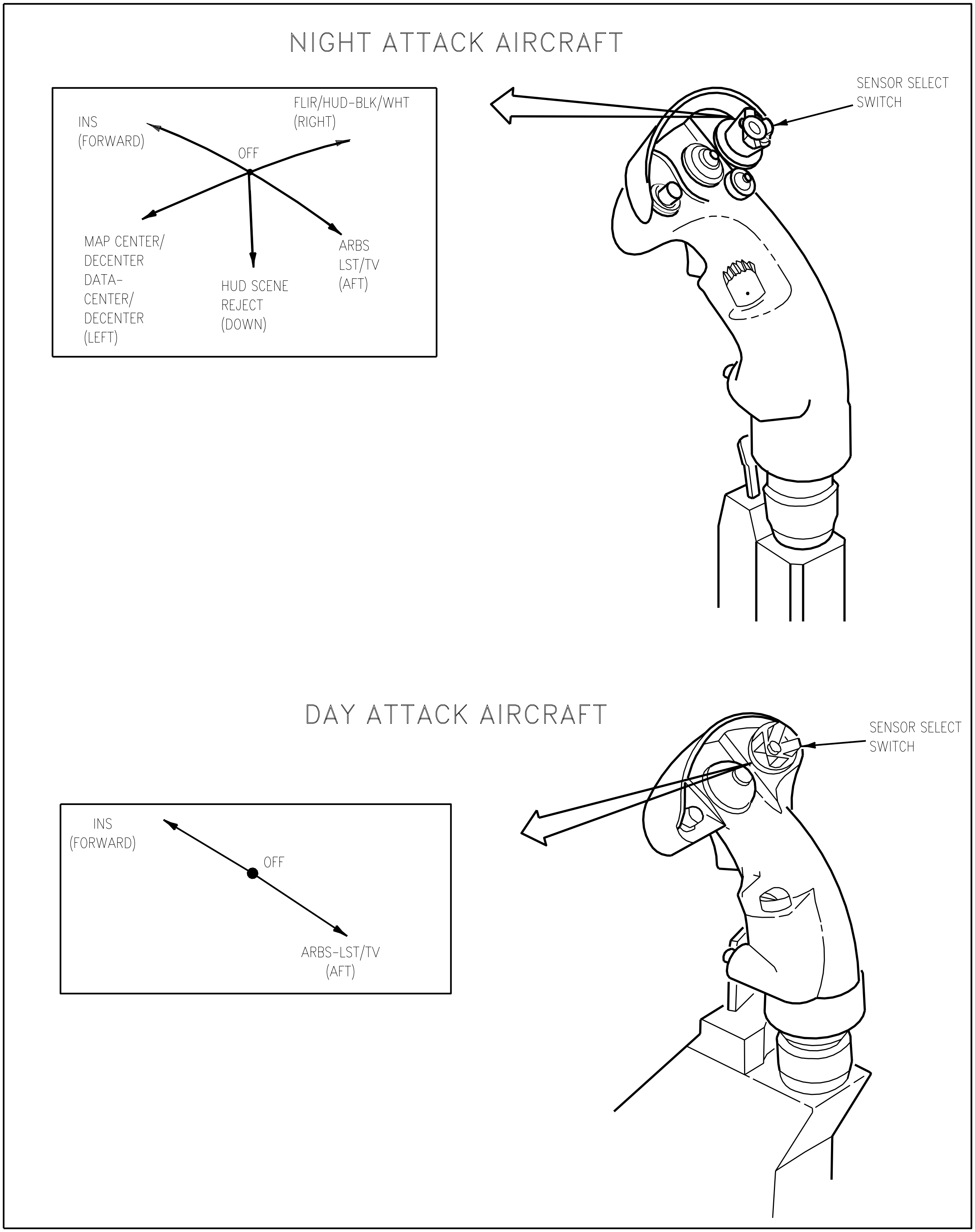

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Figure 1-127. Sensor Select Switch

(if accurate target elevation has been entered). The laser scan footprint is displayed on the DDI and can be slewed, within the DMT FOV, by using the TDC no action slewing. If action slewing is used, video will appear on the DDI. Then, when the TDC is released, the point under the video crosshairs will be INS designated; the LST display will reappear; and the narrow scan pattern will be set over the designated point.

The HUD scan can also be selected on the DDI or by pressing the undesignate button. The HUD scan pattern is a 8° to 8° bow tie pattern around the HUD center. It provides a quick reaction, aircraft referenced method for target acquisition. The HUD scan cannot be slewed and completes one scan pattern every 4 seconds.

During the run-in to the target, the pilot must maneuver the aircraft so that the ARBS/LST scan pattern covers the laser illuminated target. This will ensure that the LST receives the reflected energy necessary for designation and lock on. When the ARBS receives the correct correlated laser energy, the target is automatically designated and tracked. LST HUD symbology (with lock on) is shown for both CCIP and AUTO modes.

1. At lock on, the LST legend flashes for 5 seconds, then remains steady.

2. The LST scan symbol changes to the locked symbol and will overlay the ground designation point.

(a) Also at LST lock on, a video display of the target is automatically presented on the DDI. The intersection of the crosshairs indicates the location of the laser illuminated target on the video display.

(b) Selecting the ARBS/TV sensor mode after LST lock on transfers the designation to a TV lock on. This may be required if the laser illuminator is forced to shut down. The designation may also be transferred to the INS mode if the TV is not available; however, a short time must be allowed to develop a angular rate for delivery computations.

(c) If the designated target exceeds the DMT gimbal limits, ARBS/LST is automatically deselected and the INS sensor mode is activated. This prevents indiscriminate redesignation by the LST sensor at the gimbal limits during reattack.

(1) In the HUD, the LST symbol is replaced by the TD diamond and reattack steering appears.

(2) On the DDI, TV video is removed and the compass rose appears to aid in reattack.

1.10.5.2 ARBS/TV Designation. When no previous designation exists, the TV will initialize at the HUD velocity vector, the dot in the velocity vector represents the TV FOV centroid. Video will appear on the DDI with open crosshairs corresponding to where the velocity vector is pointed. The recommended method for performing a TV designation is to maneuver the aircraft to visually position the velocity vector on the target and then press and release the TDC. Another method is to action slew the TV FOV box over the target and release the TDC to command target acquisition. In either case, releasing the TDC commands target lock on. Check the DDI to ensure the target is being tracked. If the TV is locked on the wrong point and time permits, transfer head-down to the DDI and *sweeten* the designation by slewing. Use either action or no-action slewing; however, the no-action position is better for fine tuning a designation.

When the slew is activated, via the TDC, the HUD TV FOV symbol appears and moves away from the velocity vector based on the pilot's slew commands. The FOV symbol is smaller than the total TV sensor FOV and is roll-stabilized. It is limited to the HUD FOV and will become dashed when it reaches a limit. Pressing and holding the TDC down in the action position will ground-stabilize the TV scene. When not ground-stabilized, the HUD TV FOV symbol remains referenced to the velocity vector. Releasing the TDC from the action position commands TV lockon and track.

When lock on is commanded, the TV will search the large acquisition gate (on the DDI) for the area of greatest contrast. During this period of time (160 ms), the acquisition gate collapses to form the tracking gate, which is a small rectangle encompassing the actual tracked target. In the HUD, the TV FOV symbol is replaced by the TV track symbol which is a smaller box.

The aircraft position is fixed on the DDI display and is indicated either by a waterline, velocity vector, or depressed attitude symbol which matches the symbol displayed in the HUD. The horizon line is referenced to this symbol and indicates roll and approximate pitch or flight path angle. True, or calibrated, airspeed and altitude are also shown to match the HUD readout.

The ARBS/TV sensor can use a red or yellow filter. The red filter, used for normal daylight conditions, is automatically selected; however, the effects of the two filters should be compared. In low light conditions, the yellow filter may be better. The filter can be sequentially changed by pressing the FLTR button on the DDI. Also, the video display can be completely removed by pressing the NITE button.

If a target is within the DMT gimbal limits and it is already designated, by any means, and ARBS/TV is selected, TV lock on will be commanded. The TV will attempt lock on to whatever is in the acquisition gate. Therefore, the ARBS/TV sensor mode should not be selected until range and line-of-sight to the intended target are within limits.

After the aircraft overflies the target, the ARBS/TV sensor mode is automatically disabled and the INS sensor mode enabled. This prevents indiscriminate redesignation by the TV sensor at the gimbal limits during reattack. In the HUD, the TV symbol is replaced by the TD diamond and reattack steering appears. On the DDI, TV video is removed and the compass rose appears to aid in reattack.

1.10.6 Tactical Considerations. When planning for weapons delivery utilizing ARBS/TV or ARBS/LST, it is important to remember that you are using a passive sensor. As such, the DMT is subject to certain limitations. It would be foolish to think of the DMT as a simple “point and shoot” system. It is imperative that preflight considerations be given to predicting sensor performance which will result in a plan that will optimize the use of the DMT. Of the many factors affecting the DMT, the most basic is simply the physical condition of the components. Pits, crazing, salt spray or bug juice on the glass dome will obviously have an adverse impact on DMT performance before you even launch. Also, any BIT codes need to be griped and rectified.

The target area environment may include factors that will affect DMT performance depending on which sensor you are trying to utilize.

In the case of the ARBS/TV or LST, factors such as sun azimuth and elevation need to be considered. Don’t plan a delivery that will result in a run-in line that places the DMT directly into a low rising/setting sun. If the sun’s intensity is great enough, the DMT sun shutter will close and render the DMT useless.

Shadowing will not affect ARBS/LST but could effectively *wash out* the contrast that the ARBS/TV is looking for to lock on. Plan run-ins that will optimize the effects of shadowing and leave your target with the greatest contrast. Low visibility will obviously have an impact on ARBS/TV and depending on the reason for the low visibility (fog, rain, haze and clouds) will adversely affect ARBS/LST performance.

High humidity will reduce the expected laser acquisition ranges due to laser diffusion and could affect the ARBS/TV by reducing the visible contrast available.

Terrain characteristics need to be considered when planning ARBS/TV and to some extent, ARBS/LST deliveries. Remember that the TV attempts to lock on to the area of highest contrast in the acquisition gate. Terrain that provides high contrast objects such as bushes and buildings will be tempting targets for the ARBS/

TV. It is critical to conduct a boresight check on the ground to maximize the TV's chances of locking on the desired target on the first designation attempt.

In the case of the ARBS/LST, objects such as glass, dense vegetation and moisture may be more reflective than your target and the ARBS/LST may be drawn off the target if the laser spot spills over onto these objects. The 6:1 magnification that the TV provides should be used to verify that the laser spot is locked on to a real target.

Battlefield obstructions will impact your success with the DMT. Smoke from fires or other ordnance, if it obscures your view, will obviously obscure the *view* of the DMT. Plan deliveries that will minimize the effects of these obstacles by trying to avoid placing them between you and your target.

Specifically, in the case of ARBS/LST, you must know the designator to target line. It makes no sense to attempt an LST delivery that does not put the aircraft into the laser *basket* (± 45° azimuth and < 60° elevation based on the DTL).

Remember that in an auto delivery, the system will attempt to hit the designated target. When using the TV to designate the target, knowledge of where the TV will typically lock on certain target types is critical to mission planning and success. For example, the edges of a revetment may provide sharper contrast than the artillery piece that is located within. An auto delivered Mk-83 that lands on the designation (in the berm of the revetment) may do little toward destroying that target. Linear targets (horizontal or vertical) will typically draw the TV to their extremes. On vertical targets the TV typically locks at the top, on horizontal targets the TV will typically run to an end, neither of which may be the place of desired bomb impact. Against such targets the TV is useful for LOS rate but CCIP with a TV lock and pilot placed bombs will most likely be preferred.

Finally, the target itself must be considered in detail. What color is it? How much contrast can be expected? What is the laser reflectivity? What size will it be at slant range? If it is hard for you to see, then the TV will have trouble *seeing* it too. All are questions that need to be answered prior to walk time. The answers to these questions will prepare you for the upcoming attack. The goal being to reduce the number of surprises you encounter in the target area where you least desire to be surprised.

If these factors are considered prior to launch, you will enter the target area with a solid plan to optimize your attack systems. If your plan is to deliver in AUTO/TV but your TV locks onto a bush 30 feet away, you will be ready because you will have thought about switching to CCIP in such a case. If the TV breaks lock, you will be ready to transfer the designation to the INS and still deliver bombs on target on the first pass. The bottom line is that wings level in the dive is *not* the time to be making these decisions. These decisions will have been already made in the planning phase.

1.10.7 ARBS Preflight Management. This section covers controls and displays as needed for the preflight management of ARBS BIT and boresight procedures. Also included are several considerations which may be performed by the pilot before flight to assist in mission efficiency such as LST code insertion, DMT filter selection, and the NITE option. The dual mode tracker (DMT) is the primary attack sensor in the Day and Night Attack aircraft. It provides TV contrast or laser spot tracking of targets. The MC uses precision target-to-aircraft angle and angular rate data to compute target range. In addition, TV video of the tracked target, magnified six times, is presented on the DDI to assist the pilot in target recognition.

1.10.7.1 Sensor Select Switch. On Day Attack aircraft, the sensor select switch utilizes two momentary positions, forward and aft, and a center OFF position. On Night Attack aircraft the sensor select switch is a six position switch (center being OFF). See Figure 1-125.

Pushing the switch forward selects the INS sensor mode. Successive actuations aft alternates ARBS/LST and ARBS/TV sensor modes if a valid code has been entered. If no code has been

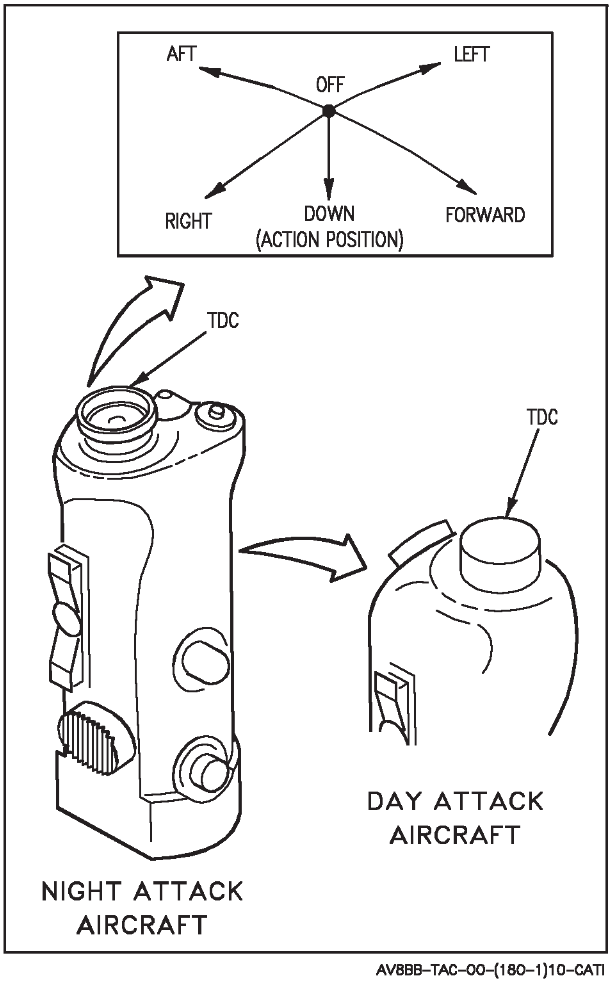

Figure 1-128. Target Designator Control (TDC)

entered, then only ARBS/TV is selected. On night attack aircraft, if NITE is not boxed, DMT display appears on the right DDI.

1.10.7.2 TDC. The TDC is an isometric switch with lateral displacement in all directions. See Figure 1-128. It is located for thumb operation and incorporates both action and no action slewing in combination with fast and slow slew rates. It is utilized for sensor designation slewing, and commanding MAP, FLIR, INS or ARBS/TV (INS or ARBS/TV on day attack aircraft) sensor designation.

1.10.7.3 LST Code. LST mode selection is inhibited until a valid laser code has been entered. The LST laser code is the same for both the LST and AGM-65E Laser Maverick and needs to be entered only once. A laser code must be entered if the ARBS/LST sensor is needed in flight since the code is zeroed at transition of weight-off-wheels to weight-on-wheels. To enter the laser code, a code option pushbutton is provided on the DMT display. See Figure 1-129. The pilot can select the DMT display on the DDI by pressing MENU and DMT, or selecting one of the three sensor modes (INS, TV, LST) on the sensor select switch. See Figure 1-127. Selecting CODE enables the UFCS for laser code entry and boxes the CODE option on the DMT display. See Figure 1-129.

The current code is displayed on the UFC scratch pad when the CODE option is selected. See Figure 1-130. The pilot enters a new code by keying in a four digit number and pressing ENT on the UFC.

The C (counter-countermeasures) option initializes to the stored selection as indicated by the presence or absence of a colon. The pilot may change the C status by actuating the adjacent pushbutton.

1.10.7.4 TV Filter Option Pushbutton. The DMT TV sensor can utilize yellow or red filters. The red filter, which is used for normal daylight conditions, is automatically selected. In low light conditions, the yellow filter may be desirable. The pilot changes filters by alternate actuations of the FLTR pushbutton (see Figure 1-131) on the DDI DMT display. The function is displayed only when video is present. Successive actuations of the filter option pushbutton alternately selects the red and yellow filter in the DMT receiver processor. The red filter is selected when the FLTR legend is unboxed for normal daylight conditions. The yellow filter is selected when desired for low light conditions by boxing the FLTR legend.

1.10.7.5 NITE Option Pushbutton. The pilot also has the option to disable the DDI video by selecting the NITE option on the DDI DMT display. See Figure 1-131. The NITE option pushbutton is used to prevent ARBS video from temporarily blinding the pilot during night conditions. Actuating the NITE option pushbutton

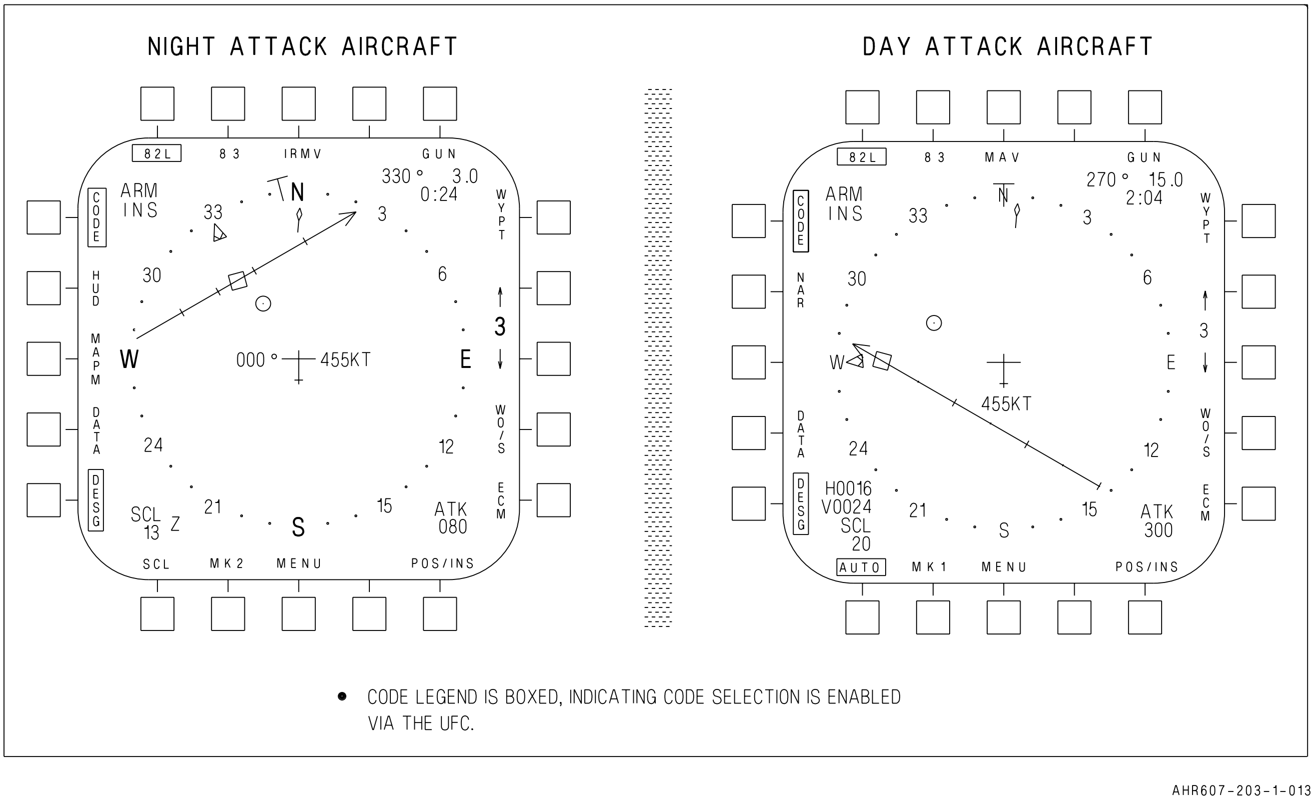

Figure 1-129. DMT Display Without Video (CODE Selected)

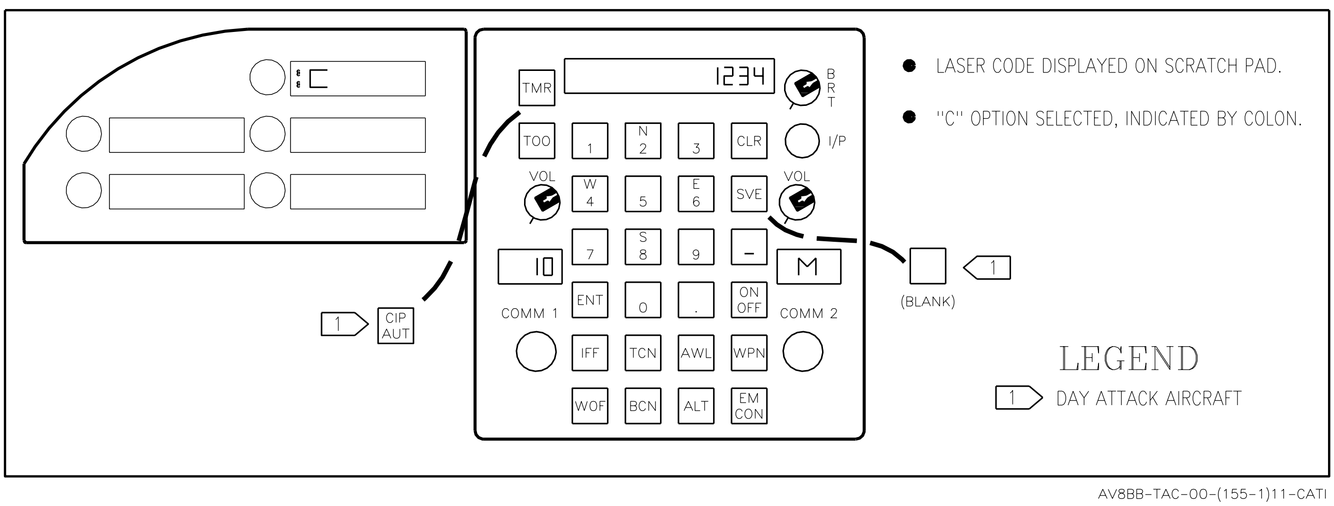

Figure 1-130. Code Options

boxes the NITE legend and commands the MC to disable the TV display. ARBS video can still be used at night if the NITE option is not selected and the DDI brightness control is adjusted. The NITE option can also be used to disable automatic selection of TV video in the A/A mode when the Sidewinder seeker is locked on a target. Actuating the NITE option pushbutton when NITE is boxed deselects the NITE option.

1.10.7.6 DMT Operation. There are basically two procedures the pilot should perform, when possible, to ensure the proper operation and

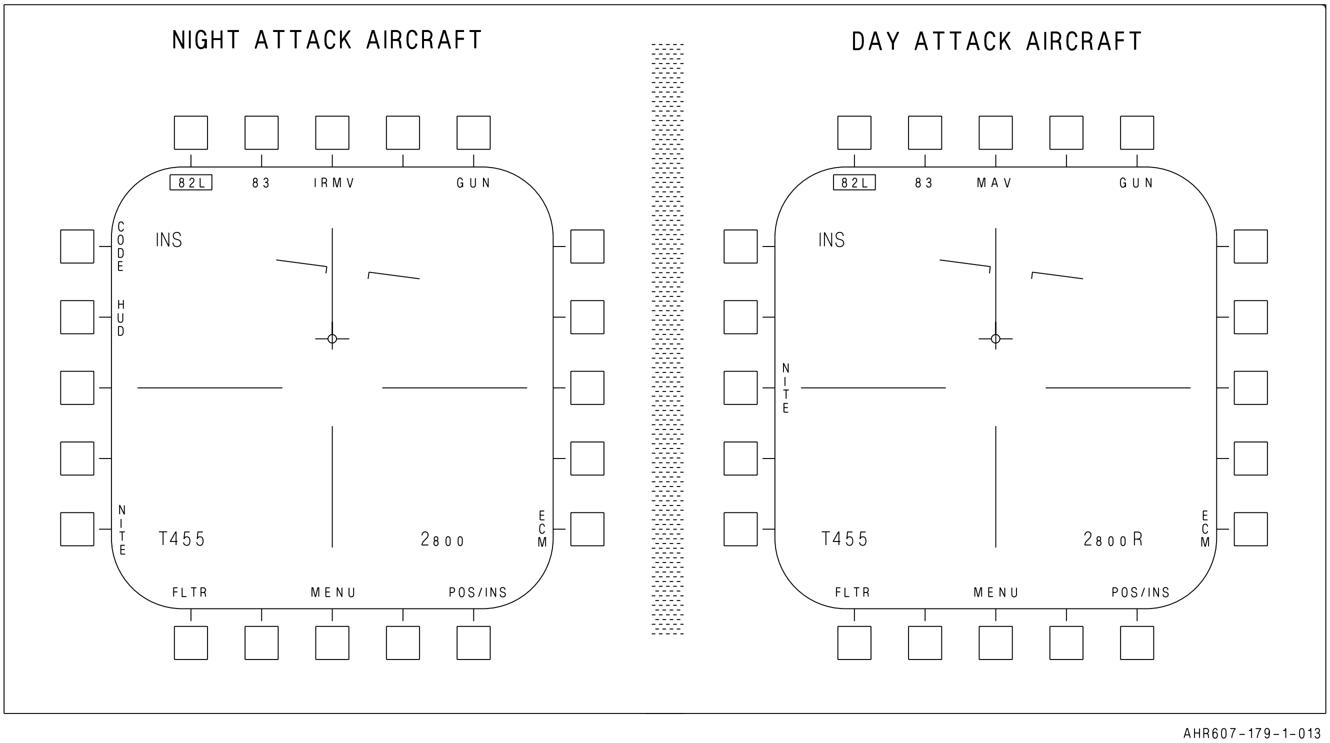

Figure 1-131. DMT Display With Video

alignment of the dual mode tracker before take-off; built in test (BIT) and boresight.

1.10.7.6.1 BIT. The first step is to place the DMT power switch to the DMT position to apply power for warmup. See Figure 1-132. Next select the BIT display on the DDI by selecting BIT on the DDI menu display. The pilot may perform the DMT BIT one of two ways. Normally, AUTO BIT is performed which includes a BIT of the dual mode tracker. The second method, actuating the DMT option pushbutton on the BIT display performs the same basic test of the system, but in addition, displays a video presentation of the test. It also allows the pilot to test only the DMT. Once the DMT option pushbutton is actuated, the initiated BIT is started and the following sequence of test displays appear in a period of 12 to 16 seconds:

1. LST lock on - Test target appears as a bright dot near center of LST crosshairs.

2. LST track - Test target driven down and left, then returns to center of crosshairs.

3. TV lock on - Large box on TV display shrinks to TV track gate around test target.

4. TV track - Test target driven down and left, then returns to center; TV track gate follows test target.

5. BIT display reappears on DDI with DMT status blank if it passes. An asterisk (*) or numeral 1 for DMT status denotes a fault.

NOTE

The ARBS BIT may fail in a good system if the aircraft is afloat or not stationary during the BIT.

1.10.7.6.2 DMT Boresight. The pilot should always perform a boresight check to ensure that the tracking gate of the DMT matches the aiming symbol used by the pilot in the HUD. This will enhance the chances of locking on the target quickly with minimal head down sweetening on the DDI. A DMT boresight may be performed in any master mode except the air-to-air mode. From the DDI menu select BIT, then BST. See

Figure 1-133. On the HUD, the TV FOV symbol appears at the waterline and video appears on the DDI.

The TV FOV symbol should be slewed to a high contrast point (target) more than 7,000 feet away and within the HUD FOV. The target is chosen at this range to account for the parallax created by the distance between the DMT and pilot's line of sight. Transfer head down, press TDC, and slew the DMT video to place the target in the TV crosshairs. Release the TDC to command lock on, and note the actual point inside the tracking gate on the DDI. When lockon occurs, the BST option reappears on the DDI. If at this time the TV FOV symbol on the HUD matches the tracked target on the DDI, press MENU to exit the boresight mode.

If the TV FOV symbol does not match the tracked target, a boresight error exists. Reselect the BST option. See Figure 1-133. Slew the HUD TV FOV symbol over the target displayed within the TV display tracking gate. The MC stores the required movement of the HUD FOV symbol to place it over the TV target and uses this correction to correct the DMT line of sight positioning. Actuate the menu pushbutton to exit the BST mode. If time does not permit, or a suitable contrast target is not available, a boresight check may be performed once airborne by utilizing a wingman as the contrast target.

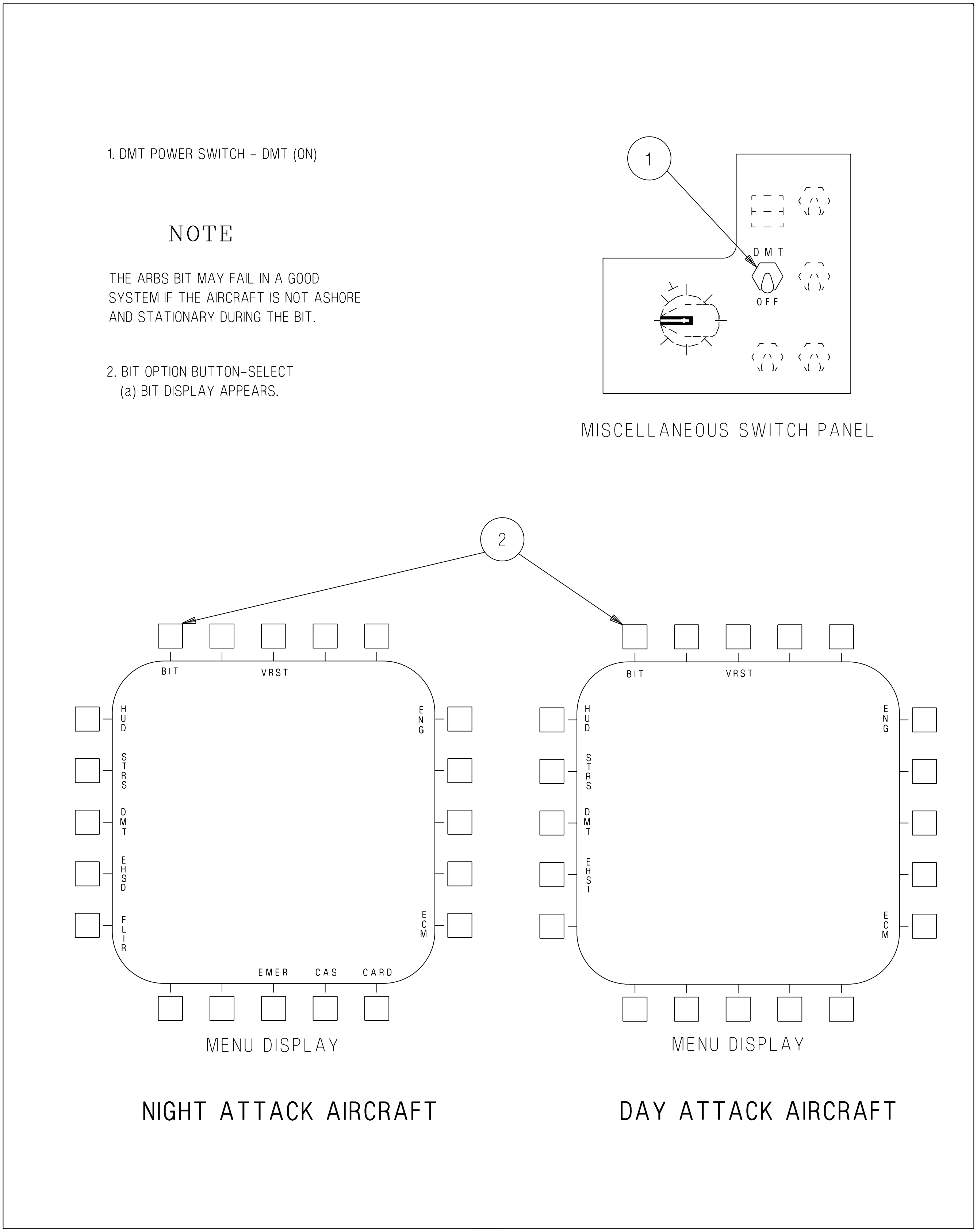

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Figure 1-132. DMT Initiated BIT (Sheet 1 of 2)

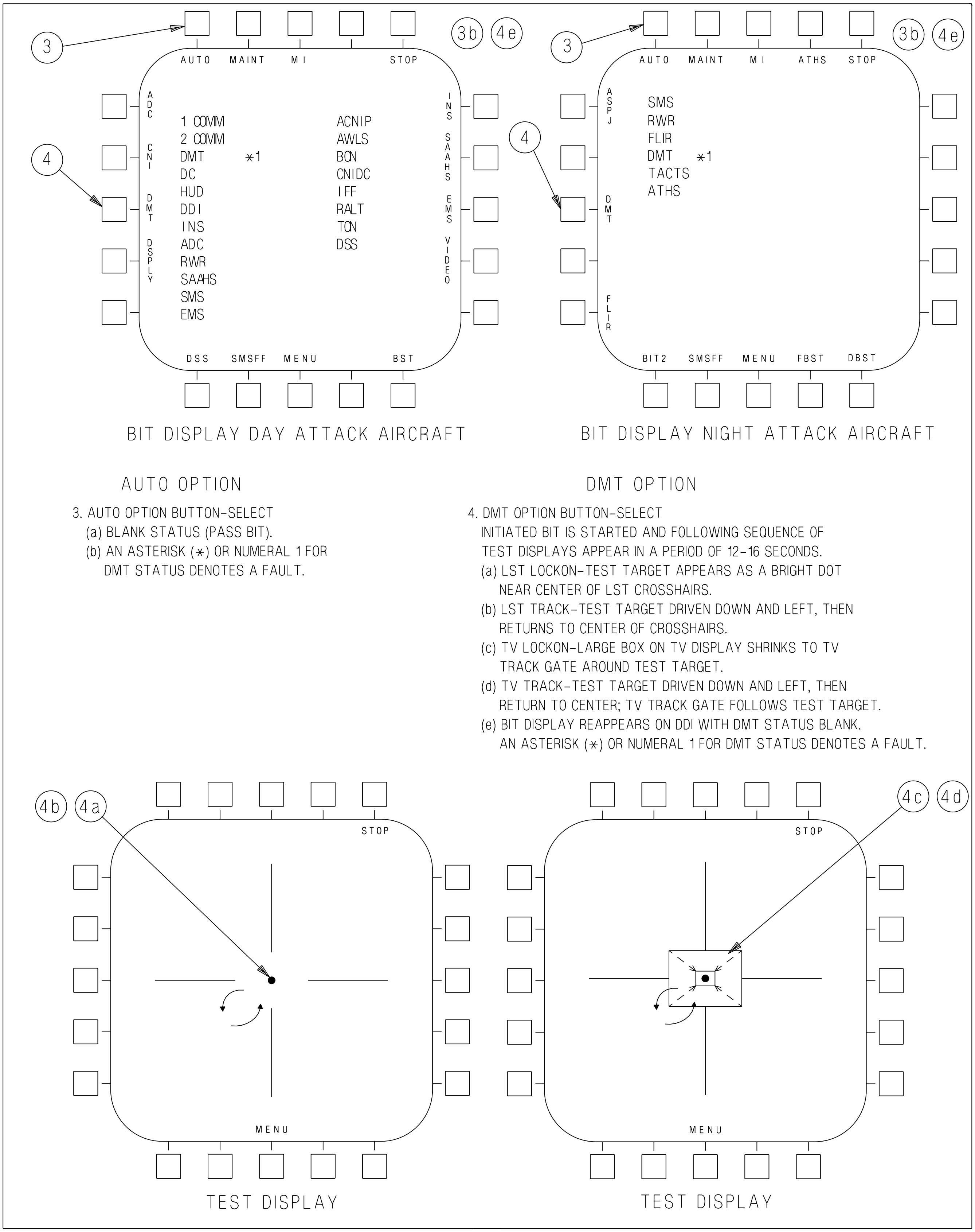

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Figure 1-132. DMT Initiated BIT (Sheet 2 of 2)

DAY ATTACK AIRCRAFT

1. BIT OPTION BUTTON – SELECT
2. BST OPTION BUTTON – SELECT
3. TDC – PRESS AND SLEW TV CROSSHAIRS TO TARGET
   SLEW TV SENSOR TO A HIGH CONTRAST TARGET AT A RANGE MORE THAN 7,000 FEET.

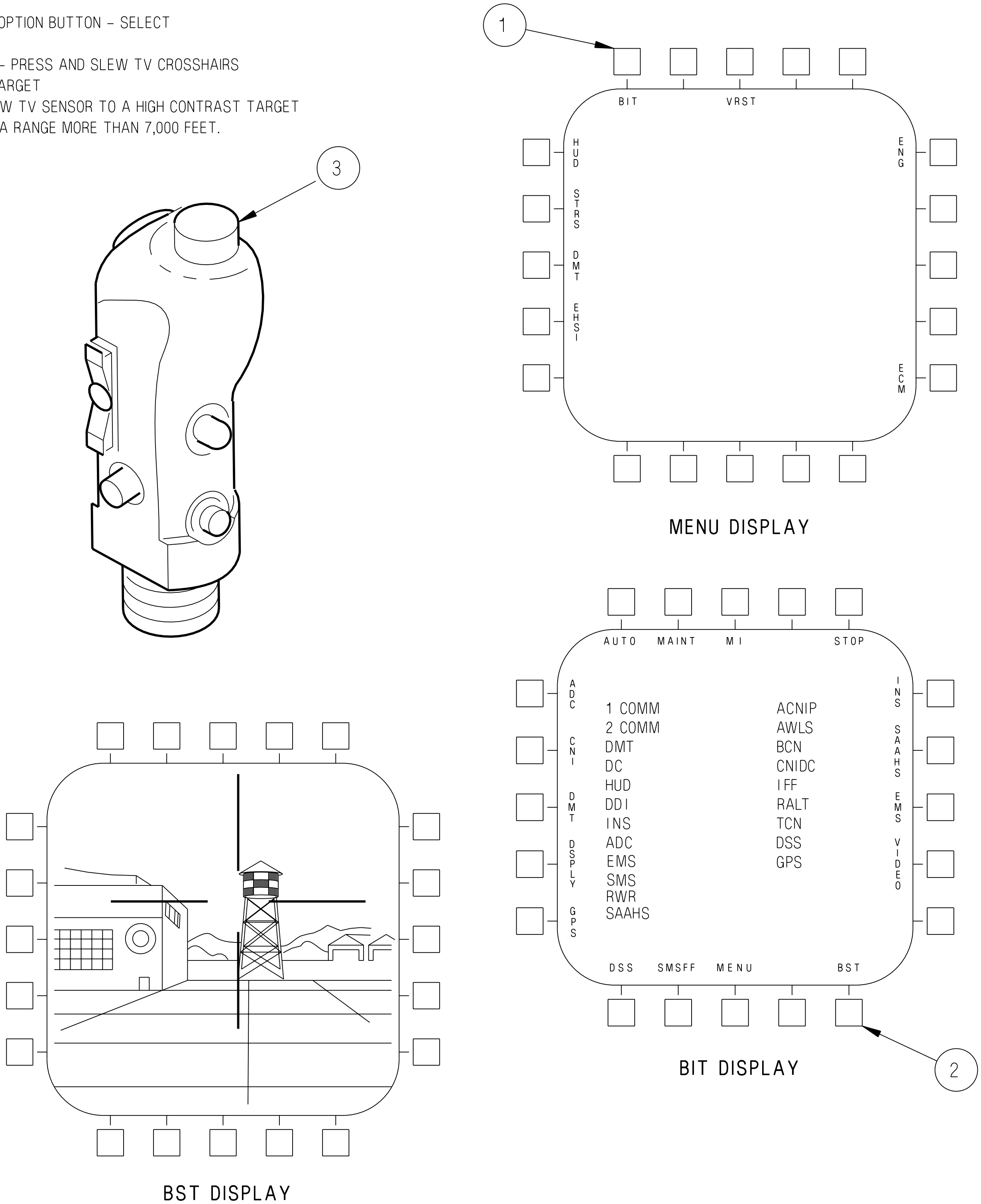

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Figure 1-133. DMT Boresight (Sheet 1 of 4)

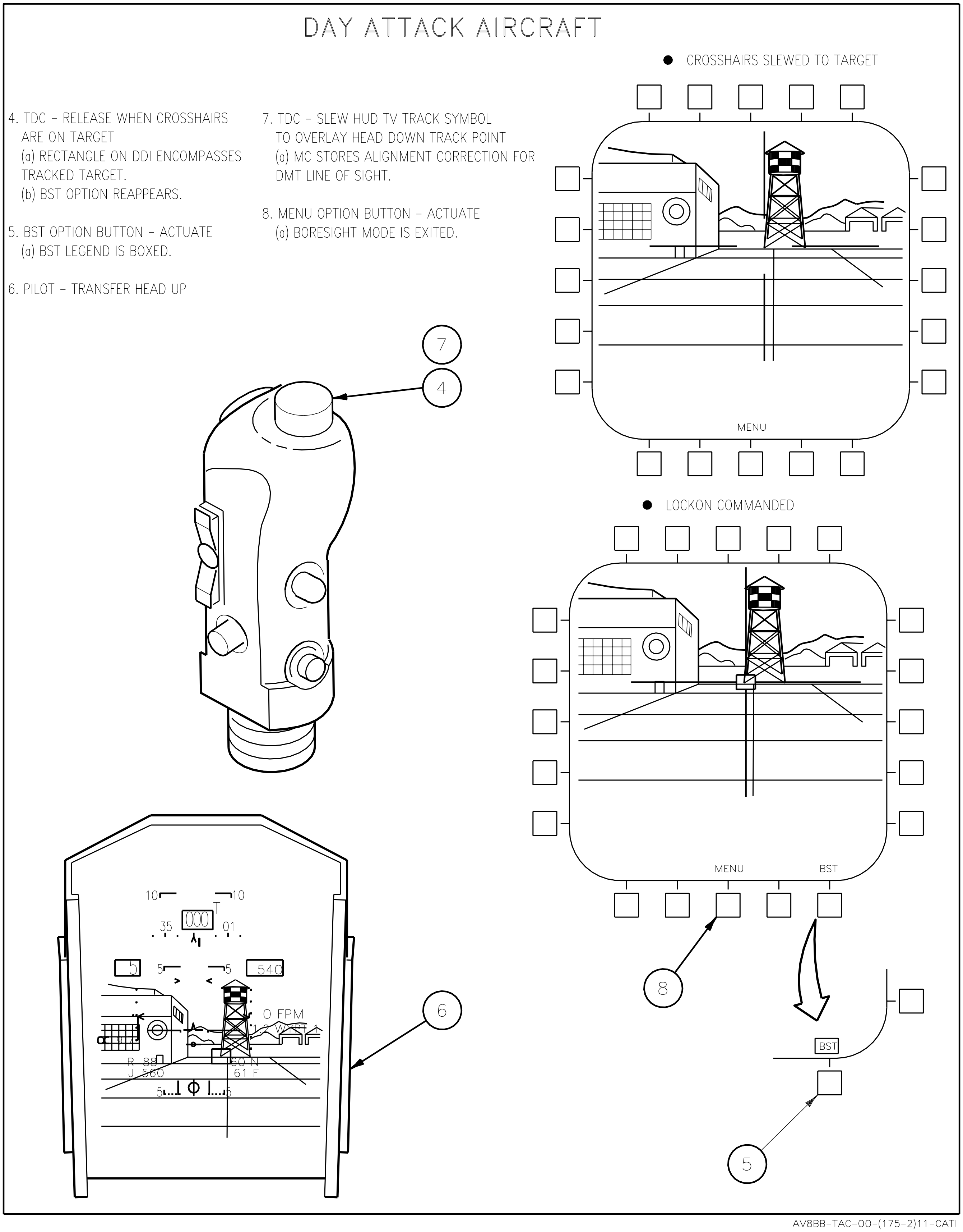

Figure 1-133. DMT Boresight (Sheet 2 of 4)

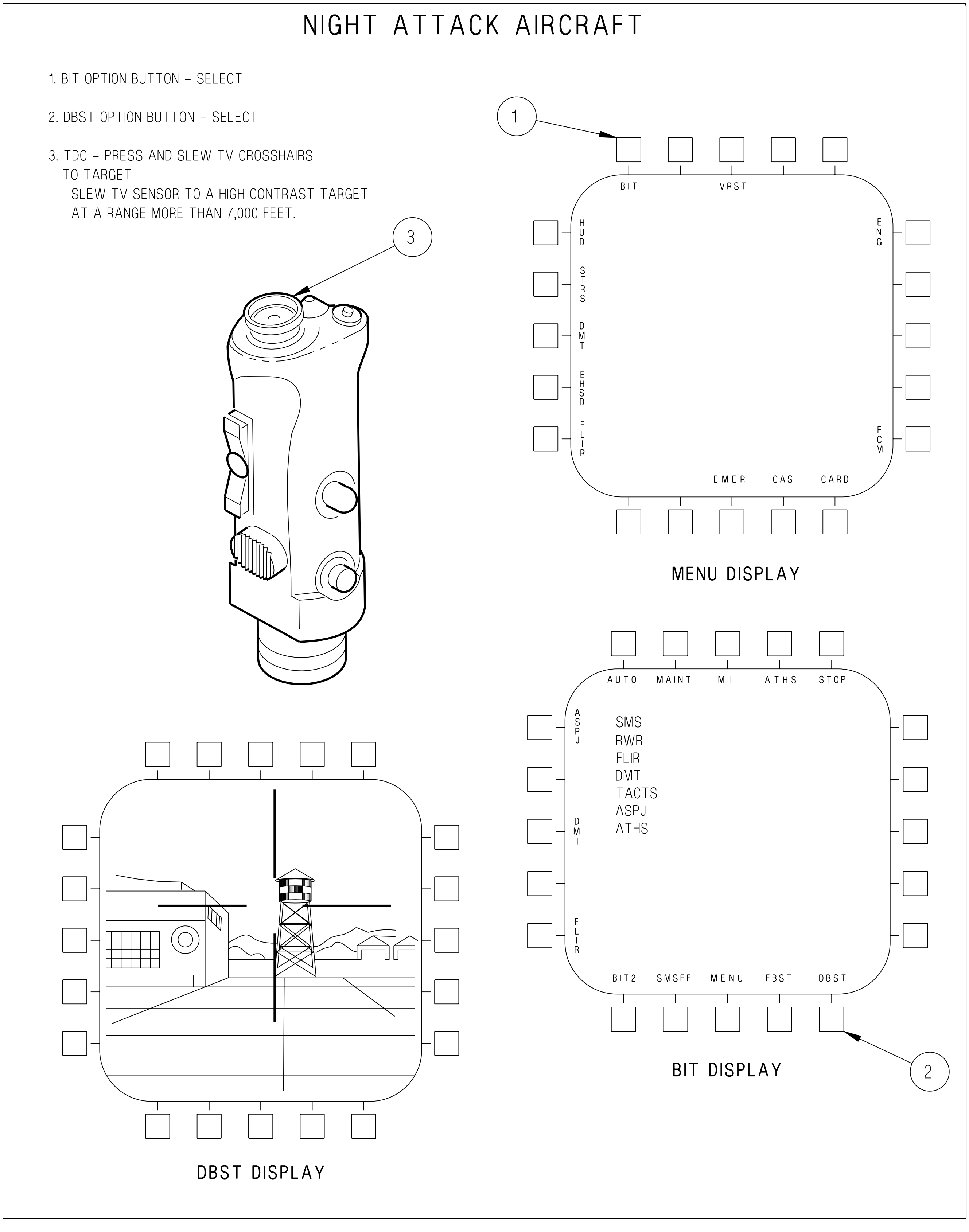

Figure 1-133. DMT Boresight (Sheet 3 of 4)

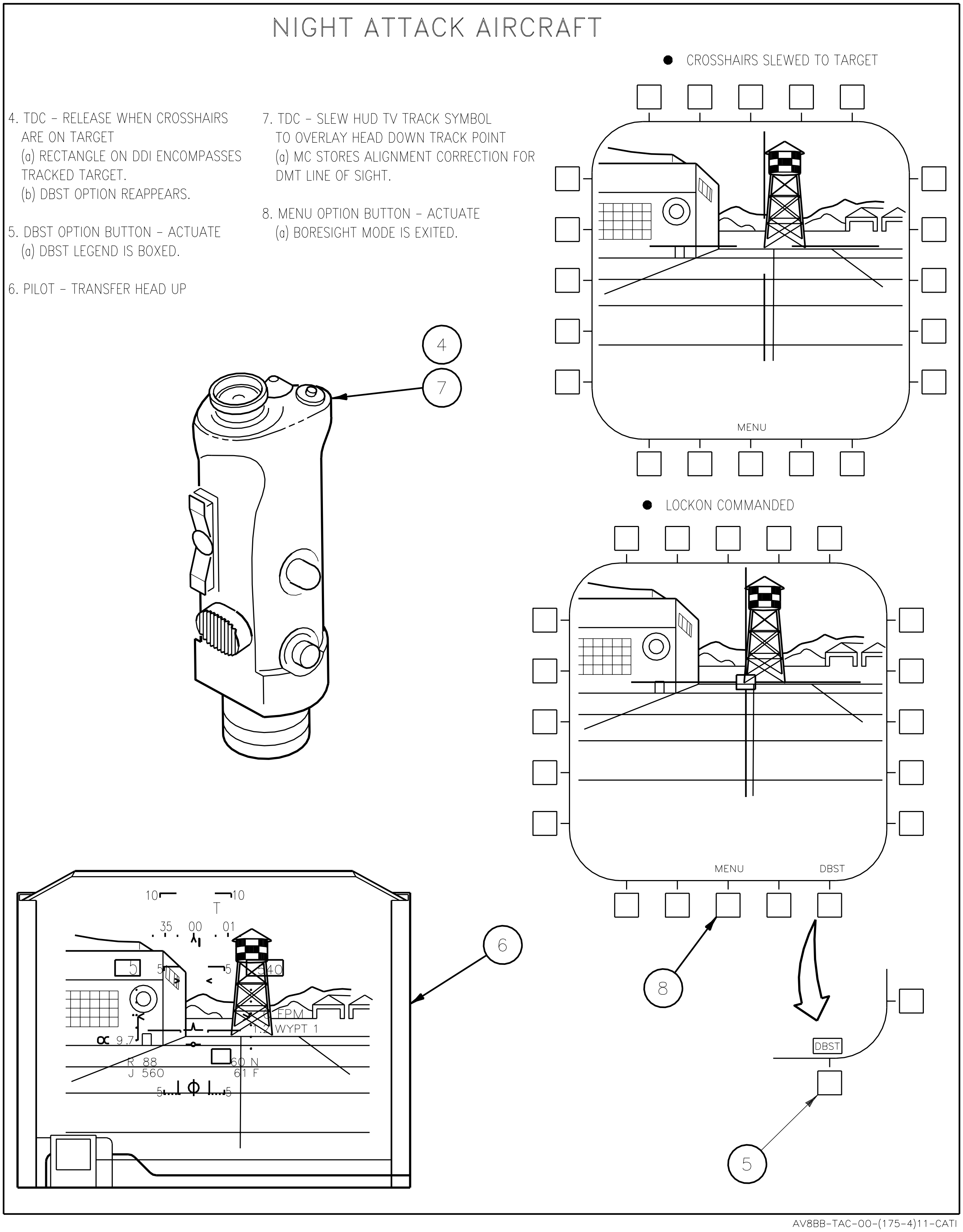

Figure 1-133. DMT Boresight (Sheet 4 of 4)

1.11 INERTIAL NAVIGATION

1.11.1 Inertial Navigation Theory. The INS is an integral part of the navigation and weapon delivery solution. As the primary attitude reference in the AV-8B, it is used by the pilot to check dive angle for noncomputed deliveries. For computed deliveries it provides INS velocities, attitude, and information for wind data. For this reason the pilot must have a basic understanding of INS theory in order to optimize system accuracy or realize limitations imposed by a degraded INS. In order to understand an inertial navigation system we must consider both the definition of "inertia" and the basic Laws of Motion. Newton's three "Laws of Motion" state:

1. A body continues in a state of rest, or uniform motion at a constant velocity, unless acted upon by an external force. Force equals mass times acceleration (F=ma).

2. The acceleration of a body is directly proportional to the sum of the forces acting on the body.

3. For every action, there is an equal and opposite reaction.

The first law defines inertia. The second law states that acceleration (rate of change of velocity) is directly proportional to the force acting on the body. Velocity and distance are computed from sensed acceleration by integrating the data with respect to time. The relationship between acceleration, velocity, and displacement or distance is shown in Figure 1-134. Note that velocity changes whenever acceleration exists and remains constant when acceleration is zero.

The basic measuring instrument of the inertial navigation system is the accelerometer. Three accelerometers are mounted in the system, one which measures the aircraft accelerations in the north-south direction, the second which measures the accelerations in the east-west direction, and the third which measures vertical accelerations.

The accelerometer is basically a pendulum device. See Figure 1-135. When the aircraft accelerates, the pendulum, due to inertia, swings off the null position. A signal pickoff device tells how far the pendulum is off the null position. The signal from this pickoff device is sent to an amplifier and current from the amplifier is sent back into a torquer located in the accelerometer. A torque is generated which will restore the pendulum to the null position. The amount of current that is going into the torquer is a function of the acceleration which the device is experiencing.

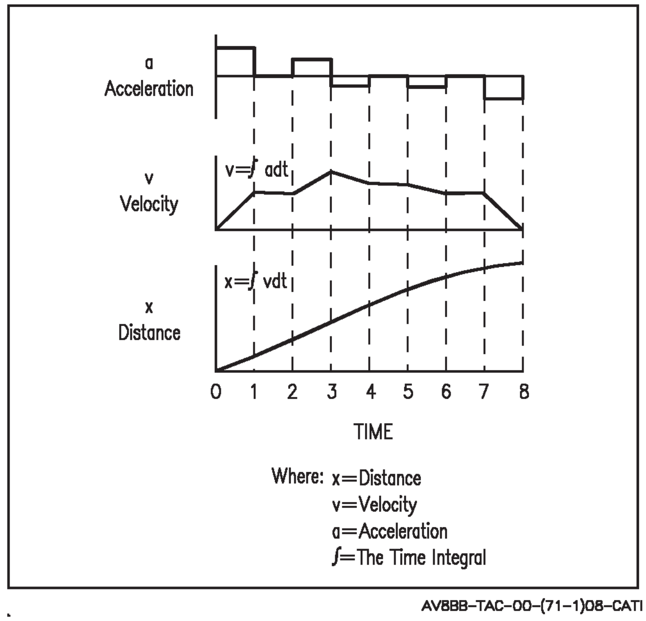

Figure 1-134. Acceleration/Velocity/Distance Relationship

The acceleration signal from the amplifier is also sent to an integrator which is a time multiplication device. The integrator starts out with acceleration, which is in feet per second per second and multiplies it by time; the result is a velocity in feet per second.

The velocity data is then sent through a second integrator, which when multiplied by time, results in a distance calculation of feet or miles. The outputs of the integrators are aircraft velocity in the northerly direction and distance traveled. Only one accelerometer is shown; however, there are three, one in the north/south direction, one in the east/west direction, and one in the vertical.

The computer associated with the inertial system knows the latitude and longitude of the

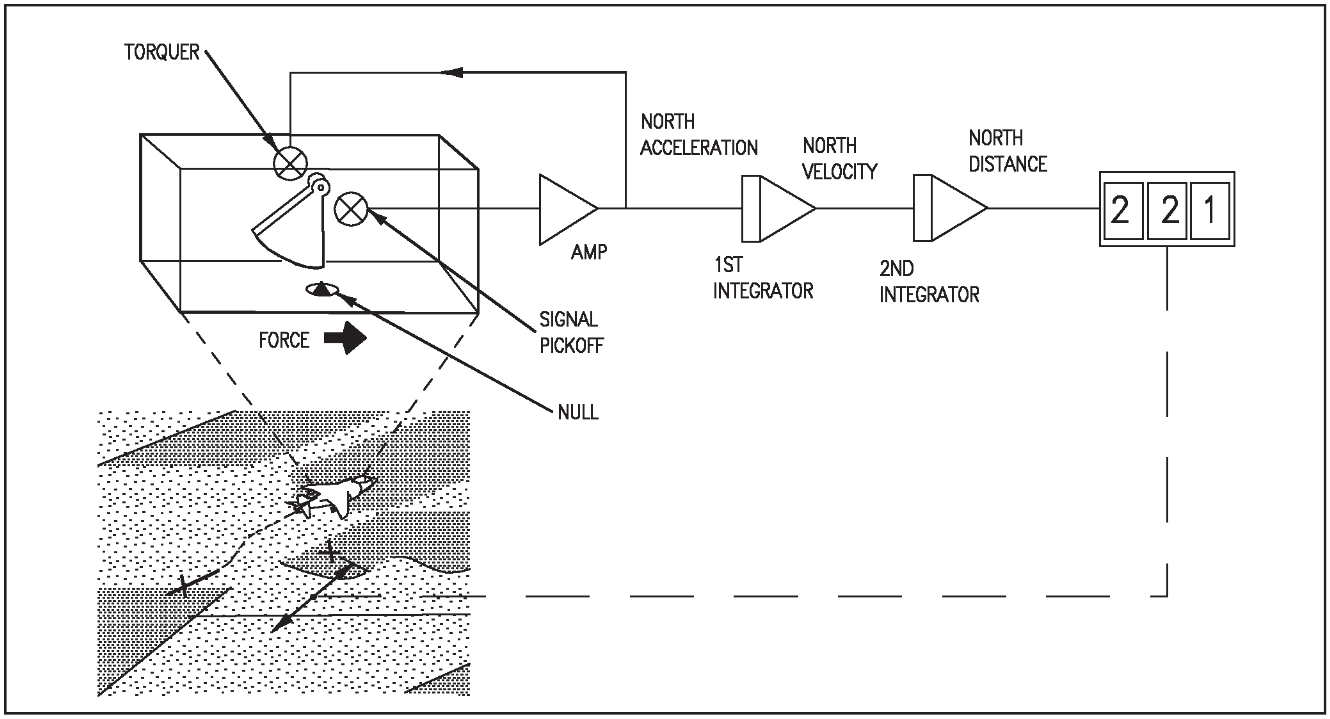

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Figure 1-135. Accelerometer and Integrator

takeoff point as entered by the pilot. It calculates aircraft travel in the north/south direction and in the east/west direction by means of the accelerometers. It is fairly simple for a digital computer, then, to continuously compute the new present position of the aircraft.

Up until now, an accelerometer has been illustrated which is hard mounted to the aircraft. If it were, it would be affected by the attitude of the aircraft. In Figure 1-136, the aircraft is shown in a takeoff pitch attitude. The fact that the accelerometer has been tilted tends to make the pendulum swing off the null position due to gravity. This would obviously output an erroneous acceleration signal which would result in an erroneous velocity and distance traveled. Therefore, there is a false acceleration problem caused by pitch angle. The solution to this problem is to keep the accelerometer level.

To keep the accelerometer level, it is mounted on a gimbal assembly, commonly called the platform. See Figure 1-137. The platform is nothing more than a mechanical device which allows the aircraft to go through any attitude change and yet the very inner element of the platform on which the accelerometers are mounted is able to stay level.

Gyroscopes which are used to stabilize the platform are also mounted on the innermost element of the platform. They provide inputs to amplifiers and motors which control the gimbals and, therefore, the level of the accelerometers.

Figure 1-138 shows how the gyro is used to control the level of the platform gimbal set. The gyro and accelerometer are mounted on a common gimbal. When this gimbal tends to tip off the level position, the spin axis of the gyro remains fixed. The case of the gyro, then, is moved off level and the amount that the case is tipped will be detected by the signal pickoff in the gyro. That signal is then amplified and sent to a gimbal drive motor which restores the gimbal to the level position again. Since the accelerometer is always kept level, it does not sense a component of gravity and is able to sense only the horizontal accelerations of the aircraft as it travels across the surface of the earth. Shown here is a single axis platform; in reality, movement may occur in three axes, the pitch, roll, and heading axes of the platform.

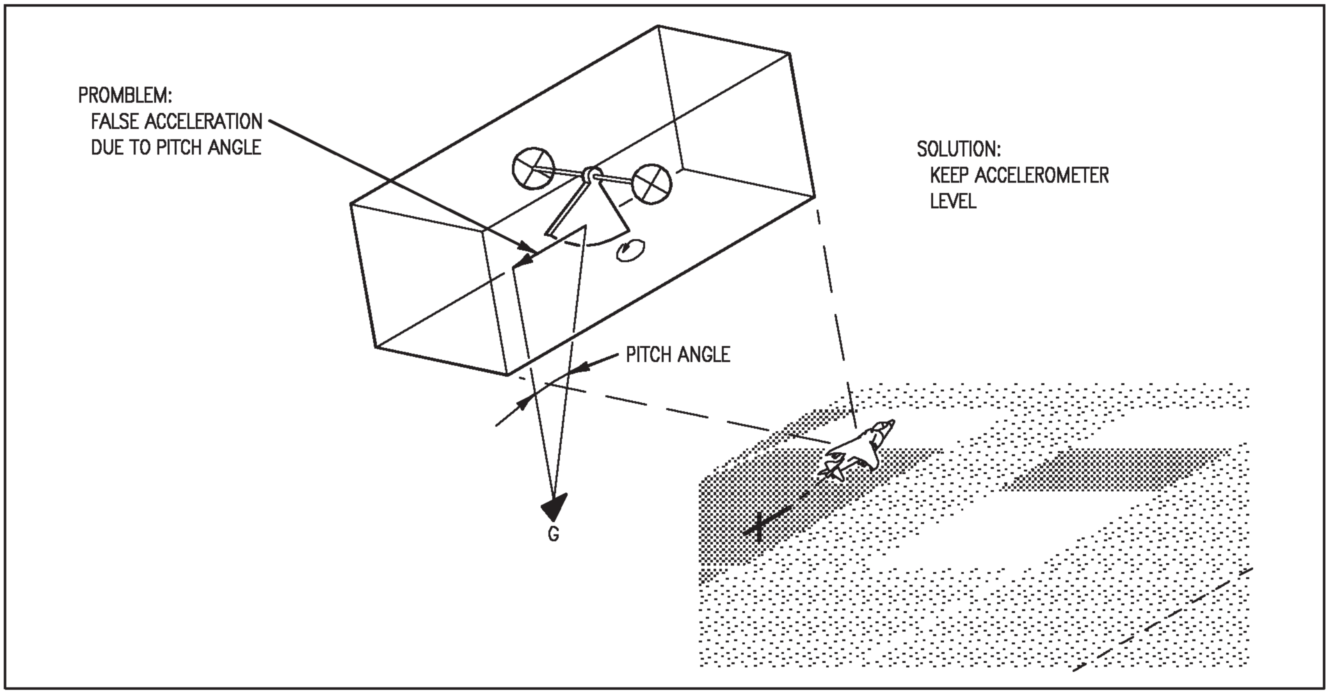

Figure 1-136. Effects of Gravity on Accelerometer

The previously described gyro stabilized platform would remain fixed in space, but the aircraft is not operating in space. It is operating on an earth which is rotating and an earth which is round. See Figure 1-139. In order to keep the accelerometers level with respect to the earth so that they sense acceleration of the aircraft in a horizontal direction only, some compensation must be made for these two facts.

The left side of Figure 1-140 shows what occurs if compensation were not made for the earth's rotation. Take the example of looking down at the earth from a vantage point in space over the north pole. At noon, the platform is level so that the accelerometers sense only horizontal accelerations. Now, as the earth rotates, the platform would maintain the same orientation in space. However, from an earth vantage point, it would appear to tip over every 24 hours.

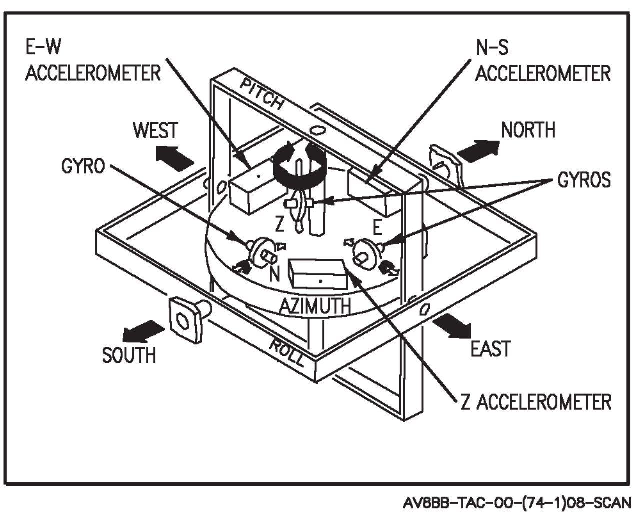

Figure 1-137. Platform Structure

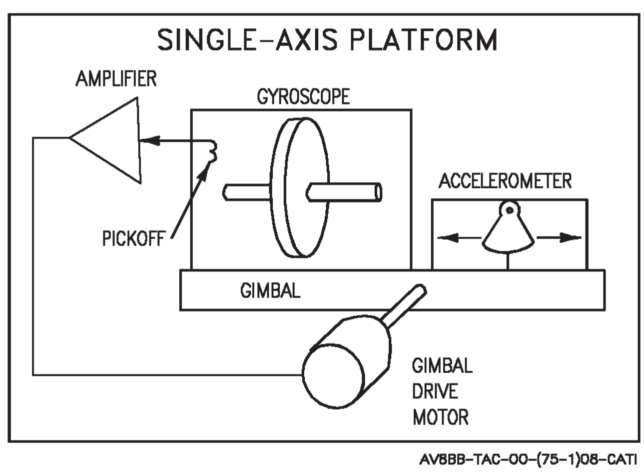

Figure 1-138. Gyro Control of Gimbal

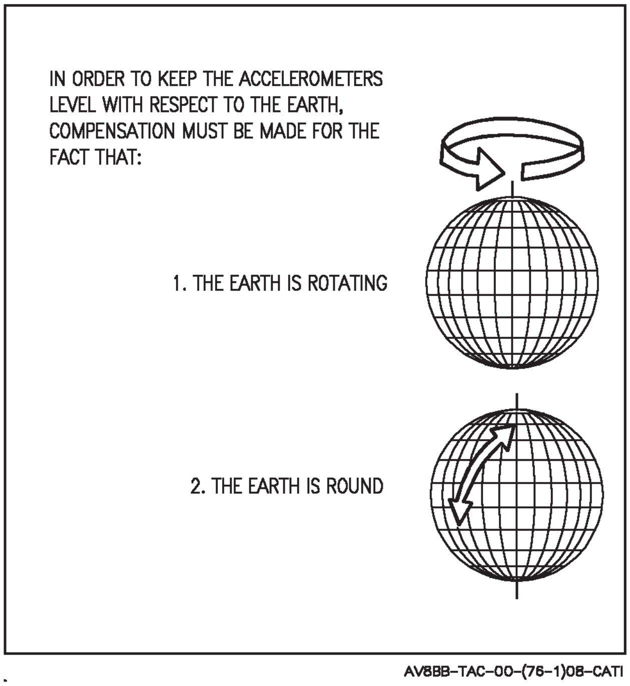

Figure 1-139. Earth-Orienting the Platform

To compensate for this apparent tipping, the platform is forced to tilt in proportion to the earth turning rate. In the example at the right (Figure 1-140) the platform is shown with the earth rate compensation added. From our space vantage point, it appears to tip over every 24 hours, while from an earth vantage point it remains fixed and level as required for proper system operation.

The required earth rate compensation is a function of latitude since what is being compensated for is the horizontal component of earth rate felt by the gyros, and that varies with latitude. At the equator, this value is 15.04° per hour, and with travel either further north or south, it reduces until it becomes zero at the poles.

Movement of the aircraft around the earth has the same effect on the INS platform as that caused by earth rotation. This is caused by the fact that the aircraft is flying in an arc as it follows the contour of the earth. Compensation for aircraft movement is developed using the aircraft velocity signal.

Both the earth rate and aircraft movement rate compensations are implemented in the system by torquing the gyro. See Figure 1-141. Two integrators are shown on the right, and in actuality, the integrators are part of a computer.

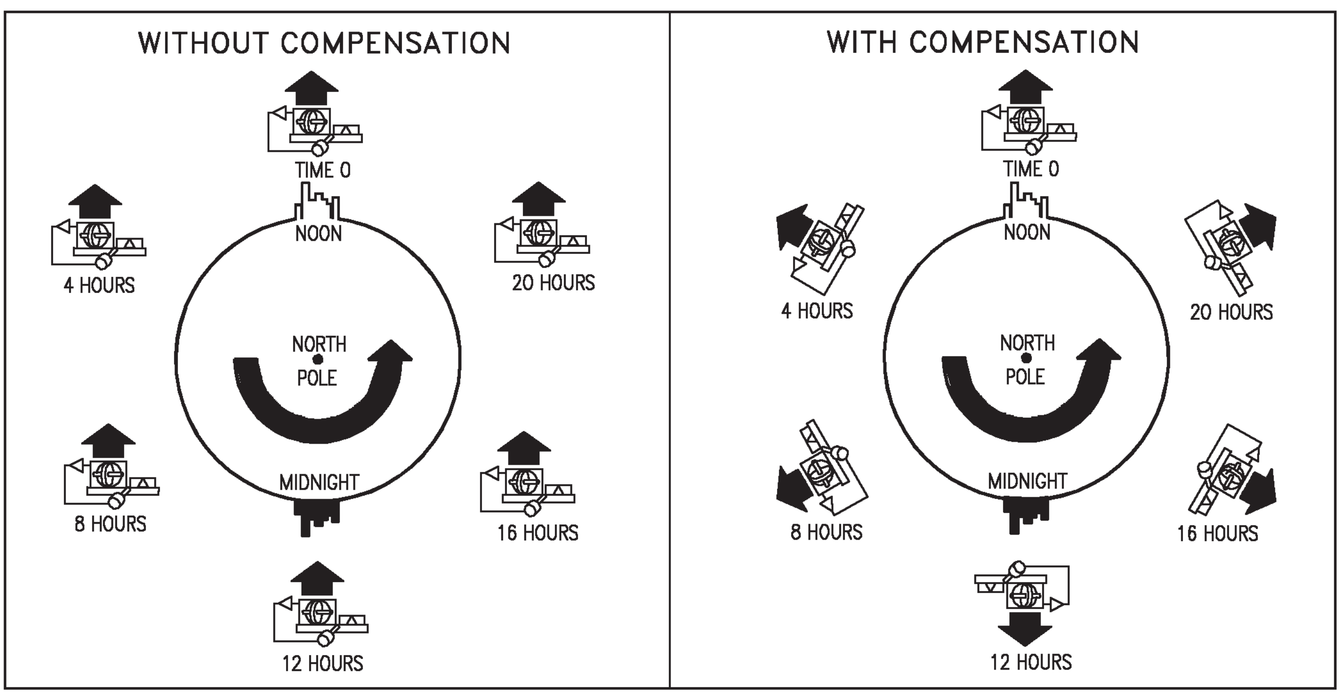

Figure 1-140. Earth Rotation Rate Compensation

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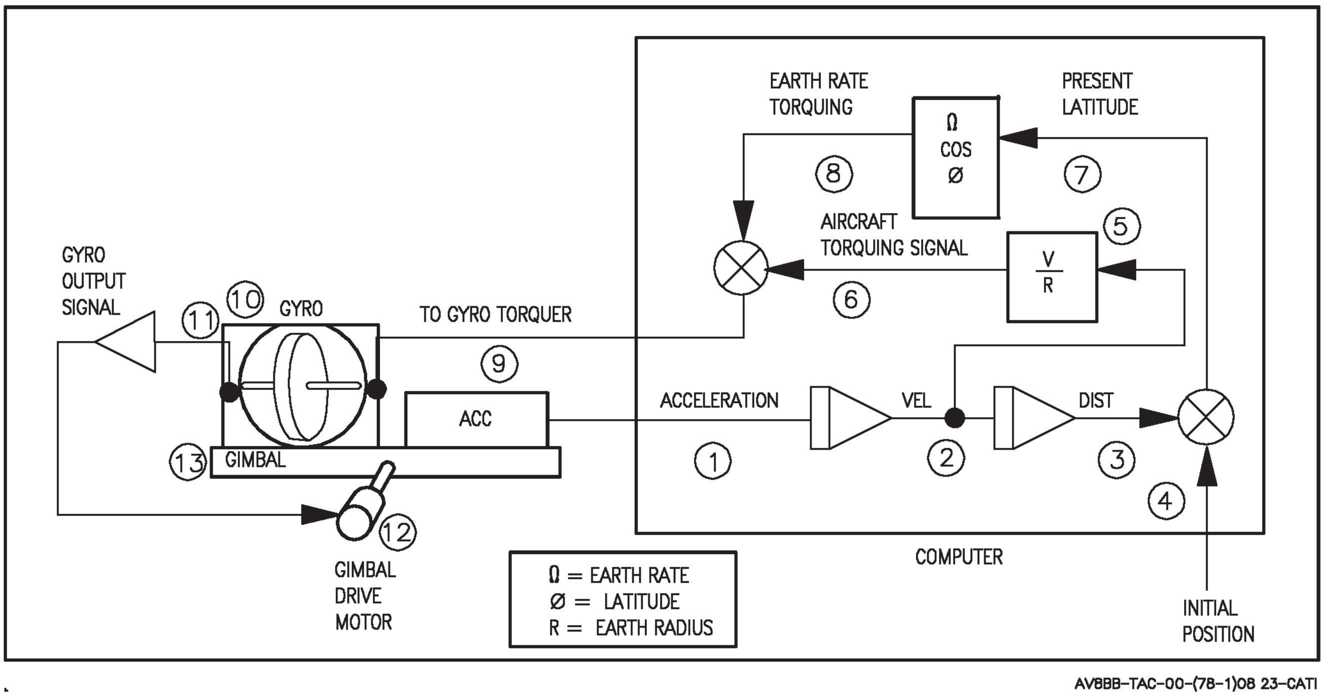

Figure 1-141. Gyro Torquing

Follow the numbers starting with acceleration from the accelerometer (1). Integrate once to get velocity (2) and then a second time to get distance (3).

Now take the distance traveled and sum it with the initial position (4) that the pilot has inserted into the system. The system updates the present latitude (7). This present latitude data is sent through some electronics to develop the term called earth rate torquing (8).

The velocity signal (2) is also sent (5) through some electronics to develop the aircraft movement rate torquing signal (6).

The aircraft movement rate and the earth rate terms are summed (9) and they are sent into the gyro torquer. This causes the rotor of the gyro (10) to tilt with respect to the case. When it does, an output signal (11) is generated which is amplified and used to drive the gimbal drive motor (12) which causes the gimbal (13) to tilt in proportion to the two input terms, earth rate torquing and aircraft movement rate torquing.

There are a number of other compensations generated within the system. The two examples shown just give an idea of how a simplified inertial system works, but other compensations are necessary.

Another correction that must be applied to accelerometers is a correction for pendulum effect known as Schuler tuning. A pendulum is a suspended mass, free to rotate about at least one axis in a horizontal plane and whose center of gravity is not on the rotational axis. Any pivoted mass which is not perfectly balanced is, by definition, a pendulum. Perfect balance is a highly desirable, never achievable, manufacturing process where balance is the desired end result. This holds for the manufacture of inertial platforms and all devices designed to provide a vertical reference for a moving vehicle. Such devices behave as do all pendulums; they align to dynamic vertical when at rest (with pivot axis and center of gravity both in the gravity vector on the bottom), and they tend to break into their natural period of oscillation whenever the vehicle is accelerated.

Pendulous oscillation is periodic angular motion having the gravity vector as its midpoint. Periodic motion around the local vertical produces obvious error from an inertial platform

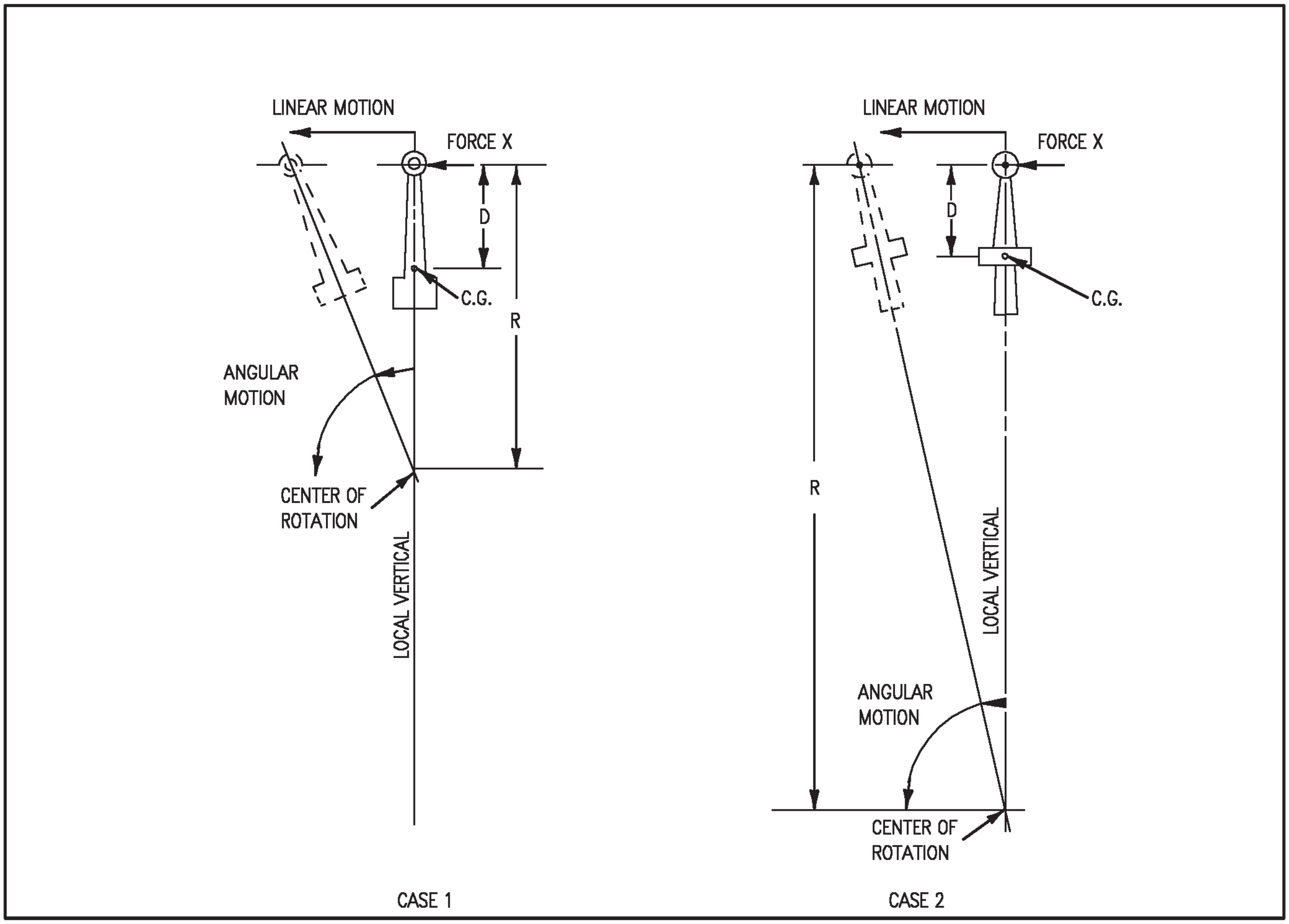

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Figure 1-142. Accelerated Pendulum

since misalignment relative to horizontal introduces gravity components on accelerometer inputs. The system will interpret gravity accelerations as horizontal accelerations of the vehicle.

The problem reduces to this: a pendulum is said to be at static rest only when its center of gravity and its pivot axis are resting in the same local vertical vector. When a vehicle carrying a pendulum accelerates, the acceleration is introduced to the pendulum via the pivot axis which moves out of the gravity vector it has shared with the pendulum's center of gravity. The center of gravity lags behind. The longitudinal axis of the pendulum now forms some angle other than zero with the local gravity vector. In short, the linear acceleration produced an angular acceleration of the pendulum. Thereafter, during an established constant velocity, the pendulous mass seeks to return to the vertical directly under the pivot axis but continually overshoots; periodic oscillation has begun.

When the acceleration was first introduced and the longitudinal axis misaligned to the local vertical, a downward extension of that longitudinal axis still intersects the original gravity vector at some point well below the pendulum's center of gravity. See Figure 1-142, Case 1.

For a given mass, the closer the pivot axis is brought to the center of gravity, the lower will be the period of oscillation and the further below the center of gravity will lie this center of rotation. See Figure 1-142, Case 2.

If the pivot axis and center of gravity are brought close enough together, the center of turning can be made to coincide with the center of the earth. Once such a pendulum is brought to

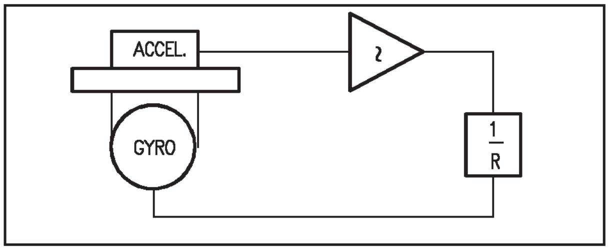

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Figure 1-143. Schuler Tuned Platform

static rest, accelerations of the pivot axis cannot cause the pendulum's longitudinal axis to form any angle with the gravity vector other than zero. All horizontal velocities will be accompanied by the proper angular velocities to maintain constant alignment of the pendulum to the rotating gravity vector. The pendulum will not oscillate because of horizontal accelerations.

To prevent vehicular accelerations from causing an oscillation of the stable element in inertial navigation system, the inertial platform is mechanized to have an equivalent length of a pendulum extended to the center of the earth. Any acceleration of the platform is about the earth's center of mass and that of the mechanized pendulum's center of mass. However, any errors which would introduce an offset in the system causes the effective mass of the mechanized pendulum to be displaced and introduces an oscillation with a period of 84.4 minutes to the stable element. This oscillation causes the platform error to be averaged out over a period of 84.4 minutes.

The typical mechanization of a Schuler tuned inertial platform is simplified in Figure 1-143. The output of the accelerometer is integrated to provide a velocity signal. The velocity signal is multiplied by 1/R, where R is equal to the earth radius, deriving an angular velocity about the earth's surface. This angular velocity is then used to torque an integrating gyro and cause the platform to precess about the earth's surface at the same rate that is being transported over the surface, thereby maintaining the platform normal to the local vertical.

With the platform initially unlevel or disturbed to an unlevel position, the accelerometer will sense a component of gravity. This signal is then integrated, resulting in a velocity signal. The velocity signal is then used to precess the gyro and, in turn, the accelerometer back to a level attitude. Even after the accelerometer is positioned level so as to sense zero gravity, the velocity output continues to torque the platform since no deceleration signal has been generated to zero the velocity signal. The accelerometer now tilts in the opposite direction and senses a gravity component of opposite polarity. This signal causes the velocity signal to decrease to zero and then build up in the opposite direction, attempting to precess the platform back to a level attitude in the other direction. The period of oscillation set up by this mechanization is 84 minutes, equal to that of the Schuler pendulum. Figure 1-144 shows the buildup and decay of acceleration and resultant velocity signals as a result of such disturbances just described. Therefore, the real purpose of Schuler tuning is to bound any errors in the system to acceptable limits so they do not continue to build.

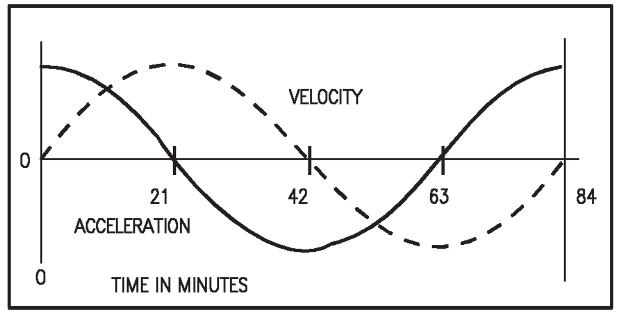

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Figure 1-144. Schulering Acceleration Versus Velocity

Two other forces which must be considered in accurately measuring accelerations are the Coriolis and centripetal forces or accelerations. These are considered to be external or phantom accelerations. Coriolis forces are apparent because the aircraft is referenced to the rotating earth, and appear whenever the aircraft has a velocity. Due to Coriolis, an aircraft moving to the north has an eastward acceleration; an aircraft moving to the east has an upward and southward acceleration; and an aircraft moving upward has a westward acceleration. This means that an aircraft flying from the equator to the north pole, though flying a straight course with

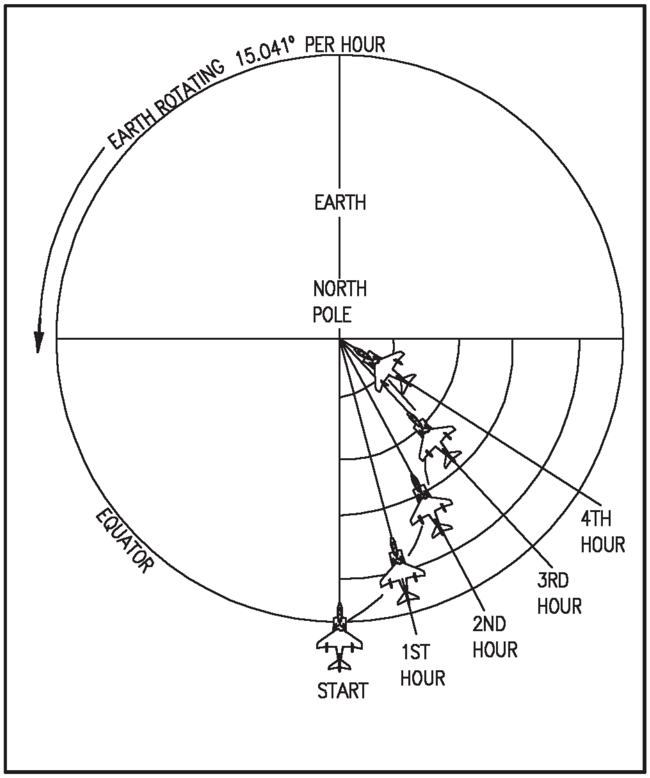

Figure 1-145. Coriolis Effect

respect to the earth, will be observed flying a deflected or curved path in space. See Figure 1-145. For the aircraft to maintain its northward heading, the accelerometer signals must be corrected according to aircraft velocity and present position.

The oblateness of the earth causes centripetal accelerations in certain latitudes where the plumb line to the center of the earth does not exactly coincide with the true vertical. See Figure 1-146. The resulting stable element imbalance causes spurious centripetal accelerations. Compensations for this spurious acceleration must be made before the accelerometer signal is integrated to obtain velocity.

Up to now, it was assumed that the system was all lined up and ready to go, but when the system is first turned on, there are a couple of things it has to do. First, the accelerometers must be leveled, and second, the system must oriented with respect to true north. This is normally called gyrocompassing.

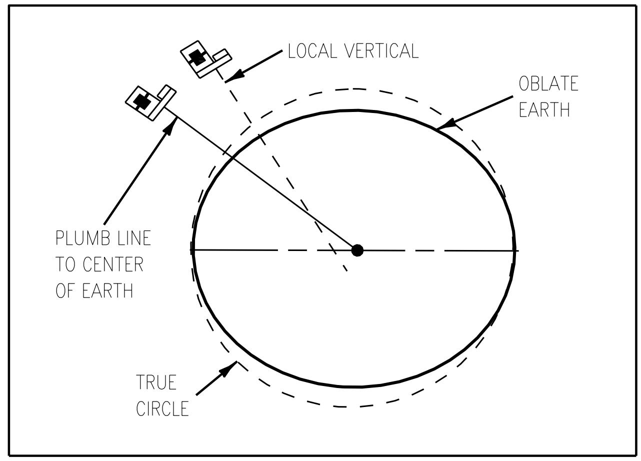

Figure 1-146. Oblated Earth Effect

Inertial navigation depends on integration of acceleration to obtain velocity and position. In any integration process one must know the initial conditions, which in this case are velocity and position. The accuracy to which the navigation problem is solved depends greatly upon the accuracy of the initial conditions. Therefore, system alignment is of paramount importance.

In the analog leveling mode, rather than taking the output of the accelerometer and putting it into the integrators, the output of the accelerometer is put through some electronics and into the gyro torquer. This causes the signal coming out of the gyro at the signal pickoff end to the gimbal drive motor to move the gimbals until the pendulum of the accelerometer is lined up with the gravity vector. At this point, there is zero output from the accelerometer, and the computer sets velocity to zero. At this point, attitude is available (first order AHRS).

Figure 1-147 depicts how a platform is oriented to true north in a north pointing inertial system. At the far left, the platform is shown level, but there is some misalignment angle with respect to true north. However, it is initially assumed by the computer, that the platform is aligned with true north and all of the earth rate compensation is fed into the X gyro. The X gyro would be sensitive to all the earth rate if the platform were in fact aligned with true north. No earth rate compensation is sent to the Y gyro.

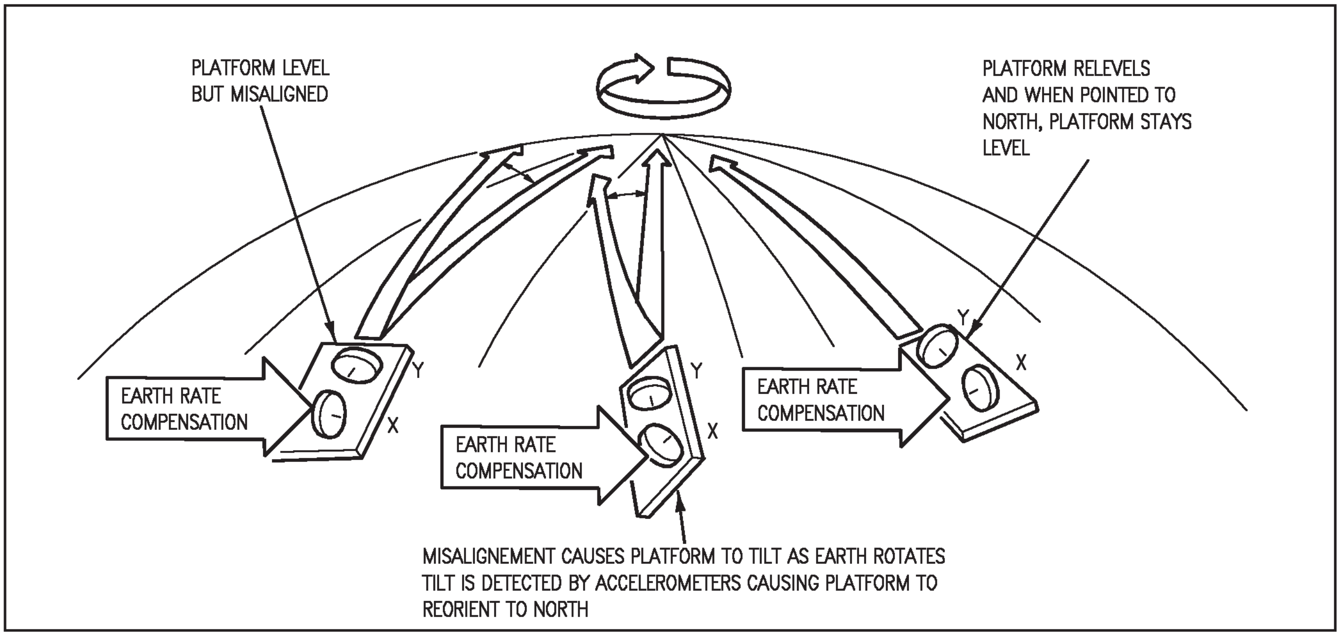

Figure 1-147. Platform North Alignment (Gyrocompassing)

The fact that the platform is misaligned with respect to true north means that the wrong compensation is being sent to the gyros. Therefore, as the earth rotates, the platform will begin to tilt off level. This tilt is detected by the accelerometers and a torquing signal is developed and sent to the gyro that controls the platform in the azimuth or heading axis. This gyro control loop physically re-orients the platform toward north.

Eventually when the platform is pointed to true north, the Y gyro requires no compensation and the X gyro is properly compensated for all of the earth rotation as sensed by the accelerometers. Since the gyros are correctly compensated, the platform will not tilt as the earth turns and the platform will remain aligned to north. As the system is flown in the navigation mode, north alignment of the platform is maintained by the computer torquing the azimuth gyro using a combination of earth rate and aircraft movement rate. The platform level is thereby maintained.

The system just described is called a north pointing inertial system. A north pointing system has the disadvantage that it cannot be operated in polar regions. Since the platform must always be physically pointed north, it can be seen that when a system is flown directly over the pole, the platform would have to rotate 180° at the instant it crossed the pole. This is physically impossible and in fact, most north pointing systems cannot be operated within several hundred miles of a pole because of the high platform torquing rates necessary to maintain north pointing. This problem is solved with a wander azimuth inertial system, which is used in the AV-8B.

The basic fundamentals of a wander azimuth system are identical to a north pointing system except that during gyrocompassing the platform is allowed to take an arbitrary angle with respect to true north, that is the initial wander or alpha angle. See Figure 1-148. Note the platform is leveled as before; also it is initially assumed the alpha angle is zero; therefore, all the earth rate compensation is sent to the X gyro. Because this assumption is not correct, the platform will tilt off level as the earth rotates in exactly the same manner as it did in a north pointing system. This off level condition is detected by the accelerometers as before, except that now the gyro torquing signal will be split up between the two gyros to compensate for the earth's rotation rate. Instead of continuing to send all the earth rate compensation to the X gyro and orienting the platform to north to satisfy that condition, some earth rate compensation is sent to the Y gyro.

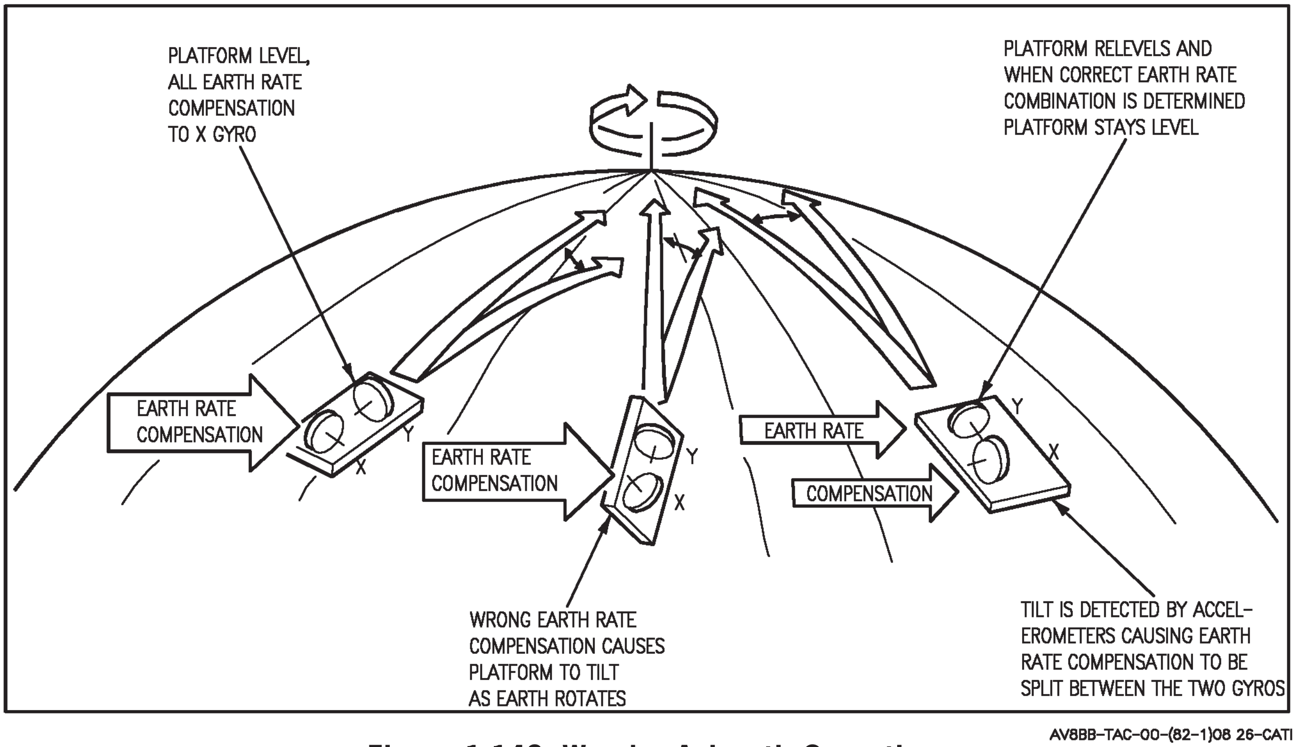

Figure 1-148. Wander Azimuth Operation

Eventually the right combination of earth rate compensation to the gyros is determined for the particular wander angle; the platform will then remain level as the earth rotates. The ratio of earth rate compensation to the gyros is then used to compute the initial wander or alpha angle.

As a "Wander Angle" system is flown in the navigate mode, the platform angle relative to true north (alpha) will change (that is wander) as a function of the longitude due to the convergence of the longitude meridians.

Operation of a wander azimuth system is the same as a north pointing system, except that the wander angle is taken into account in all computer computations. For example, the accelerometers are not oriented along north-south and east-west directions but are offset by the wander angle. However, the computer knows the wander angle and can easily compute N-S and E-W accelerations using the sensed acceleration and the wander angle.

1.11.2 Inertial Navigation System. The aircraft utilizes either the AN/ASN-130A or AN/ASN-139 inertial navigation system (INS). The INS is a self-contained, fully automatic dead reckoning navigation system that detects aircraft motion and provides acceleration, velocity, present position, pitch, roll, and true heading to related systems.

1.11.2.1 AN/ASN-130A. Installed on AV-8B 161573 thru 164130, and TAV-8B 162747 thru 164137 the system contains a gyro stabilized platform, power supply, central processor unit (CPU), memory unit, and the INS/mission computer system (MC) input/output interface unit and other electronics to maintain a stabilized platform and interface with aircraft systems.

The platform contains three accelerometers and two gyros which are isolated from external angular motion by a set of four gimbals. Each accelerometer is mounted so that the unit is sensitive to motion on a specific axis. The accelerometers provide accelerations for system computations. The gimbal positions provide pitch, roll and heading and provide 360° freedom of rotation. The gyros provide the stabilization of the platform to maintain accurate outputs.

The CPU provides alignment and navigation computations using platform outputs and data stored in memory. Computed data is stored in memory and continuously updated. The input/output interface provides the communication circuitry between the INS unit and the MC.

1.11.2.2 AN/ASN-139. Installed on AV-8B 164131 and up, and TAV-8B 164138 and up the system consist of a inertial measurement unit (IMU), signal data converter (SDC), and a power supply.

The IMU consists of three ring laser gyros (RLG), three accelerometers and a sensor electronics. The RLG's, one mounted in each reference frame, detect motion in their sensitive axis and provide outputs to the sensor electronics.

The accelerometers, one mounted in each aircraft reference frame, detect acceleration in their sensitive axis and provide linear acceleration to the sensor electronics.

The sensor electronics monitors the RLG's and accelerometers operation to provide stabilization. The sensor electronics processes the RLG inputs and provides pitch, roll, and yaw rate outputs. Accelerometer inputs are processed producing delta acceleration outputs.

The SDC contains input/output devices, memory files and a central processor unit (CPU). The input/output devices provide communications between the INS and related systems. The memory file provides for storage of the CPU program, calibration constants, post flight data, and critical data used in navigation computations. The CPU provides for inertial alignment and navigation computations, mode control, program control, and timing.

The power supply converts essential 115vac, 400Hz, phase A, and 28vdc aircraft power to dc voltages for internal use.

1.11.2.2.1 Ring Laser Gyro Theory. The ring laser gyroscope (RLG) operates on an optical principle called the Sagnac Effect which deals with the properties of two light beams traveling in opposite directions around a closed loop. The effect may be described as two athletes running in opposite directions, but at the same speed around the race track. If the athletes start together at the same point, then they will cross the finish line at the same time. See Figure 1-149. If, in Figure 1-149, we can control the rotation of the race track, then we can control the outcome of the race. If the race track is rotated in a clockwise direction, while both athletes are on the track, then even though they run at the same speed, the clockwise runner will reach the finish line first. In this analogy of the Sagnac Effect, the athletes are the light beams and the race track becomes the closed light path formed by four carefully aligned mirrors.

Two lasers are directed into this ring of mirrors, one laser in the clockwise direction and the other in the counterclockwise direction. See Figure 1-150. If the ring of mirrors rotates, clockwise for example, while the light beams are moving then the clockwise beam will seem to travel a shorter distance than the counterclockwise beam and exit the ring at the finish line first. As the beams exit the laser path cavity they combine and form a fringe pattern that moves across the light detector. By counting the number of fringes crossing the light detector, a measure of the rotation (pitch, roll, and yaw rate) can be obtained.

Stabilization of the RLG is obtained by eliminating two error sources. Laser lock-in is an error that occurs when the RLG rotation rate is very low. When this condition exists, the cw and ccw beams are so close in frequency that they pull together and couple. This coupling (lock-in) results in no output at low rotation rates. Lock-in is prevented by mechanical dithering (oscillating the RLG block). Path length variation is an error that occurs due to temperature and mechanical dithering. The path length is controlled by an electronic circuit which adjusts one of the RLG mirrors to maintain an average laser intensity (cavity length control transducer).

The RLG assembly consists of three RLG and the triad assembly of accelerometers, pulse rebalance circuitry, a high voltage harness, and a calibration memory on a rigid block that provides the required alignment and orthogonality

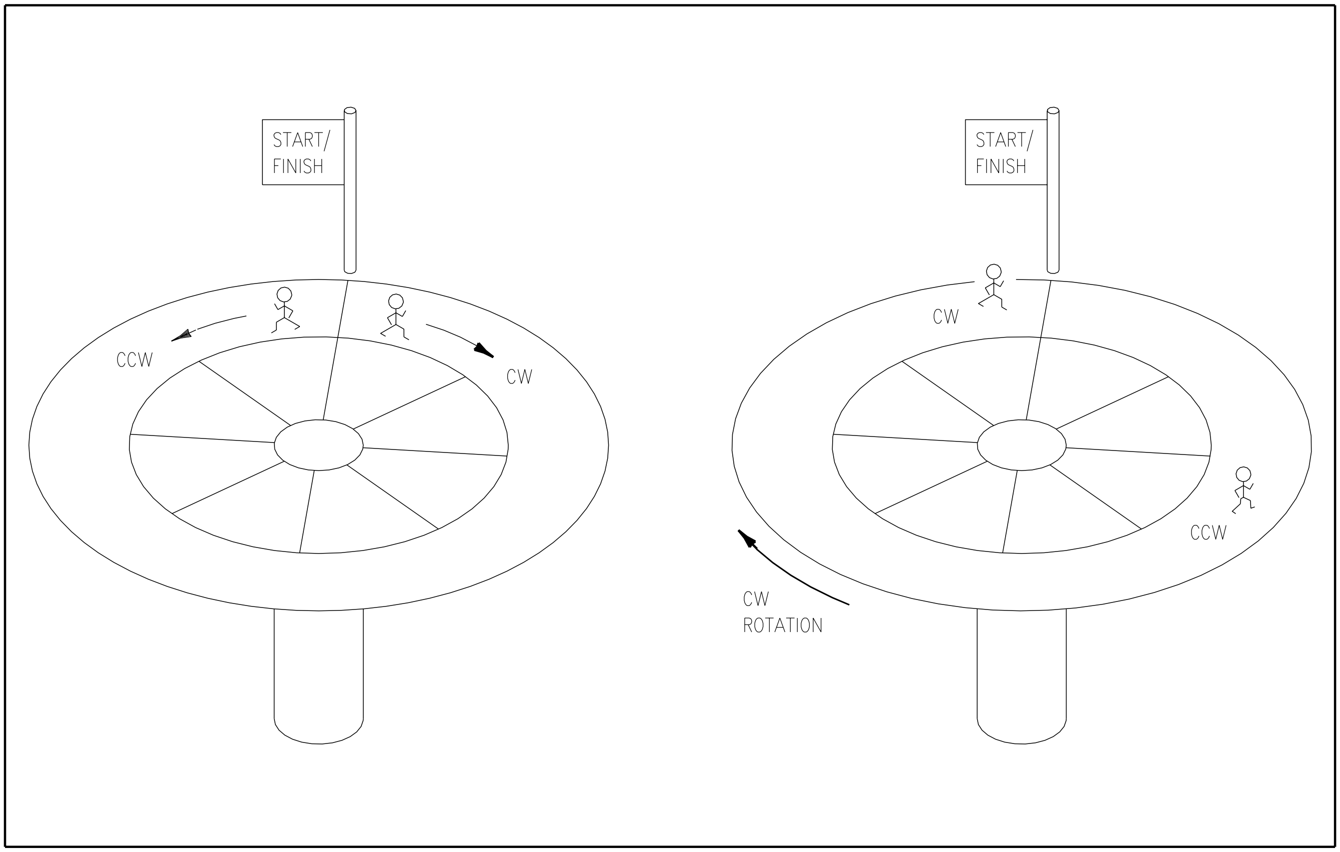

Figure 1-149. Ring Laser Gyroscope Theory

between the instruments. Each RLG contains separate mechanical dither and set of cavity length control transducers.

The accelerometer is a three-axis accelerometer triad package of modular construction. See Figure 1-151. The triad includes three accelerometer restoring amplifiers (ARA) that are hybridized analog servos, providing digital outputs of longitudinal, lateral, and vertical accelerations. These outputs combined with the RLG outputs are used to calculate position, velocity and rotational rates in the inertial and earth reference frames.

A sensing element is suspended in a pendulous manner within the frame by a pair of hinges which defines the axis of rotation. Aircraft acceleration causes the sensitive element to rotate relative to the case. The amplitude and polarity of relative motion is sensed by an optical pickoff that produces a dc signal, the difference of two currents flowing in the two photodiodes. This signal is applied directly to the input of the ARA. The ARA output is sent to the pulse rebalance electronics. Torquing pulses (each of a fixed quantity of current) from the rebalance electronics are then fed back into the accelerometer forcer coil to restrain the sensing element to the pickoff null. The pulse rate is then a precise measure of the input acceleration.

1.11.3 INS Management Techniques.

1.11.3.1 AN/ASN-130A INU Authorized Software Loads. Three INU OFPs have been developed and Fleet released for the AV-8B. They are most commonly referred to as B02, B45, and SMAL.

1.11.3.1.1 B02 and B45. B02 is short for: INS software load 879010-01-84B02, and B45 is short for: INS software load 879010-01-84B45. There are a number of issues surrounding the differences between these two loads, issues which include aircraft type compatibility, shipboard compatibility, and depot level configuration control. Basically, B02 is the INS loadout authorized

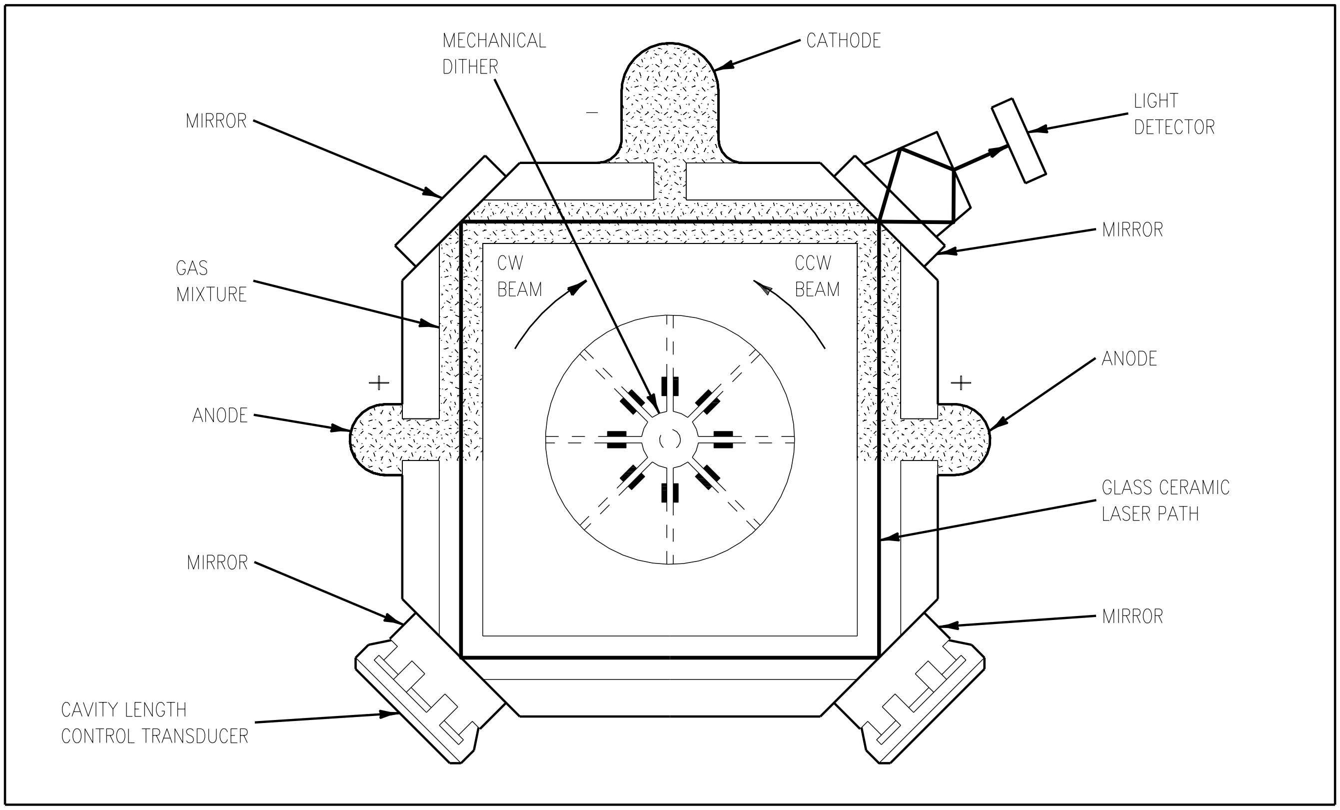

Figure 1-150. Laser Operation

in the F/A-18 and EA-6B. B02 was also authorized in AV-8B aircraft before 163176 (first DSU) and prior to AFC-269 with ASC-027. After AV-8B 163176, and following incorporation of AFC-269 with ASC-027, B45 and more recently SMAL are the only authorized AN/ASN-130A software loads. AFC-269/ASC-027 provides the capability to align the INS at sea with no restriction on the carrier's maneuvering. Specifically, allowable pitch and roll rate values are expanded making the SINS capability more compatible with L-class deck motion. In addition, the capability to conduct shipboard Higher Orders AHRS alignments are included. In B02 software, before the pitch and roll rates were changed, an alignment aboard an amphibian would have likely resulted in extended periods of an align hold condition. Back when B02 software was a current AV-8 load, it would (and still does) support SINS in F-18 and EA-6B, but the AV-8 did not have the cable connector or the MC change that would enable a comparable ″restricted carrier maneuvering″ SINS. Thus, when AFC-269/ASC-027 with B45 was released, it represented initial AV-8B SINS capability.

1.11.3.1.2 SMAL. Fleet introduction of Omnibus 6+C in January 1995 included an integrated INS/GPS capability in the navigation and targeting suite. A new INS software load designated ″Single Mode Alignment″ (SMAL) was introduced to support the Miniature Airborne GPS Receiver (MAGR) capability. SMAL INS software is compatible with any combination of C1 and 7.1 utilizing ASN-130A. (ASN-139 Ring Laser Gyro hardware has its own software load: 90X-L9CU. A minor ASN-139 hardware change, ECP-005, is required for MAGR compatibility.) The system is designed to incorporate the new software load with no degradation in INS performance regardless of the aircraft OFP or MAGR installation.

1.11.3.2 Determining the INU OFP. Because an INU loaded with B02 (F-18 or EA-6B compatible) is hardware identical to a B45 or SMAL loaded INU, the NSN is the same. Thus B02 software often appears in the supply system. All

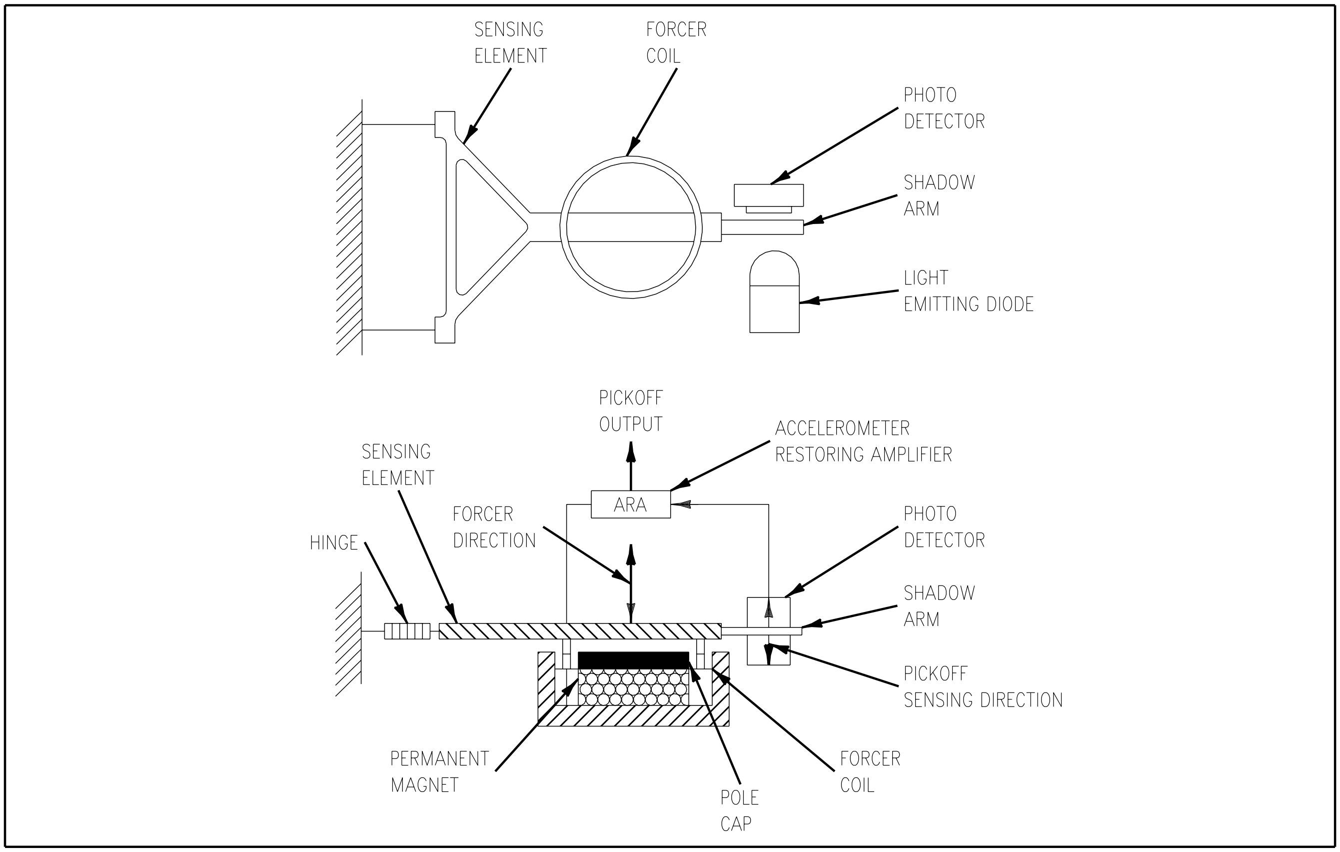

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Figure 1-151. Accelerometer

OFPs can be loaded into the INU at the I-level, and the INU's label is supposed to be stamped with its current OFP, so in theory AV-8 squadrons should only be delivered INUs with B45 or SMAL software. In practice, however, B02 loaded INUs continue to find their way into the AV-8B with remarkable frequency.

Whenever an INS related anomaly is observed (either behavior or performance), the software load should be verified. INU software load can be determined from the cockpit via a "Memory Inspect" of the INU. A Memory Inspect is essentially a request for an information read-back from a particular unit (avionics box), at an address (specific piece of information) which results in an answer from the box in the form of a checksum (reported octal code). If the request includes the proper INU unit and address codes, the reported checksum will uniquely identify the OFP that is loaded in the INS. An INS Memory Inspect may be conducted in the Day Attack, Night attack, and Radar aircraft with WOW using either APU or main generator power. INU Memory Inspects may also be conducted at the I-level test bench. To access the INU Memory Inspect checksum, do the following:

1. On MPCD/DDI select - MENU/BIT/MI
   (ODU displays UNIT in window 1 and ADDR in window 2)

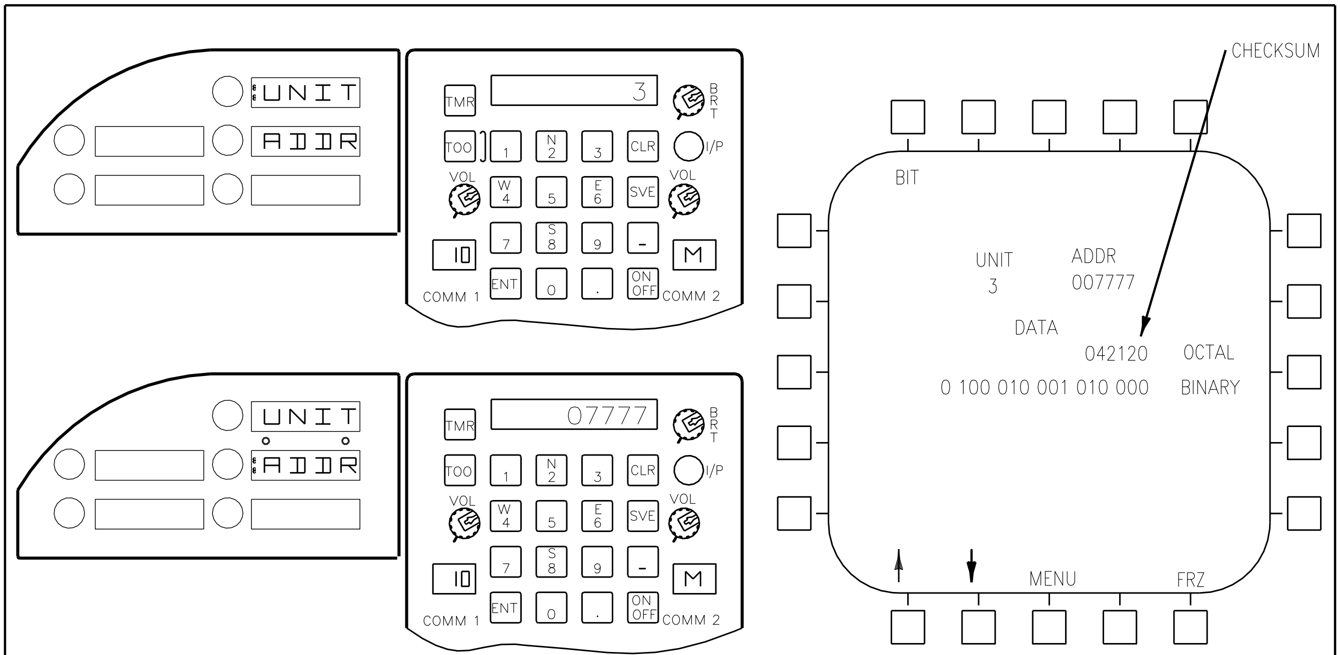
2. On ODU colonize - UNIT

3. On UFC enter - 3

4. On ODU colonize - ADDR

5. On UFC enter - 7777
   (MI page reports the checksum of the current INU. See Figure 1-152)

1.11.4 INS Alignment. During alignment the INS compares reference inputs with its own outputs to compute heading (wander angle), tilts (platform level), and gyro mini-biases (minute corrections to the platform gyroscopes). For a



		AIRCRAFT MEMORY INSPECT		
SYSTEM	OFP ID	UNIT	ADDRESS	CHECKSUM
AN/ASN-130A	84-B02	3	7777	042120
AN/ASN-130A	84-B45	3	7777	027307
AN/ASN-130A	SMAL	3	7777	142436
AN/ASN-139	90X-L9CU	3	7777	000002

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Figure 1-152. INU Memory Inspect

ground alignment, the reference input is a non-changing position (waypoint zero). In the case of a carrier alignment, the reference input is from the Ship's Inertial Navigation System (SINS). For a GPS in-flight alignment, the reference input is from the miniaturized airborne GPS receiver (MAGR) and the magnetic compass; and for a GPS carrier alignment, the reference input is from the MAGR only. The following is a list of alignment modes:

1. Primary align

   (a) ground align (GND)

   (b) carrier align (SEA)

   (c) GPS carrier align (IFA)

2. Primary sub-align modes

   (a) stored heading align (GND or SEA)

   (b) manual SEA align (SEA)

3. Back-up align mode (in-flight)

   (a) GPS airborne align (IFA)

The alignment sequence is illustrated in Figure 1-153. An alignment executes the following six steps:

1. Cage - INS is aligned with aircraft fuselage. gimbals are torqued to null pitch/roll synchros and azimuth resolver.

2. Heat - gyros and accelerometers are heated to an operating temperature of 170 °F at a rate of 2.5 °F per second.

3. Spin - gyros are spun up to 22,500 rpm.

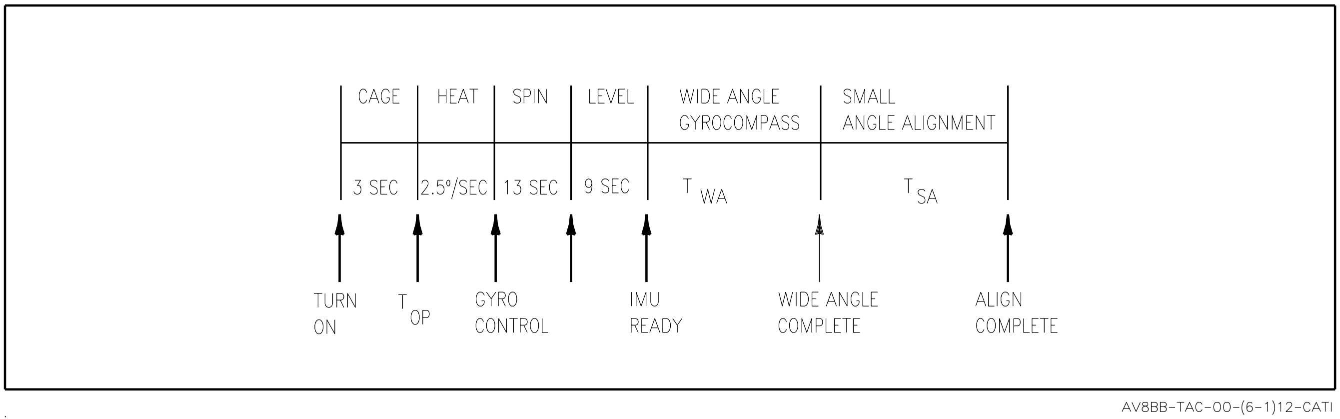


Figure 1-153. AN/ASN-130A Alignment Sequence

4. Level - INS platform is leveled with respect to local vertical. Gyros are torqued to null the accelerometer outputs.

5. Wide Angle Gyrocompass - system determines north to within about 2°. The approximate time required to do this depends on the alignment type:

GND align	=	66 seconds
SEA (SINS)	=	80 seconds
IFA (GPS carrier)	=	80 seconds
SEA (manual)	=	240 seconds

The beginning of wide angle gyrocompass is termed "IMU Ready" and at this point ATT NOT OK disappears from the DDI/MPCD, and the QUAL number (align quality) appears and begins to count down.

6. Small Angle Alignment - system computes heading, tilts, and gyro mini-biases to the fine degree necessary for precise inertial navigation. The beginning of small angle alignment is indicated by the HDG legend displayed across from the QUAL digits on the DDI/MPCD.

The following important points should be kept in mind:

1. A SEA alignment on a pitching deck, while turning, will last several minutes longer that a ground alignment. This is because the wide angle and small angle adjustments for leveling vary with the position and motion of the aircraft relative to the earth. During high rate maneuvers, the INS will not indicate align complete until the turn rate decreases (below 2.5°/second).

2. The duration of the heat step varies directly with the initial temperature of the INS. It simply takes longer to heat the unit from 40° to 170 °F than it does from 120° to 170 °F. If you are on the first launch on a cold morning, this step will take a long time (about a minute). If you are the second launch on a quick turnaround, on a hot afternoon, this step will be short (about 10 seconds).

1.11.4.1 Initial Present Position. Initial present position *may not* be changed once the QUAL number has started counting down. This is because the INS continuously receives a present position input from the MC during the alignment but only uses the last present position received before "IMU Ready". Aircraft data position *may* be changed anytime after "IMU Ready" without affecting the initial present position/alignment.

1.11.4.2 Taxi During Alignment. The most accurate alignments are produced by not moving the aircraft until an OK is displayed. However, if it is necessary, the INS has a taxi feature that allows the aircraft to be moved during alignment. Releasing the parking brake after wide angle align complete (HDG appears on the DDI/MPCD, indicating valid true heading), causes the INS to go into "align hold". During the align hold time, the INS uses the accelerometer outputs and the computer's navigation program to keep track of aircraft position. Reapplying the parking brake causes the alignment to resume. If taxiing occurs during alignment, the align time increases by an amount equal to the total taxi interval plus 20 seconds. The 20 seconds are necessary to dampen out any error sources generated during the taxi.

Remember it is best not to move the aircraft until align complete (OK displayed on the DDI/MPCD), but if taxi is required prior to complete, the lower the QUAL number, the better (less than 5 preferred.) In any case, *never* taxi before "IMU Ready" (ATT NOT OK disappears).

If taxi is necessary prior to the wide angle align complete (HDG displayed on DDI/MPCD), the alignment will be restarted after the parking brake is reapplied. Once the parking brake is set, check the INS present position. If the known aircraft position differs from the position displayed by the INS by more than 1 minute of latitude or longitude, perform a manual position correction.

One exception to the preceding rules is the GPS carrier alignment. Taxi during GPS carrier alignment will not suspend or degrade the alignment. However, shadowing of the GPS antenna by the ship's superstructure or other large obstructions may block reception of GPS satellites causing an align hold.

CAUTION

NEVER takeoff, fly, or land with the INS in the OFF mode as this may cause damage to the inertial platform.

NOTE

- Although taxing with the INS in the OFF mode is permitted, it is better to switch to GYRO mode first, wait for "IMU ready", and then taxi.
- If the aircraft parking brake is released during a manual SEA alignment, the INS will automatically sequence to free inertial navigation mode if the QUAL number is less than or equal to 5 or attitude heading reference system (AHRS) true heading mode if the QUAL number is greater than 5. In either case, the manual SEA alignment will not resume when the parking brake is reapplied.

1.11.4.3 SEA Alignment. Two submodes of SEA alignment are available, stored heading alignment and manual SEA alignment. When ship's inertial navigation system (SINS) data is available, it should be acquired with either the data link (RF) or cable (CBL) and used to perform a normal alignment or a stored heading alignment. In the event SINS and GPS are not available, a manual SEA alignment may be performed (GPS carrier alignments are discussed in paragraph 1.11.4.9.2).

SINS data dropouts during a SEA alignment will not cause an align hold indication. The SEA alignment will automatically transition to a manual SEA alignment using the last valid SINS data. When SINS data becomes valid again, the alignment will automatically transition back to a normal SEA alignment. SINS SEA alignment displays are shown in Figures 1-154.

1.11.4.4 Stored Heading Alignment. The purpose of performing a stored heading alignment is to reduce the total align time by bypassing the wide angle gyrocompass step. This submode will save 60 seconds for a SEA alignment (stored heading is not available for a manual SEA alignment).

To perform a stored heading SEA alignment, the "stored heading available" discrete in the INS computer must be valid. To do this, the following must have happened:

1. The spotting angle has been saved from the previous alignment (To save: perform an alignment until an OK is displayed, then turn the mode selector switch to OFF - DO NOT GO TO NAV). The spotting angle is the angular difference between aircraft heading and ship's heading.

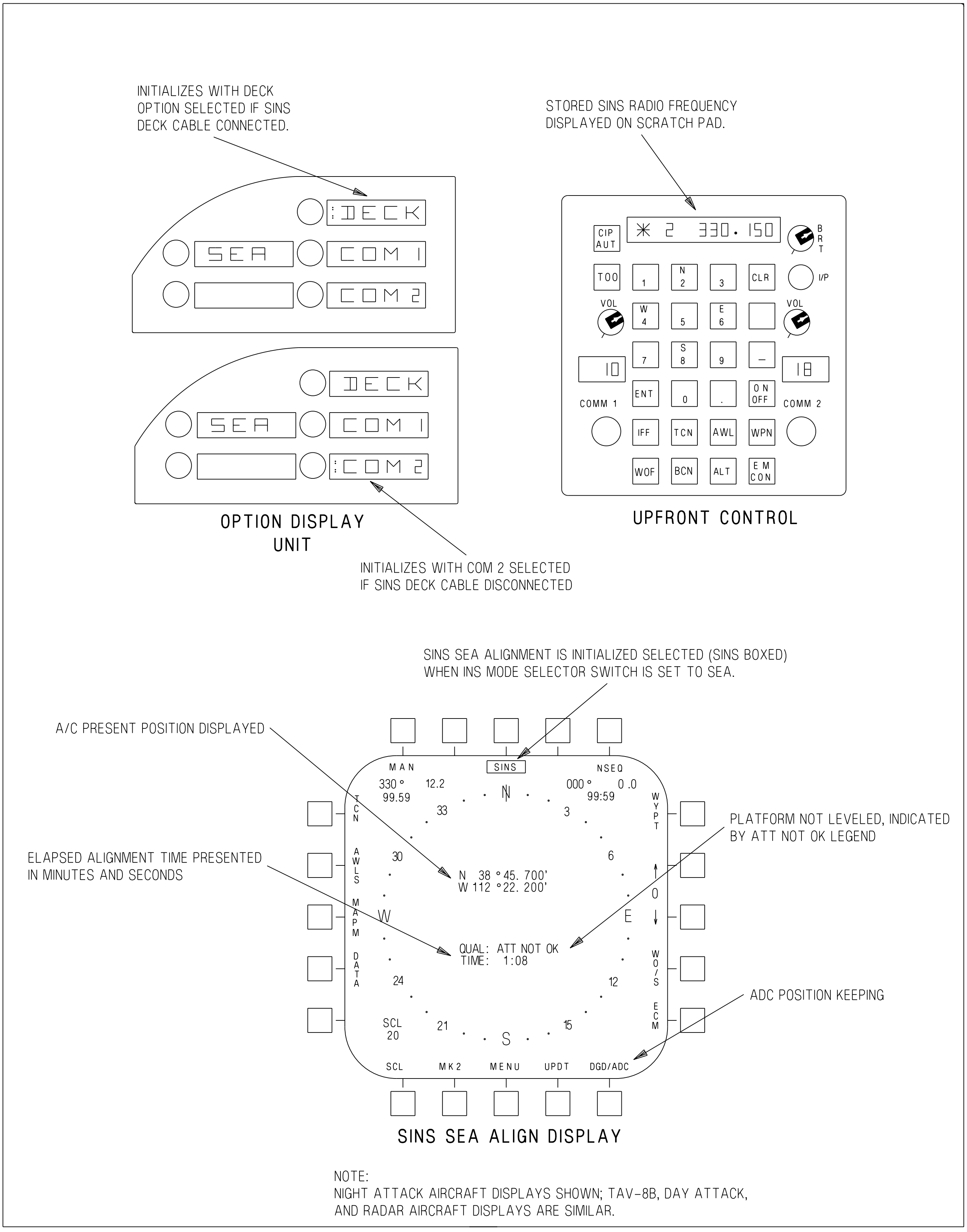
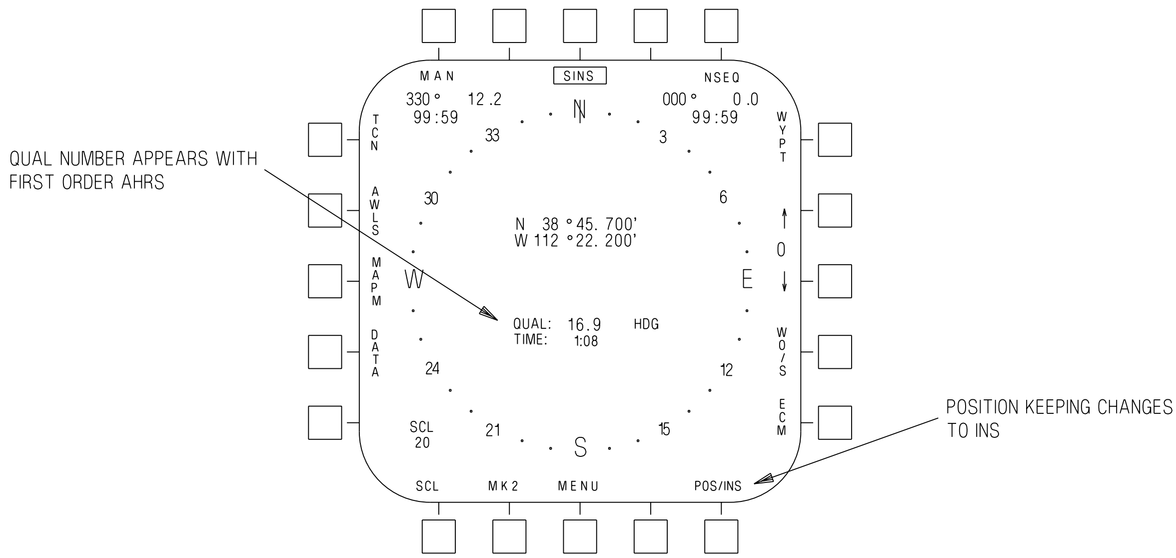
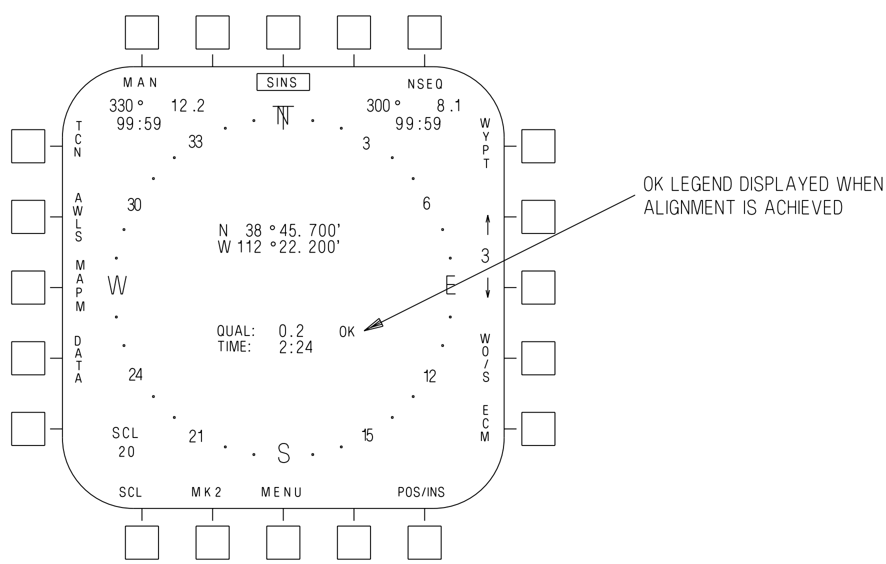


Figure 1-154. SINS Sea Alignment (Sheet 1 of 2)



SINS SEA ALIGN DISPLAY



SINS SEA ALIGN DISPLAY

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Figure 1-154. SINS Sea Algnment (Sheet 2 of 2)

2. The parking brake has not been released since the previous alignment was performed (i.e., the aircraft has *not* been moved).

To begin the stored heading alignment, select the SEA position on the INS mode selector switch and press the SHDG pushbutton before the QUAL number appears on the DDI/MPCD. The INS initializes true heading to the ship's heading plus the stored spotting angle.

NOTE

If the aircraft has been moved after a stored heading is saved, the stored heading option will still be available. However, if selected, the stored heading information used by the INS will be incorrect and the INS may never completely align.

1.11.4.5 Manual SEA Alignment. The manual SEA alignment should only be used when SINS and GPS are not available. In this event, the reference data required by the INS must now be entered by the pilot via the UFC. If the ship's speed changes by more than 1 knot, the pilot must reenter the new data and at this time the alignment will automatically restart at ″IMU Ready″. The total alignment time for a manual SEA alignment will be approximately 15 minutes and the navigation performance will be as accurate as the data entries.

During a commanded manual SEA alignment, if valid SINS data becomes available, the alignment restarts utilizing SINS reference data per paragraph 1.11.4.3. However, if SINS data becomes available when the QUAL number is less than 4, the manual SEA alignment continues without interruption. Manual SEA alignment displays are shown in Figure 1-155.

NOTE

- Hand-entered values for ship's heading and speed must be non-zero. If either is zero, the INS indicates align hold.
- The stored heading option is not available during manual SEA alignment.

1.11.4.6 Ground Alignment. The ground alignment (GND) mode is utilized when the aircraft is on land. The initial inputs to the INS are initial position (latitude and longitude) and parking brake set. A position update during ground alignment if greater than 1 nm causes the alignment to restart at ″IMU Ready″. Also, two position updates during ground alignment, regardless of magnitude, causes the alignment to restart at ″IMU ready″. Changes in altitude during taxi do not affect the alignment. If the aircraft must be moved during alignment, refer to paragraph 1.11.4.2, Taxi During Alignment. Ground alignment displays are shown in Figure 1-156.

1.11.4.7 Stored Heading Mode. As with SEA align, a stored heading GND alignment reduces the total align time by bypassing the wide angle gyrocompass step. This submode saves 30 seconds for a GND alignment. The conditions required to perform a stored heading GND align are the same as those required for a stored heading SEA align (paragraph 1.11.4.4) except that GND is selected on the mode selector switch instead of SEA.

1.11.4.8 Automatic Stored Heading Mode. This mode allows selection of a stored heading alignment following a flight which had a full ground alignment prior to the flight. If the INS was operating in NAV during the flight and no BIT failures occurred, the INS heading is saved at power shutdown and the aircraft must not be moved. This stored heading is available for the next ground alignment. The procedure to initiate the automatic stored heading alignment is the same as the ground stored heading alignment.

1.11.4.9 IFA Alignment. On GPS equipped aircraft the in-flight alignment (IFA) mode provides the pilot with the capability of performing a GPS airborne alignment, completing a partial alignment, or performing a GPS carrier alignment. Refer to A1-AV8BB-NFM-000, Chapter 23 for Radar aircraft in-flight alignment.

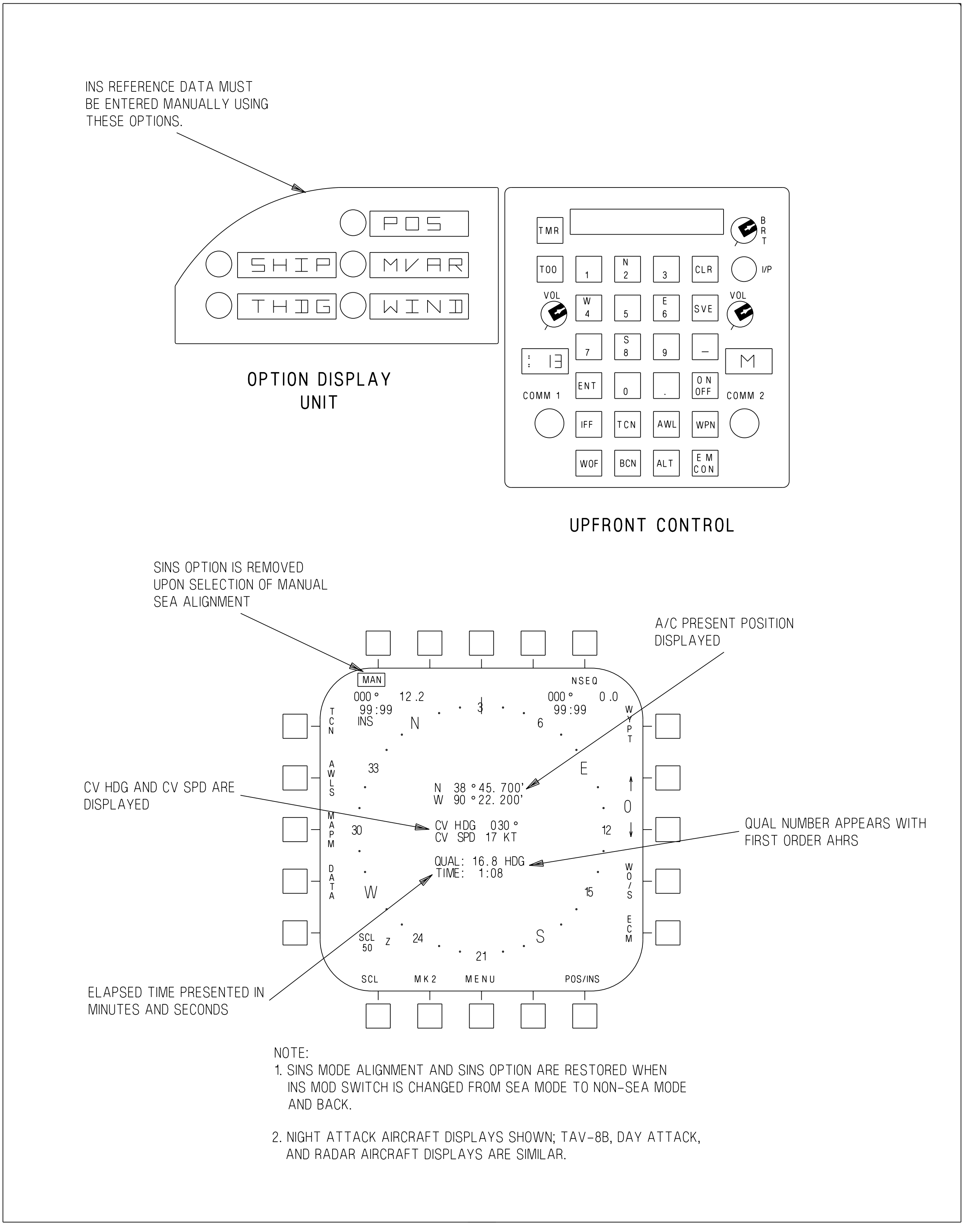
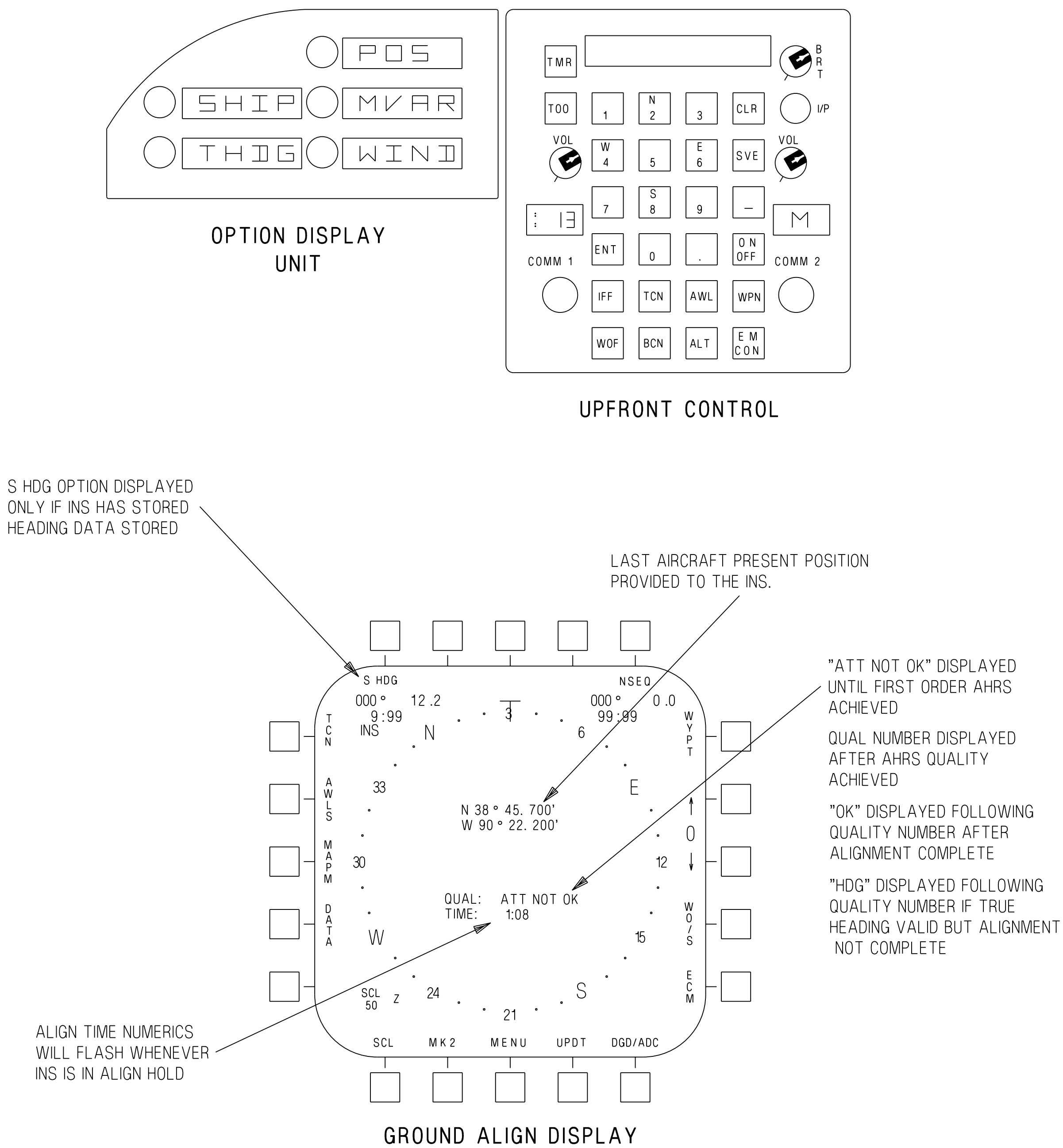


Figure 1-155. Manual Sea Alignment



NOTE

NIGHT ATTACK AIRCRAFT DISPLAYS SHOWN.
TAV-8B, DAY ATTACK, AND RADAR AIRCRAFT DISPLAYS ARE SIMILAR.

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Figure 1-156. INS Ground Alignment

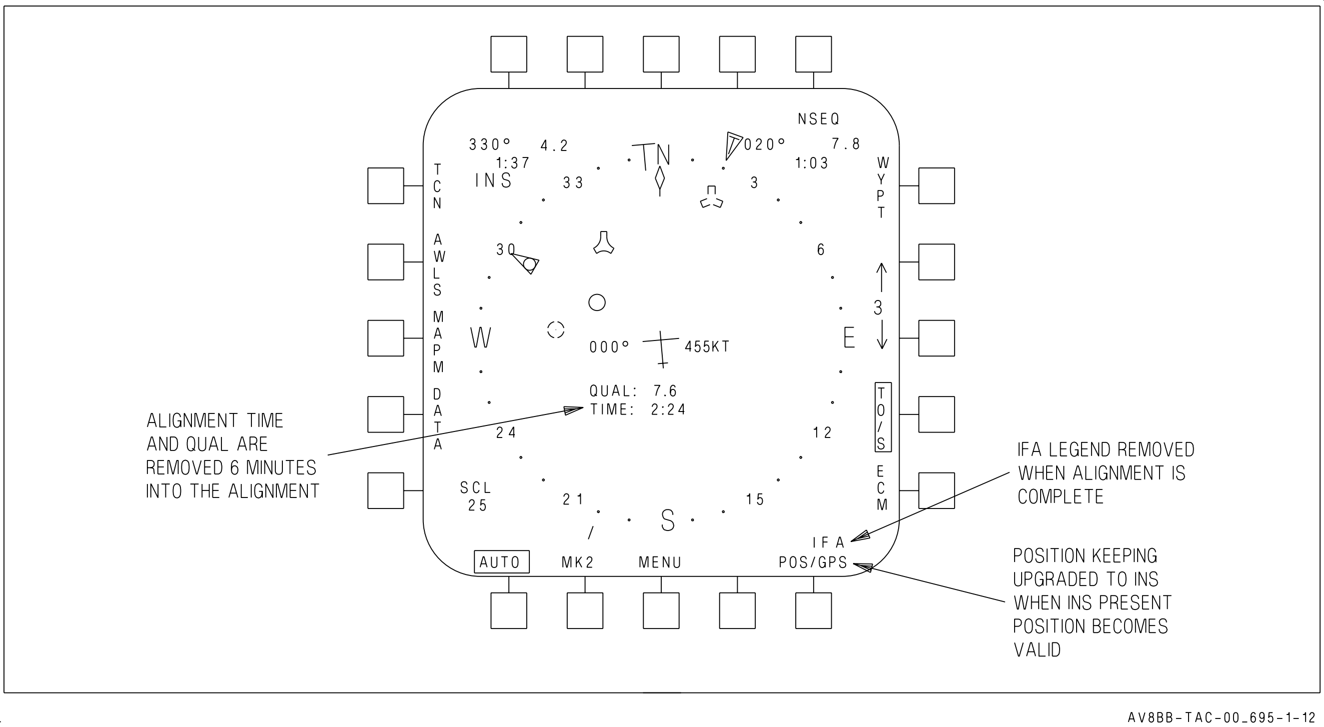

Figure 1-157. GPS Airborne/Carrier Alignment

The partial alignment submode is used to complete an unfinished GND or SEA alignment. This might happen when taxi and takeoff is necessary before align complete. An unfinished alignment is defined as an alignment in which IFA or NAV was selected after wide angle complete, but before align complete (HDG displayed on the DDI/MPCD). The procedure for completing the partial alignment is to switch to IFA before taxiing for takeoff. An OK will be displayed when the alignment is complete. The pilot may then select NAV or remain in IFA (aided nav).

NOTE

For the AN/ASN-130A, if the INS mode selector switch is moved directly from OFF to IFA, the HUD VSTOL master mode sideslip ball will not appear until weight-off-wheels (i.e., after take off). To obtain the sideslip ball prior to takeoff, select NAV until the sideslip ball appears (i.e., approximately 5 seconds) then reselect IFA.

1.11.4.9.1 GPS Airborne Alignment. A complete airborne IFA may be initiated after a total INS shutdown (select OFF, wait 30 seconds, then IFA) or after a GYRO alignment (select GYRO, wait 5 seconds, then IFA). Whichever case, the alignment may take up to 10 minutes to complete.

During the IFA the MC must provide valid GPS data from the MAGR, valid magnetic heading from the ADC, and valid magnetic variation from the pilot. If the reference heading information from the MC (mag heading + mag var) differs from the aircraft true heading by more than 10°, the INS may never reach align complete due to errors induced. For this reason, ensure the correct value for magnetic variation had been entered. The IFA display is shown in Figure 1-157.

1.11.4.9.2 GPS Carrier Alignment. In the event that SINS is not available, a carrier alignment using GPS may be performed. To initiate a GPS carrier alignment turn the mode selector switch from OFF to IFA.

A GPS carrier alignment is very similar to a SINS alignment. Both begin the alignment in wide angle mode (aircraft heading is unknown) and both require reference position and velocity. During the GPS carrier alignment, the MC must provide valid GPS data from the MAGR receiver. The magnetic heading input is not required, since the INS performs a wide angle alignment.

NOTE

If GPS velocity becomes invalid before wide angle alignment complete (HDG displayed in the DDI/MPCD), the alignment will restart. This is due to the Kalman filter extrapolations which require valid reference velocities without interruption before high order AHRS.

1.11.4.10 GYRO Alignment. The GYRO alignment provides a fast reaction AHRS capability. First order AHRS is achieved in about 22 seconds and then high order AHRS is achieved making a total gyro align time of about 33 seconds (on land) or 45 seconds (at sea). GYRO alignment requires the following:

1. Parking brake set
2. Mag heading valid
3. Weight on wheels
4. Turn the mode selector switch from OFF to GYRO.

If the GYRO position is selected while in flight, the INS reverts to acceleration-leveled AHRS. This is the least accurate mode and should be selected only if the INS attitude is significantly in error. Once GYRO is selected, full inertial navigation mode can be regained by switching to IFA. The GYRO alignment displays are shown in Figure 1-158.

1.11.5 Navigation.

1.11.5.1 Free Inertial Navigation. The INS may be placed in free inertial navigation by selecting NAV on the mode selector panel or using the Auto Nav feature. During free inertial navigation, the INS does not use any reference data except for position updates. On GPS equipped aircraft the INS enters a loosely coupled or uncoupled mode and is not automatically updated by the GPS. On non-GPS aircraft this is the normal operating mode (NAV selected). A typical NAV display is shown in Figure 1-159.

1.11.5.1.1 Auto Nav. The AN/ASN-130A has a built-in feature called Auto Nav, that is used to transition the INS to navigate mode from GND or SEA alignment when true airspeed exceeds 80 knots and there is no weight-on-wheels. To use Auto Nav, the mode switch must be left in GND or SEA and the parking brake must be reapplied after every taxi. This allows the INS to remain in alignment longer, which enhances the navigation accuracy. Once airborne, the mode switch may be changed to NAV or remain in GND or SEA.

NOTE

There is no Auto Nav feature from manual SEA alignment.

1.11.5.1.2 Position Updates. In general, if the INS is working properly and was completely aligned, the need to update the present position should be minimal. Erroneous position updates, intentional or unintentional, degrade the accuracy of the INS in flight. This is true even if you eventually get the correct position back in the system. If you routinely make large (over 10 nm) position update errors, the INS navigation accuracy will deteriorate during that flight. Simply put: DON'T LIE TO YOUR INS.

Erroneous updates cause poor INS navigation performance during the current flight (>1.5 nm/hr), but will not affect future flights, if the next flight's initial present position input is correct.

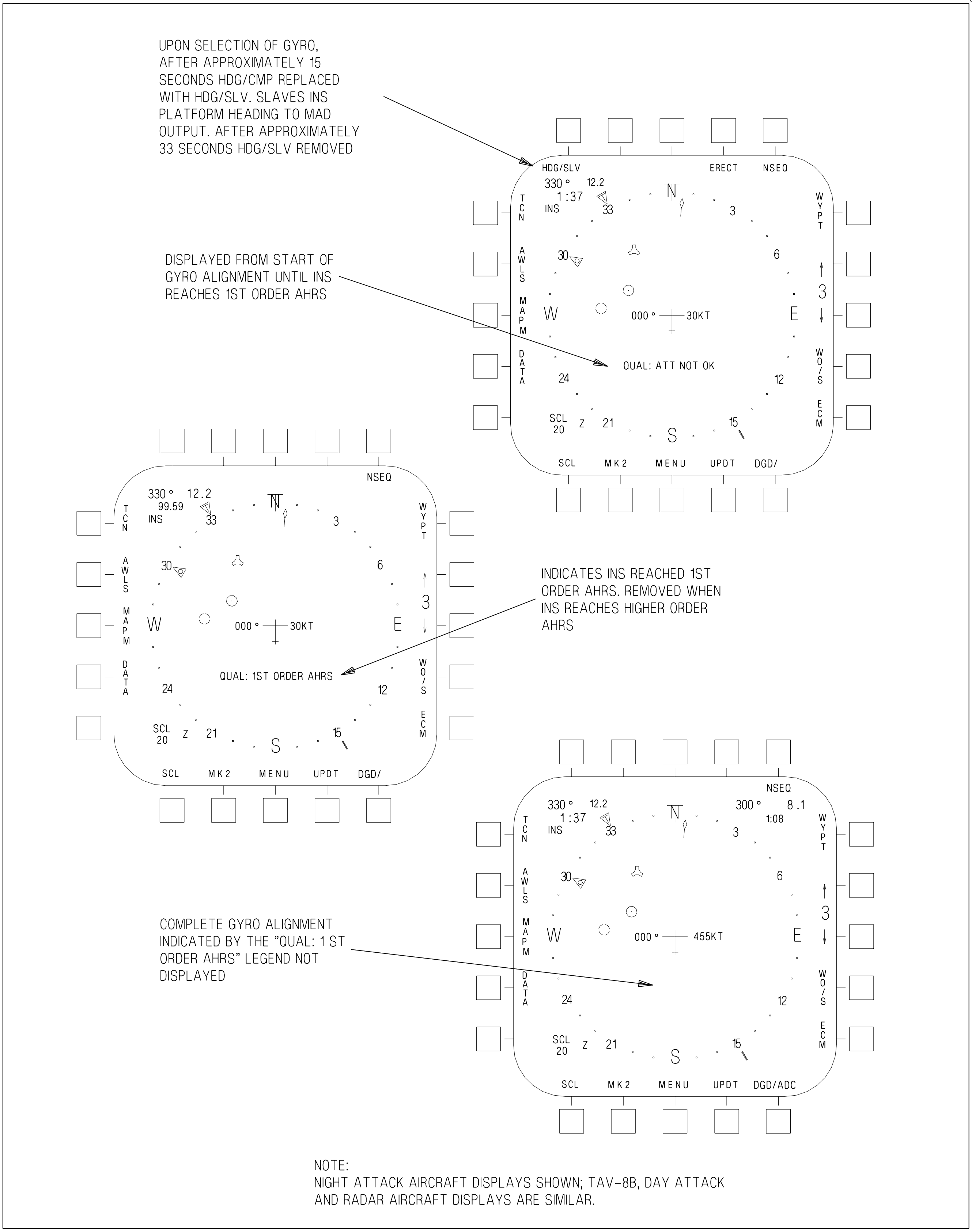

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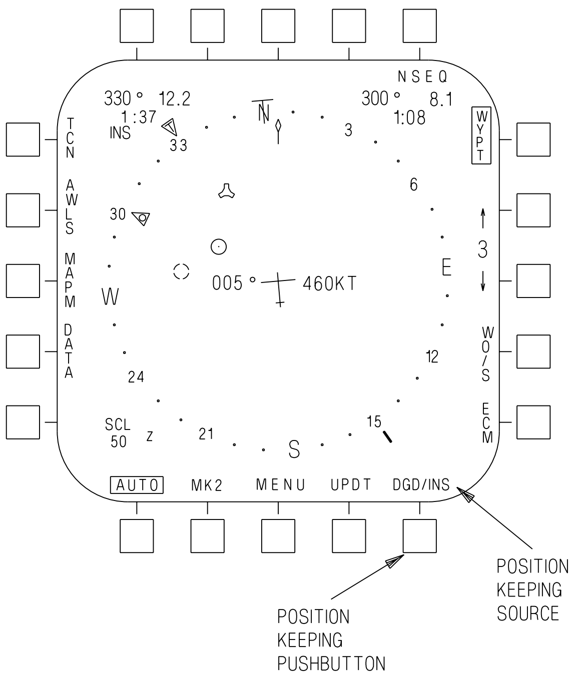
Figure 1-158. INS Gyro Alignment



- THE METHOD OF POSITION KEEPING IS CHANGED BY PRESSING THE POSITION KEEPING PUSHBUTTON.
- THE POSITION KEEPING SOURCE DISPLAYS IN THE NAV AND IFA MODE ARE AS FOLLOWS:

INS MODE SWITCH	POSITION KEEPING SOURCE DISPLAY		
	DAY ATTACK	NIGHT ATTACK A/C	RADAR A/C
NAV	DGD/INS DGD/GPS DGD/ADC DGD/	DGD/INS DGD/GPS DGD/ADC DGD/	DGD/INS DGD/GPS DGD/ADC DGD/
IFA	POS/INS POS/GPS	POS/INS POS/GPS	POS/INS POS/GPS

- LEGEND CHANGES TO DGD/blank IF DATA BECOMES INVALID OR NOT AVAILABLE.

NOTE

NIGHT ATTACK AIRCRAFT DISPLAY SHOWN.
DAY ATTACK AND RADAR AIRCRAFT DISPLAYS ARE SIMILAR.

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Figure 1-159. Navigation Position Source

Listed below are the three types of position updates and their respective error budgets in INS. The error budgets represent the modeled errors in the Kalman filter for each type of position update:

Tacan	1.0 nm CEP
Overfly	1/2 altitude (max is 1.0 nm CEP)
Designate	0.1 nm CEP

1.11.5.2 Aided Nav. On GPS equipped aircraft the INS operates in the "aided nav" mode if the mode selector switch is placed in the IFA position and align complete is achieved. GPS data is used during this mode of operation.

NOTE

The INS should periodically be flown in NAV mode (no GPS aiding). This allows INS errors to be observed that otherwise might be masked by coupling with the GPS. Terminal position errors after the flight should be examined for acceptable navigation performance (less than 1 nm radial position error per 1 hour of nav). It is recommended that every fifth flight hour be flown in NAV mode (See paragraph 1.11.7, INS Performance Evaluation).

1.11.6 Post-Flight. It is essential to the operation of an INS to keep the gyroscopes stable in reference to the earth. Gyro precession must be corrected and platform reference (local level) must be maintained as the aircraft moves across the earth. The INS computer makes corrections by sending an electrical torquing signal. The magnitude of these corrections are directly affected by the gyro bias.

Due to the changing characteristics of gyros with time and use, the gyro bias is comprised of three parts. The permanent bias which is updated at the factory or depot, the mini-bias which is updated on the aircraft, and the filter bias which is updated during each alignment. All three biases are added together for the gyro bias used during alignment and flight. The permanent bias and the mini-bias are saved in non-volatile memory, but the filter bias is saved in volatile memory and is lost after INS shutdown. The filter bias is the only run-time adjustment to the gyro bias.

There are two methods of updating the mini-bias after flight depending on the INS mode selected in flight. Both are discussed in the following paragraphs.

1.11.6.1 Mini-bias Update After NAV. The post flight update after flying in free inertial navigation mode (NAV selected) allows the INS to calculate a final position error rate (radial position error divided by time in NAV). The position error rate is used to make a final adjustment to the filter bias before updating the mini-bias. *An accurate post flight update is essential to continued INS performance.*

Inorder to calculate an accurate post flight update the following must have occured.

Prior To Takeoff -

1. INS has performed a GND align.

2. INS ground align showed ″OK″.

3. The INS alignment quality number was less than 1.

In Flight -

1. INS remained in NAV during flight.

2. No BIT failures occured.

Post Flight -

1. Final position update was made (in or near chocks with parking brake set).

2. The final position error rate is less then 1 nm/hr.

When all of the above are completed/true, a *20 second wait after the chock update is required before switching the INS to OFF in order to allow the INS enough time to process the update and correct the filter bias.* At shutdown the INS adds the filter bias to the mini-bias.

NOTE

Due to possible errors in the SINS data, it is not permitted to perform mini-bias updates during carrier ops, even if the flight begins or ends ashore.

1.11.6.2 Mini-bias Update After IFA. On Night Attack aircraft (MAGR equipped) the ″aided nav″ mode (IFA selected) provides the INS with continuous alignment information allowing the INS to calculate an accurate filter bias. The INS will *automatically* update the mini-bias after the aircraft has landed if the following requirements are met.

1. The MAGR receiver must be crypto keyed.

2. The INS issued an ″OK″ on the ground or in flight.

3. The INS alignment quality number was less than 1.

4. The aircraft has been in flight (weight-off-wheels).

5. At least 10 minutes of GPS alignment/aiding.

6. No BIT failures.

The mini-bias update may be confirmed by viewing the GB 2 screen in the relay mode. The filter biases displayed are zeroed if the mini-biases were updated. Refer to Figure 1-160.

NOTE

Only half the filter bias is added to the mini-bias. The total correction is limited to 0.00615°/hr on each axis.

1.11.7 INS Performance Evaluation. The INS should be flown in NAV mode to evaluate the INS performance and to uncover any INS errors masked by the GPS. The performance errors indicated at the end of the flight are dependent on the initial alignment. Complete alignments (OK displayed and QUAL number less than 1) that result in a post flight position error rate greater than 1.0 indicate the need for close tracking of the INS's performance. If the position error rate has exceeded 1.0 nm for three or more flights, a maintenance gyro bias should be performed.

The INS has a relay mode to evaluate the INS performance. This mode has a POST 1 and POST 2 display for each flight and the flight number is represented by the FLIGHT legend on the displays. FLIGHT 1 is the most recent flight and FLIGHT 5 is the oldest. Displays for evaluating the INS performance are shown in Figures 1-160.

1.11.8 Gyro Spin Detector. During a normal INS shutdown (i.e., one commanded by the panel switch), the gyros are brought to a halt in approximately 8 seconds by applying a reverse spin voltage. When power is removed abruptly from the INS and no reverse spin is applied, the gyros require approximately 3 minutes to coast to a stop.

The gyro spin detector inhibits the INS from sequencing on until the gyros have spun down to less than 25 percent of their synchronous speed. If power is reapplied or the INS is turned on while the gyros are still spinning down, the INS will remain in "mode sequence inhibit" (off) until the gyro spin detector enables normal mode sequencing.

When power is interrupted, the INS must be sequenced to OFF mode before the desired mode is selected. If the desired mode is selected before the gyros have stopped, the INS will automatically come up when it is ready.

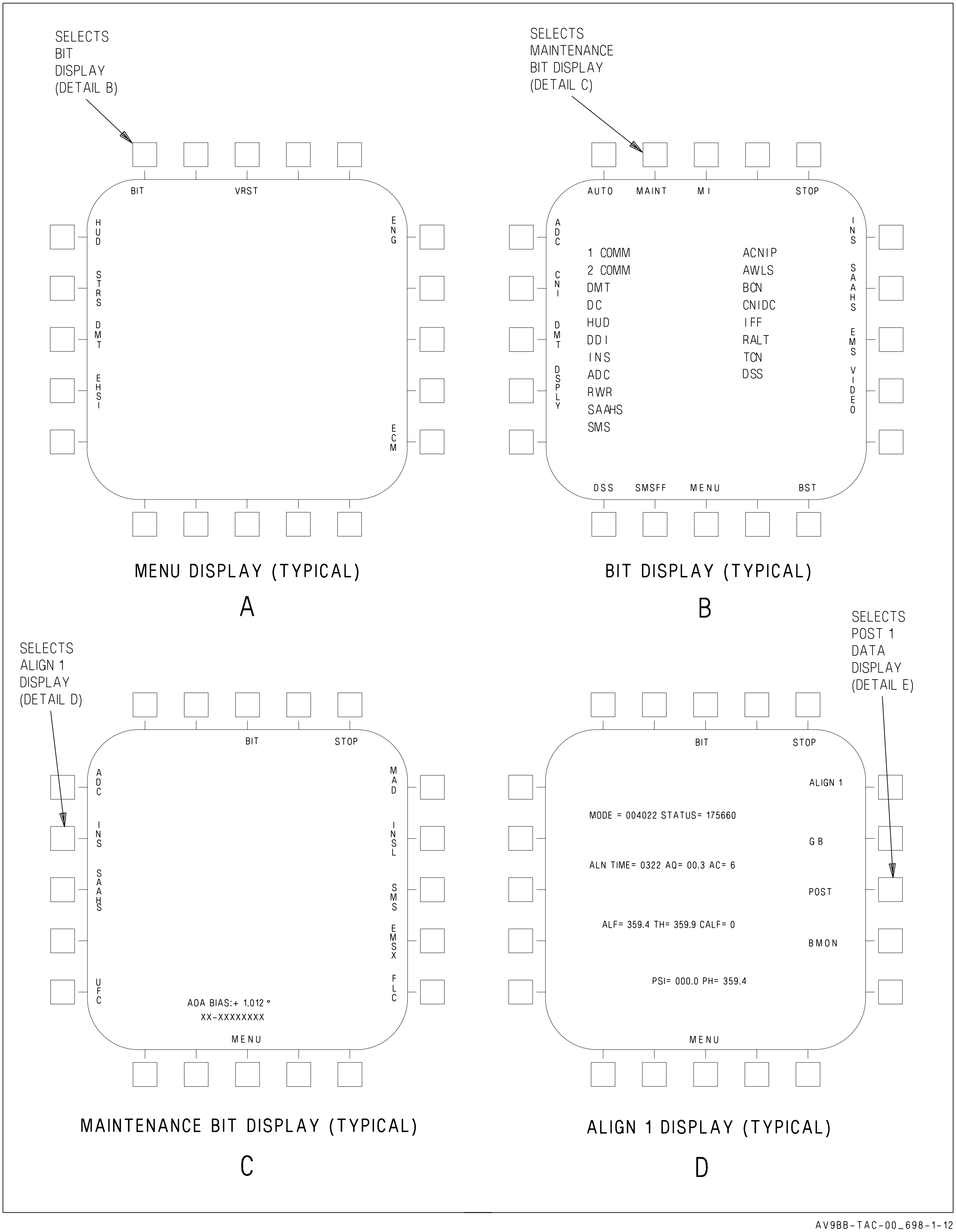
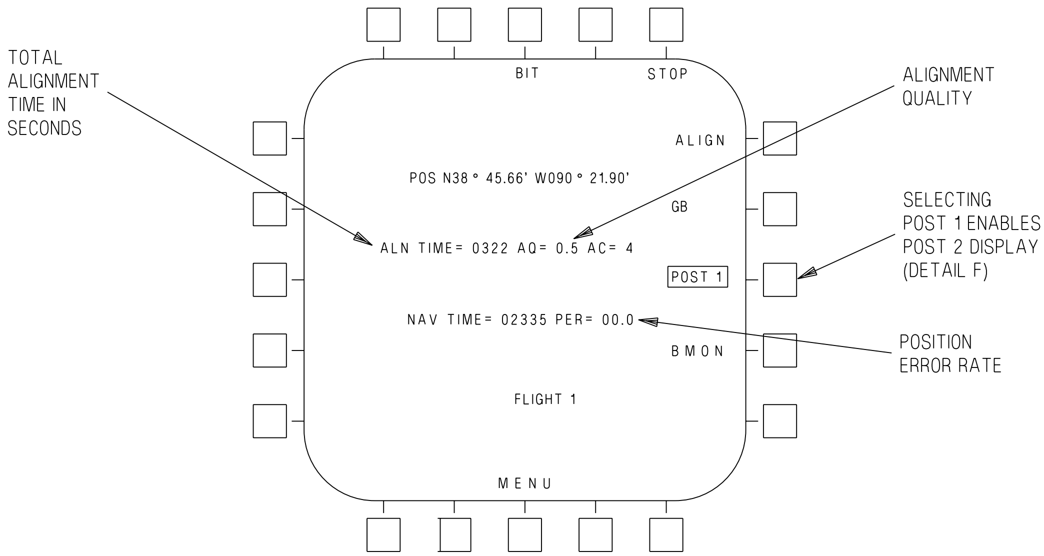
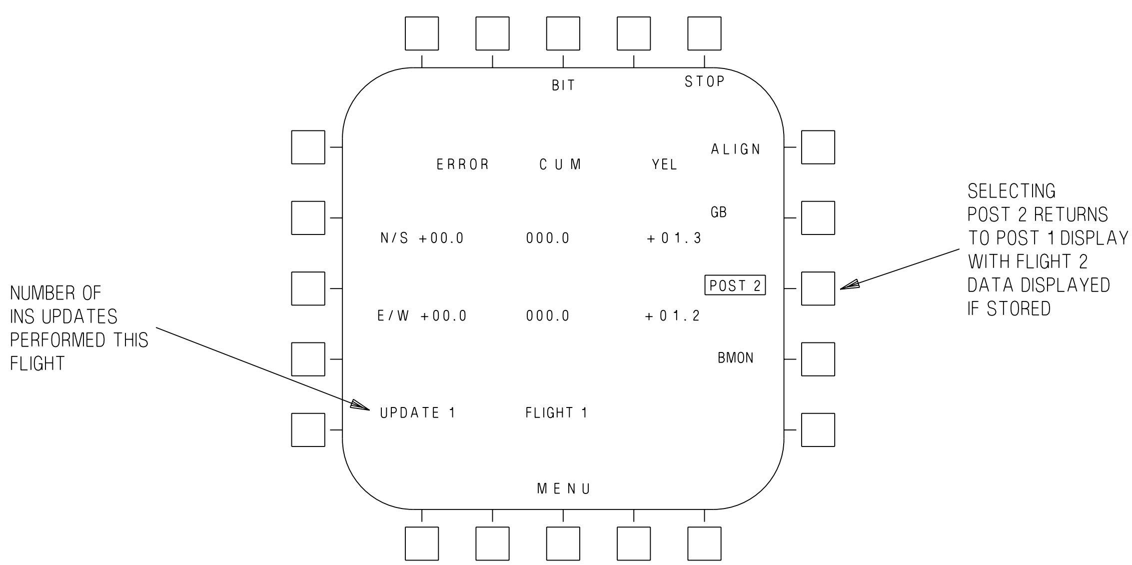


Figure 1-160. INS Performance Evaluation (Sheet 1 of 3)



POST 1 DATA DISPLAY (TYPICAL)

E

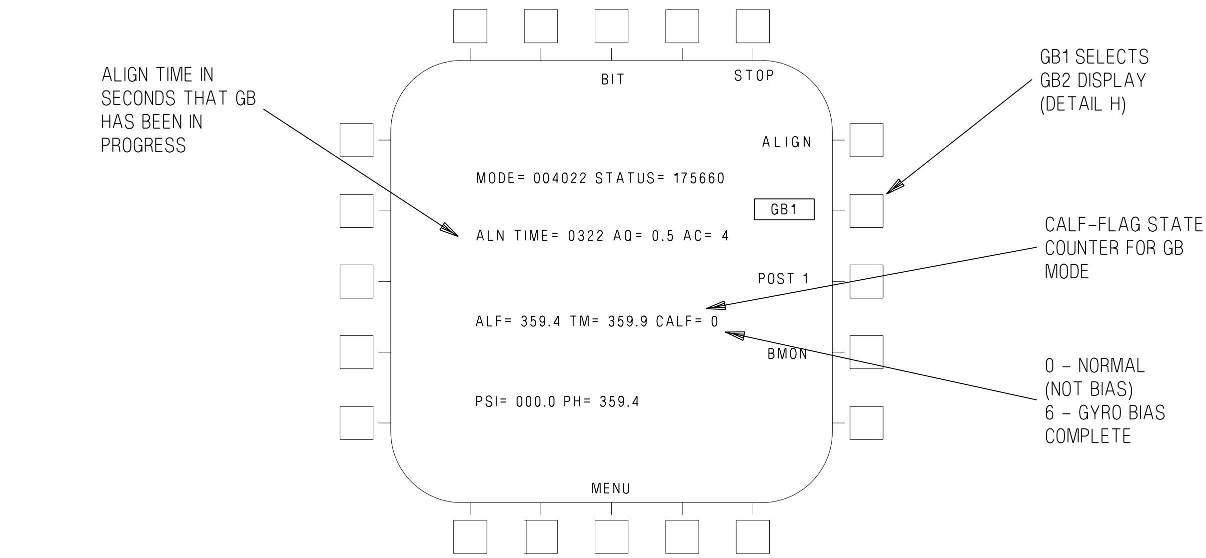


POST 2 DATA DISPLAY (TYPICAL)

F

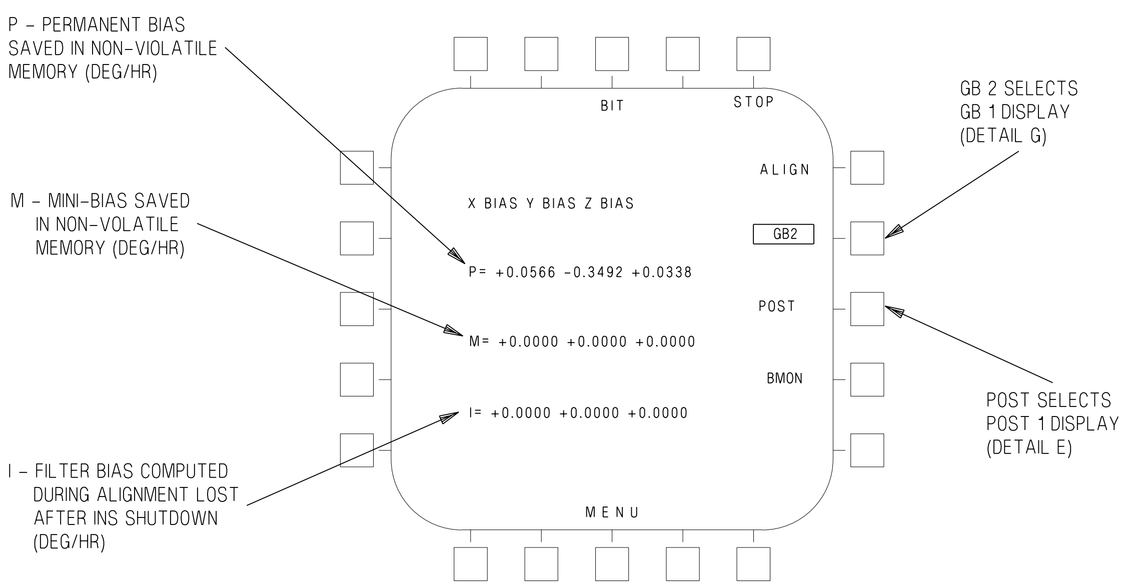
AHR607-698-2-013

Figure 1-160. INS Performance Evaluation (Sheet 2 of 3)



GB1 DATA DISPLAY (TYPICAL)

G



GB2 DATA DISPLAY (TYPICAL)

H

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Figure 1-160. INS Performance Evaluation (Sheet 3 of 3)

1.12 GLOBAL POSITIONING SYSTEM (GPS)

1.12.1 Introduction. The integration of the Miniaturized Airborne GPS Receiver (MAGR) into the AV-8B aircraft provides significant additional capability to the aircraft. The MAGR continuously updates the INS for precise position keeping, ensuring a "tight" INS to continue the mission if the GPS signal is ever lost. It provides the capability to align the INS to present position without pilot input (no SINS or aircraft position inputs required), complete in-flight alignments, and conduct self contained approaches without NAVAIDS. The MAGR allows all users to be perfectly synchronized in time without the requirement for a time hack. It does not drift, and provides an additional height above target source to be used in determining slant range for air-to-ground bombing solutions. Use of GPS shows great promise in the development of a system for precisely determining target position for the CAS mission (i.e., an "electronic mark").

1.12.2 GPS Theory of Operation. The position of a GPS equipped aircraft is determined by measuring the aircraft's distance from a group of satellites in space. The GPS utilizes 24 satellites (21 operational and 3 spares). The satellites are positioned in orbit to provide 24 hour global coverage to an unlimited number of GPS users. The relative positions from the satellites are used to triangulate the position of the aircraft in space. To determine the aircraft's position relative to the satellites, precise measurements of the range and position of the moving satellites in space is required. Assuming the computation of exactly how far away the aircraft is from the satellites and exactly where the satellites are in space can be made, the estimate of aircraft position is determined as follows.

If the position of the aircraft relative to satellite X is known, then the aircraft position is somewhere on a imaginary sphere with a known radius, centered about satellite X. See Figure 1-161.

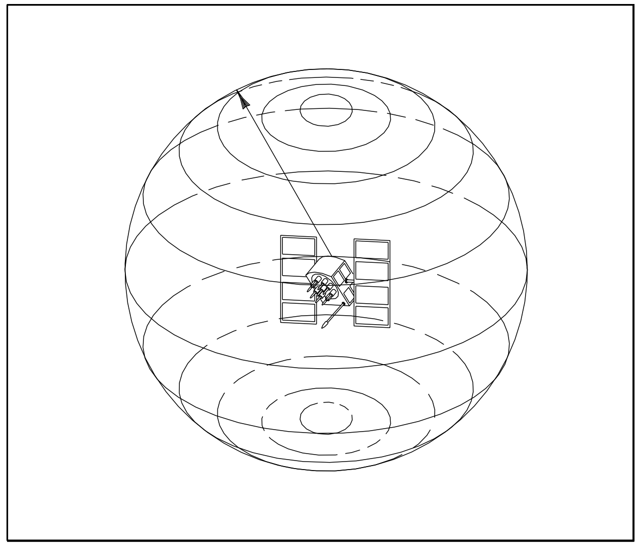


Figure 1-161. Aircraft on Sphere With Satellite at Center

If the position of the aircraft relative to satellite Y is known, then the aircraft position is also somewhere on an imaginary sphere with a known radius, centered about satellite Y. Given this data, the aircraft position can be narrowed down to a circle where the sphere about satellite X and the sphere about satellite Y intersect. See Figure 1-162.

If the position of the aircraft relative to satellite Z is known, then the aircraft position can be narrowed down to one of two points where the sphere centered about satellite Z cuts through

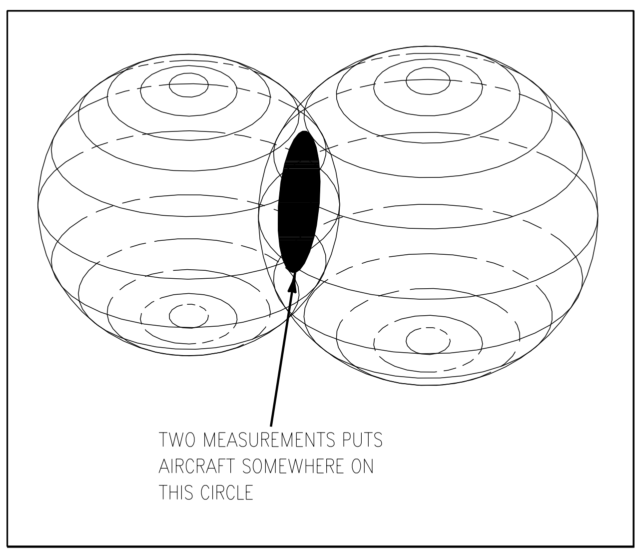


Figure 1-162. Aircraft on Circle Where Two Spheres Intersect.

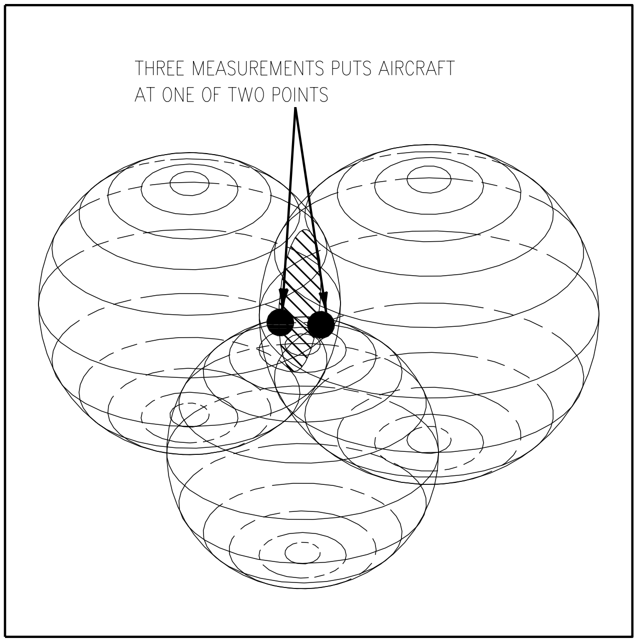


Figure 1-163. Aircraft on One of Two Points Where Three Spheres Intersect

the circle that is the intersection of the spheres centered about satellites X and Y. See Figure 1-163. Deciding which one of the two points the aircraft is positioned on can be accomplished by using a fourth satellite to yield an absolute answer or by making an assumption. Typically, one of the two points is not close to the earth or has an impossibly high velocity, and can therefore be ignored.

1.12.2.1 Measuring Distance. The distance from a satellite is calculated by multiplying the velocity of the signal from the satellite by the travel time it took the signal to reach the aircraft. The radio waves transmitted by the satellites travel at the speed of light. To permit determination of the time delay between transmission and reception of the satellite signal, the satellites and MAGR are synchronized to generate a pseudo-random code at exactly the same time. See Figure 1-164. When the MAGR receives the code within the satellite signal it scans back to the time it generated the same code to determine how long it took the signal to travel.

Perfect timing is essential for determining the distance from a satellite. If either of the clocks in the satellites or MAGR are off by as little as one hundredth (1/100th) of a second, the resulting distance calculation will be in error on the order of 1860 miles (speed of light = 186,000 miles/second). Since the satellites have atomic clocks that are extremely precise, any error due to clock timing comes from the MAGR clock or atmospheric delays. As long as the timing error is constant, all that is needed to detect and correct the error is a fourth satellite measurement.

How the MAGR is able to detect and correct timing errors with its internal clock can be described using time as a measurement of range. If the distance from satellite X is five seconds, the distance to satellite Y is six seconds, and the distance to satellite Z is seven seconds, then the aircraft's position is the intersection of the three radials from satellites X, Y, and Z. However, if there is a one second bias in all the measurements then the three radials *will not* intersect at one point. By adding another measurement from a fourth satellite, the MAGR will determine if there is a point at which all four radials intersect. If there is no single intersection point, the MAGR assumes its internal clock must have an offset and begins subtracting (or adding) time from each measurement until it converges on a single intersection point. The clock offset is retained and recomputed as necessary to provide accurate timing between the MAGR and the satellites.

In summary, the distance to a satellite is determined by measuring how long a radio signal takes to reach the aircraft from that satellite. Both the satellite and the GPS receiver onboard the aircraft are generating the same pseudo-random code at exactly the same time. The time it took the satellite's signal to reach the aircraft is calculated by comparing how late its pseudo-random code is, compared to the same code generated in the GPS receiver. Once the traveling time of the satellite signal is accurately determined, the range to the satellite is solved for by multiplying the signal travel time by the speed of light.

1.12.2.2 GPS Satellites. The satellites are placed in a very precise orbit clear of the earth's atmosphere. Because there is no atmospheric drag, the satellites will stay exactly in orbit. The orbits are known in advance and can be loaded

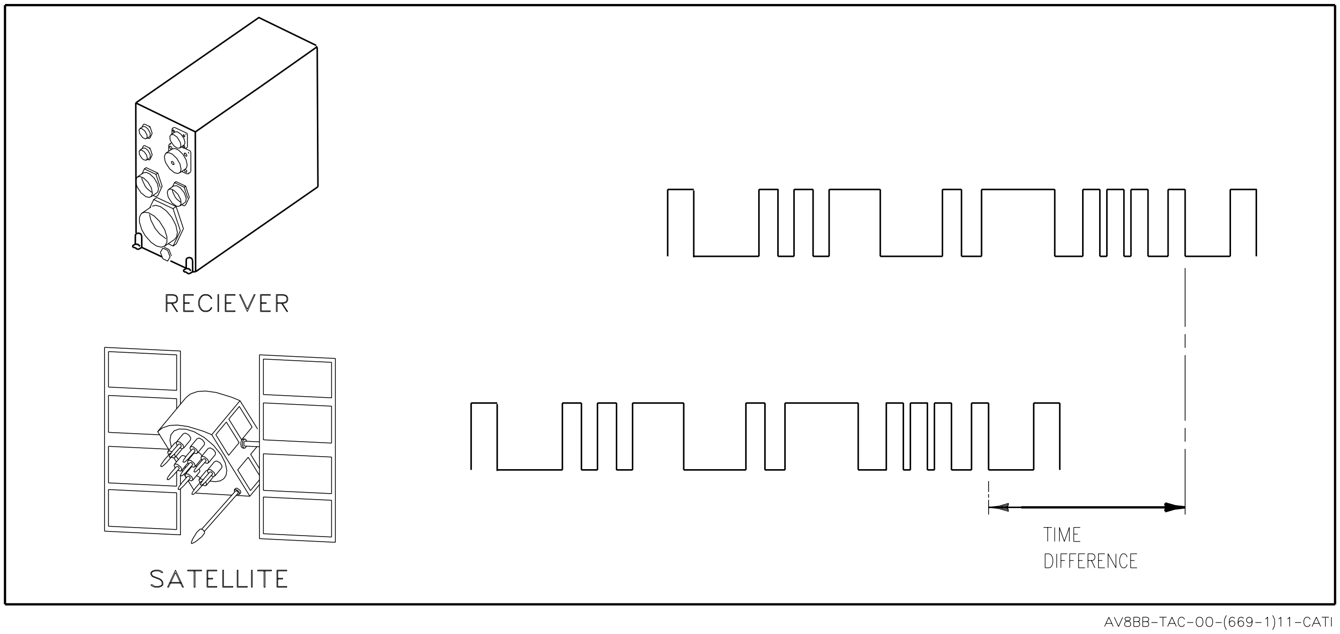


Figure 1-164. Time Difference Determination Using Pseudorandom Code.

into the MAGR as ″almanac″ data which describes where in space each satellite will be at any given moment. The satellites are constantly monitored for variations in orbit. The errors in the orbital path, called ″ephemeris″ errors, are caused by gravitational pulls from the moon and sun and by solar radiation on the satellite. Twice a day these errors are precisely measured and relayed back to each satellite. The satellites transmit these minor corrections along with the timing information. The satellites not only transmit a pseudorandom code for timing purposes, they also transmit a data message about their exact orbital location and system health. The MAGR uses the satellite almanacs to establish the best operational satellite constellation. The timing information is used in conjunction with the almanac and emphemeris data from four satellites to calculate aircraft position and velocity.

1.12.3 GPS System Overview. The GPS is a space-based radio positioning system which provides suitably equipped users with highly accurate position, velocity, and time data. This service is provided globally, continuously, and under all weather conditions to users at or near the surface of the earth. GPS receivers operate passively, thus allowing an unlimited number of simultaneous users. The GPS has features which can deny accurate service to unauthorized users, prevent spoofing, and reduce receiver susceptibility to jamming.

The GPS comprises three major segments; Space, Control, and User. The Space segment consists of a constellation of GPS satellites in semi-synchronous orbits around the earth. Each satellite broadcast radio frequency (RF) ranging codes and a navigation data message. The control segment consists of a Master Control Station (MCS) and a number of monitor stations located around the world. The MCS is responsible for tracking, monitoring, and managing the satellite constellation and for updating the navigation data messages.

The User segment consists of a varity of radio navigation receivers specifically designed to receive, decode, and process the GPS satellite ranging codes and navigation messages. Example of user receivers are the AV-8B MAGR and the PPS lightweight GPS receiver (PLGR).

The ranging codes broadcast by the satellites enable a GPS receiver to measure the transmit time of the signals and thereby determine the range between a satellite and the user. The navigation data message enables a receiver to calculate the position of each satellites at the time of transmission of the signal. Four satellites are normally required to be simultaneously "in view" of the receiver for three-dimensional (3-D) positioning purposes. This allows the user 3-D position coordinates and the user clock offset to be calculated from the satellite range and position data. Treating the user clock offset as an unknown eliminates the requirement for users to be equipped with precision clocks. Less than four satellites can be used if the user altitude or system time is precisely known.

Two levels of navigation are provided by the GPS, the precise positioning service (PPS) and the standard positioning service (SPS). The PPS is a highly accurate positioning, velocity, and timing service which is made available only to authorized users (i.e., DoD users with the correct crypto loaded). The SPS is a less accurate positioning and timing service which is available to all GPS users.

1.12.3.1 Precise Positioning Service. The PPS is specified to provide 16 meter spherical error probable (SEP) (3-D, 50 percent) positioning accuracy and 100 nanosecond (one sigma) universal time coordinated (UTM) time transfer accuracy to authorized users. This is approximately equal to 30 meters (3-D, 95 percent) and 197 nanoseconds (95 percent). PPS receivers can achieve 0.2 meters per second 3-D velocity accuracy.

In order for a user receiver to provide PPS capability it must be able to synchronize with the precise-code (P-code). The P-code is a 267 day long code sequence, with each of the GPS satellites assigned a unique one-week segment of this code. The P-code bit rate is 10.23 MHz and each satellite has a seven-day-long portion that restarts every Saturday/Sunday midnight. The P-code is transmitted on both GPS frequencies, L1 (1575.42 MHz) and L2 (1227.6 MHz). The P-code is protected against spoofing (i.e., the deliberate transmissions of incorrect GPS information) by encryption of the P-code. The encrypted P-code is called Y-code. The Y-code can only be accessed by authorized users. Acquisition of the Coarse/Acquisition-code (C/A-code) is required for the less accurate SPS, and is available to any user of GPS. The C/A-code consists of a 1023 bit code with a clock rate of 1.023 MHz; hence it takes only 1 millisecond to run through the whole code. A different C/A-code is normally transmitted on L1 only, but it can be transmitted on L2 instead of the P-code. The C/A-code is used by P-code users (i.e., MAGR) to assist the receiver in reducing the time required to acquire the longer P-code. During normal operations with a current almanac, the MAGR can acquire the P-code in about two to three minutes.

Access to the PPS is controlled by two features using cryptographic techniques. A selective availability (SA) feature is used to reduce the GPS position, velocity, and time accuracy available to unauthorized users. SA operates by introducing controlled errors into the satellite signals. In peacetime the effects of SA will be controlled to provide 100 meter (95 percent) horizontal accuracy for SPS users. System accuracy degradations can be increased (accuracy decreased) if it is necessary to do so (i.e., to deny accuracy to a potential enemy in time of crisis or war). An anti-spoofing (AS) feature is invoked at random times without warning to negate potential spoofing of PPS signals. The technique alters the P-code crytographically into Y-code (the C/A-code remains unaffected). Encryption keys and techniques are provided to PPS users which allow them to remove the effects of SA and AS and thereby attain the maximum available accuracy of GPS. PPS capable receivers that do not have the proper encryption keys installed well be subject to the accuracy degradations of SA and will be unable to track the Y-code.

PPS receivers can use either the P(Y)-code or C/A-code or both. Maximum GPS accuracy is obtained using the P(Y)-code on both L1 and L2. The difference in propagation delay between the two frequencies is used to calculate ionospheric corrections. P(Y)-code capable receivers commonly use the C/A-code to initially acquire GPS satellites and determine the approximate P(Y)-code phase.

1.12.3.2 Standard Positioning Service. The SPS provides 100 meter (50 percent) horizontal positioning accuracy to any GPS user during peacetime. This is approximately equal to 156 meters 3-D (95 percent). SPS receivers can achieve approximately 337 nanoseconds (95 percent) UTC time transfer accuracy. The SPS is primarily intended for civilian purposes, although it has many peacetime military uses as well. The SPS horizontal accuracy includes peacetime degradation of SA which is the dominant SPS error source.

The AS feature denies SPS users access to the Y-code. Therefore, the SPS user cannot rely on the P(Y)-code to measure the propagation delays of L1 and L2 and calculate ionospheric corrections. The C/A-code is unaffected by AS but is broadcast only on L1. Consequently, the typical SPS receiver uses only the C/A-code and must use an ionospheric model to calculate the corrections. This is a less accurate technique than measuring dual frequency propagation delays. The SPS accuracy includes this ionospheric modeling error. SPS P-code receivers and PPS P(Y)-code capable receivers that do not have the proper encryption keys installed will typically operate as SPS dual frequency P-code receivers and revert to C/A-code when unable to track the Y-code (this includes the MAGR).

GPS receivers perform most calculations using an earth-centered earth-fixed coordinate system. They then convert to an earth model defined by the World Geodetic system 1984 (WGS-84). WGS-84 is a very precise model that provides a common grid system for transformations into other coordinate systems or map datums.

1.12.4 Component Description. The aircraft components of the GPS system are the GPS antenna and the MAGR.

1.12.4.1 GPS Antenna. The GPS antenna is a fixed radiation pattern low profile antenna mounted on door 51 next to the water fill tank door. The antenna provides omnidirectional coverage above 10° elevation from its surface.

1.12.4.2 MAGR. The MAGR, mounted behind door 61, receives ranging codes and a navigation data messages from the NAVSTAR satellites through the GPS antenna. The ranging codes broadcast by the satellites enable the MAGR to measure the transit time of the signals and determine the range between the satellite and the aircraft. The navigation data messages enable the MAGR to calculate the position of each satellite at the time of transmission. The MAGR can track five GPS satellites and calculate the aircraft exact position from the four best satellites being tracked. The MAGR provides UTC time, aircraft position, ground track, ground speed and altitude data to the MC. The MAGR contains a battery to provide power for a clock and to maintain memory when aircraft power is not supplied. The MAGR has a built-in test used for determining the status of the receiver and the battery.

1.12.5 GPS Controls and Indicators. The controls and indicators for the GPS include the upfront control, option display unit, multipurpose color display, INS mode select switch, and GPS caution light.

1.12.5.1 Upfront Control (UFC). The scratch pad display on this control is used for displaying the position error when a GPS navigation update is performed. The display is also used to display GPS time, in UTC, when REAL is selected in the ODU.

1.12.5.2 Option Display Unit (ODU). This control/indicator provides a way of displaying and selecting the various options available for a GPS navigation update and provides the option (REAL) for selecting the GPS time display on the UFC.

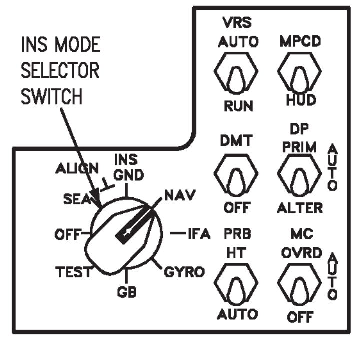
1.12.5.3 Multipurpose Color Display (MPCD). The EHSD display, BIT display, and GPS waypoint and data displays are presented on the MPCD. The 20 pushbutton switches surrounding the crt provide display selection and control.

1.12.5.4 INS Mode Select Switch. Selecting IFA initiates the in-flight alignment and enables a tightly-coupled navigation mode. Selecting NAV enables a loosely coupled, degraded, navigation mode.

1.12.5.5 GPS Caution Light. When enabled, indicates GPS data in not valid or GPS horizontal and vertical position error is not within the tolerance required for GPS navigation steering modes normal (NORM) and approach (APPR).

1.12.6 EHSD Display Format. The EHSD display format is modified to include the aircraft position keeping source, navigation system coupling mode, and additional information when utilizing the in-flight alignment mode or course-line feature.

The aircraft position keeping source is pilot selectable by scrolling the pushbutton option on the bottom right of the EHSD display format (and also on the STRS, FLIR, DMT and Maverick display formats when in A/G master mode only). The three position keeping sources in order of priority are: INS, GPS, and ADC. The position keeping mode legend identifies the navigation sensor that is being used to determine the aircraft present position. At aircraft power-up, the aircraft will initialize to ADC position keeping mode. When the GPS completes initialization, the position keeping mode will automatically upgrade from ADC to GPS. When the INS present position becomes valid, the position keeping mode will automatically upgrade from either ADC or GPS to INS. The MC will automatically upgrade to the best available position keeping mode when the better mode becomes available for the first time following aircraft power-up with weight-on-wheels. The MC also degrades to the next best available position keeping source in the event the current source is deemed erroneous or unavailable. During changes between INS and GPS position keeping modes, either GPS to INS or INS to GPS, delta terms are added to aircraft present position to provide a smooth transition to the new position keeping mode. The position keeping mode is selectable independent of the navigation system coupling mode, with one exception that ADC position keeping is not allowed in a tightly-coupled mode. The navigation system coupling mode, which controls the interface between the GPS and INS, is pilot selectable using the INS mode select switch, shown in Figure 1-165. The two coupling modes, tightly-coupled and loosely-coupled, are independent of the position keeping mode.



● FULL UP NAVIGATION SYSTEM
INS MODE SELECTOR SWITCH – IFA

● DEGRADED NAVIGATION SYSTEM
INS MODE SELECTOR SYSTEM – NAV

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Figure 1-165. Miscellaneous Switch Panel

Tightly-coupled refers to a navigation system in which the GPS is aided by ADC and INS data and continually returns corrections to the INS platform. The aiding data permits the GPS to keep satellite lock and to stabilize the internal Kalman filter. The platform correction data provides the INS with data it can use to better estimate its internal platform errors. A tightly-coupled mode is accessible when: (1) an INS with GPS compatible software is installed in the aircraft, (2) GPS navigation data is valid, and (3) the INS is in either in-flight align mode or aided navigation mode.

Selecting IFA on the INS mode select switch causes the navigation system to enter into tightly-coupled mode. Whenever the navigation system is in tightly-coupled mode, the POS legend will appear as part of the position keeping mode legend (i.e., POS/INS or POS/GPS).

In-flight alignment of the INS using GPS data is a special case of the tightly-coupled mode. If IFA is selected without an aligned INS, GPS data will be used to align the INS. During the in-flight alignment process, the GPS is aided by INS data and continually returns corrections to the INS platform. Internally, the INS will be in in-flight align mode. The alignment time and quality are displayed in the lower center of the EHSD format and the IFA legend is displayed in

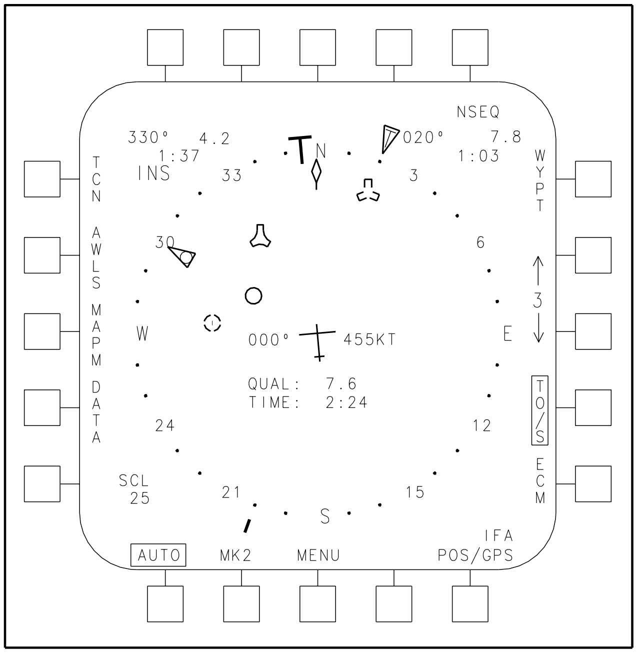

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Figure 1-166. In-flight Alignment Display

the lower right corner of the EHSD format above the legend indicating navigation system coupling and position keeping mode (e.g. POS/GPS) to cue the pilot that the INS is being aligned in-flight. See Figure 1-166.

The alignment time and the IFA legend flash when the system enters align-hold. The navigation system enters align-hold during an in-flight alignment if aircraft roll exceeds 30°, or aircraft pitch is greater than 15° or less than −5°. Once the alignment is complete (after approximately 10 minutes), the INS automatically enters aided navigation mode and the IFA legend is removed from the EHSD display format.

Loosely-coupled refers to a navigation system in which the GPS is aided by an external source, but the GPS does *not* continually provide corrections to the INS platform. Selection of free inertial navigation mode, NAV on the INS mode select switch, causes the navigation system to enter into loosely-coupled mode. In loosely-coupled mode, the INS is *not* aided by the GPS. Whenever the navigation system is in loosely-coupled or uncoupled mode the DGD (degraded) legend appears as part of the position keeping mode legend (i.e., DGD/INS or DGD/ADC). An uncoupled mode is not selectable by the pilot and is only entered when the INS and ADC, and/or GPS are not providing valid data.

A complete list of definitions of the combinations of navigation system coupling and position keeping modes is given below:

1. POS/INS - Indicates a tightly-coupled navigation system in which the INS is being used as the position keeping source.

2. POS/GPS - Indicates a tightly-coupled navigation system in which the GPS is being used as the position keeping source.

3. POS/ADC - *Not* a possible configuration

IFA
4. POS/INS - Indicates a tightly-coupled navigation system in which the INS is being used as the position keeping source. The INS is currently being aligned inflight using GPS data. (This legend appears in the final stages of an INS in-flight alignment). See Figure 1-166.

IFA
5. POS/GPS - Indicates a tightly-coupled navigation system in which the GPS is being used as the position keeping source. The INS is currently being aligned in-flight using GPS data. (This legend appears in the initial stages of an INS in-flight alignment). See Figure 1-166.

IFA
6. POS/ADC - *Not* a possible configuration.

7. DGD/INS - Indicates a loosely-coupled / uncoupled navigation system in which the INS is being used as the position keeping source.

8. DGD/GPS - Indicates a loosely-coupled / uncoupled navigation system in which the GPS is being used as the position keeping source.

9. DGD/ADC - Indicates a loosely-coupled / uncoupled navigation system in which the ADC is being used as the position keeping source.

10. DGD/*blank* - Indicates that the navigation system does not have a valid position keeping source. (This mode is not pilot selectable).

In summary:

1. POS - Indicates the INS *is* automatically updated by GPS data. No manual updates are required.

2. DGD - Indicates the INS is *not* automatically updated by the GPS. Manual updates are required to limit navigation system errors and INS drift.

Like the position keeping source, the aircraft velocity source (used for navigation and weapon delivery calculations) is automatically selected by the MC and is based on the best available velocity source. The three sources of aircraft velocity data are, in order of priority, INS, GPS, and ADC. The MC automatically upgrades to the best available velocity source when the better source becomes available. The MC also degrades to the next best available velocity source in the event the current source is unavailable or deemed erroneous by the velocity reasonableness tests. Delta terms are added to aircraft velocity to provide a smooth transition during degradation from using INS to GPS as the velocity source. The choice of velocity source is independent of the navigation system coupling and position keeping mode, with the exception of ADC position keeping mode. Whenever ADC position keeping mode is selected and the navigation system is loosely-coupled, the ADC is used as the velocity source. In the event that an unresolved velocity reasonables test is encountered, the velocity source is tied to the aircraft position keeping source currently selected and VEL ? appears above the position keeping source.

1.12.6.1 Waypoint / Waypoint Offset Steering. When waypoint or waypoint offset steering is initially selected, direct great circle steering is provided. Steering along a course line can be selected, if desired.

1.12.6.2 Courseline Implementation. Emulating tacan operation using waypoints can be accomplished by selecting waypoint or waypoint offset steering and enabling the courseline using the CRS select switch located below the HUD control panel. The courseline emulates a tacan radial, allowing the pilot to select a heading on which to approach or depart from a navigation point. The courseline is computed as the great circle course to/from a navigation point on the selected radial. If valid, the waypoint magnetic variation is used to calculate the courseline heading. If the waypoint magnetic variation is invalid, the courseline heading is calculated using the local magnetic variation. A digital readout of courseline heading is displayed in the lower right corner of the EHSD display format. The cross-track deviation, perpendicular distance to the desired course (up to a value of 99.9 nm), is displayed directly below the courseline heading. When the waypoint magnetic variation is being used, the courseline heading may not visually correspond to the displayed courseline on the compass rose since the courseline and its heading are based on the waypoint magnetic variation and the compass rose heading is based on the local magnetic variation. As the aircraft gets closer to the selected point, the great circle course bearing and the courseline heading converge. When the waypoint distance is beyond the range of the selected range scale, the waypoint symbol is not displayed, however the courseline rotates about the actual waypoint position. If the courseline is at a distance from the aircraft greater than the radius of the compass rose, a limited courseline is displayed. The limited courseline, shown in Figure 1-167, is represented by a chord that intersects the compass rose at two points whose radials to the center of the compass rose define a 30° arc. If the courseline is enabled in A/A, NAV, or VSTOL master mode, the initial courseline heading is the last selected courseline heading. If the courseline is enabled in A/G master mode with waypoint steering selected and the selected waypoint has an offset, the courseline heading is initialized from the selected waypoint to the waypoint offset. If the courseline is enabled in A/G master mode with waypoint steering selected and the selected waypoint does not have an offset, the courseline heading is the last selected courseline heading. If the courseline is enabled in A/G master mode with waypoint offset steering selected, the

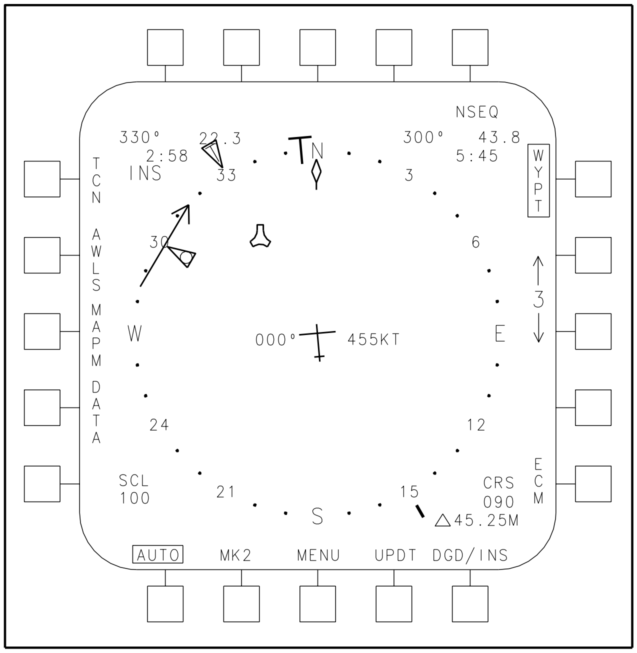

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Figure 1-167. Limited Courseline

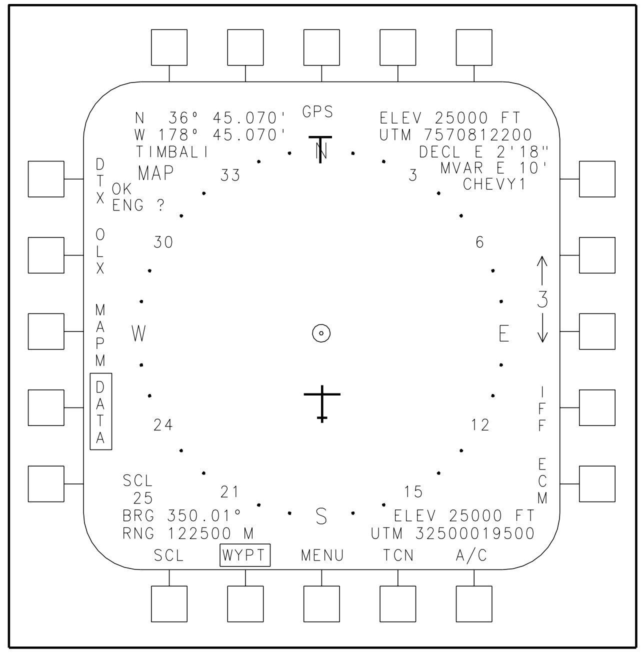

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Figure 1-168. Waypoint Data Display

courseline heading is initialized from the selected waypoint to the waypoint offset.

1.12.6.3 Markpoint Implementation. Marking a point on the ground is achieved by selecting the MK# (MK1, MK2, or MK3) option on the bottom of the EHSD display format. The current aircraft present position is stored in the markpoint, the markpoint field elevation is calculated using aircraft baro-altitude and radar altimeter altitude (if valid), and the markpoint magnetic variation is set equal to the local magnetic variation. If local magnetic variation is invalid, the markpoint magnetic variation is set equal to zero.

1.12.6.4 Waypoint Data. The WYPT-DATA display format has been modified as shown in Figure 1-168. Under the latitude/longitude indication is the geodetic datum that the waypoint data was entered in. This datum applies to waypoint latitude/longitude, UTM (15 digit), waypoint offset UTM and CAS cards that have this waypoint as the IP. Magnetic variation for the waypoint and a waypoint identifier are displayed below the waypoint UTM. The GPS option has been added at the top center pushbutton location and an additional 10 tactical waypoints are available (15 to 24), bringing the total to 25 waypoints and 3 markpoints.

1.12.6.4.1 Waypoint Latitude / Longitude. To take advantage of the increased positional accuracy furnished by the GPS, waypoint latitude / longitude is entered and displayed in degrees, minutes, and thousandths of minutes or degrees, minutes, seconds, and tenths of seconds. Waypoint latitude / longitude entries require only the degrees and minutes to be entered, however the coordinates can be entered to the nearest tenth, hundredth, thousandth of a minute, or degrees, minutes, seconds, and tenths of seconds. Examples of valid entries for waypoint latitude are as follows:

N, 3, 5, 4, 1, ENT (N3541)
N, 3, 5, 4, 1, ., 2, ENT (N3541.2)
N, 3, 5, 4, 1, ., 2, 3, ENT (N3541.23)
N, 3, 5, 4, 1, ., 2, 3, 4, ENT (N3541.234)
N, 3, 5, 4, 1, 2, 0, ENT (N354120)
N, 3, 5, 4, 1, 2, 0, ., 4, ENT (N354120.4)

The same format is also acceptable for waypoint longitude entry.

1.12.6.4.2 Waypoint Magnetic Variation. The ODU/UFC is enabled for waypoint magnetic variation entry by first selecting the waypoint ELEV option on the ODU. Once cued, the ELEV option can be toggled between elevation entry and magnetic variation (MVAR) entry. Valid entries for MVAR remain unchanged (E 90 to W 90).

1.12.6.4.3 Waypoint UTM. The ODU/UFC is enabled for waypoint UTM entry when the UTM option on the ODU is selected/cued. UTM coordinates have 15 digits. The grid zone identifier (i.e., 12S) followed by the 100.000 meter square identification (i.e., MV) and 10 easting/northing digits (i.e., 12345 67890). This precision is only available with a functioning MAGR. If the MAGR is offline, standard six digit UTMs appear for both the waypoint and offset; no mixing of datums is possible. If the waypoint is used as an IP, the CAS page will display that datum and locate the offset in that datum.

1.12.6.4.4 Waypoint DECL. Declination angle entry is accessed "under" the UTM option. Once UTM is cued, the ODU/UFC can be toggled between UTM entry and DECL entry by depressing the corresponding ODU button.

1.12.6.4.5 Waypoint Datum. Datum selections can be made through the ODU/UFC (option 4). Datums are identified by numbers 1 through 47. See Figure 1-169. The datum name associated with each number should be listed by the pilot on an admin or brief card. Selecting a new datum changes the latitude, longitude, and UTM of the waypoint/offset, but does not move the waypoint/offset symbol on the display. Datum transformations take place in the MAGR in approximately 2 to 3 seconds. While the MAGR calculates the new coordinates, the waypoint/offset symbol disappears. The waypoint/offset reappears when calculations are complete.

NOTE

Do not enter any WYPT info while this translation is processing; the latitude/longitude/UTM changes on the display but NOT in the MC. The old waypoint data remains in the system.

NO.	NAME	ABBREVIATION
1	Adsindan	ADINDAN
2	Arc 1950	ARC 1950
3	Austrailian Geodetic 1984	AUST 1984
4	Bukit Rimpah	BUKIT RIM
5	Camp Area Astro	CAMP AA
6	Djakarta	DJAKARTA
7	European 1950	EURO 1950
8	Geodetic Datum 1949	1949
9	Ghana	GHANA
10	Guam 1963	GAUM 1963
11	G. Segara	SEGARA
12	G. Serindung	SERINDUNG
13	Herat North	HERAT NORTH
14	Hjorsey 1955	HJORSEY
15	HU-TZU-SHAN	HU-TZU-SHAN
16	Indian	INDIAN
17	Ireland 1965	IRLAND 65
18	Kertau	KERTAU
19	Liberia 1964	LIBERIA 64
20	User Defined	WGS-84
21	Luzon	LUZON
22	Merchich	MERCHICH
23	Montjong Lowe	MONTJONG
24	Nigeria	NIGERIA
25	North American 1927 (CONUS)	NAD 27 CONUS

Figure 1-169. Geodetic Datums (Sheet 1 of 2)

NO.	NAME	ABBREVIATION
26	North American 1927 (Alaska and Canada)	NAD 27 NORTH
27	Old Hawaiian, Maui	MAUI
28	Old Hawaiian, Oahu	OAHU
29	Old Hawaiian, Kuaui	KUAUI
30	Ordnance Survey of Great Britain 1936	OSGB 1936
31	QORNOQ	QORNOQ
32	Sierra Leone 1960	SIERRA 60
33	South American (Provisional South American 1956)	S. AMERICA
34	South American (Corrego Alegre)	COR ALEGRE
35	South American (Campo Inchauspe)	CAMPO INCHAU
36	South American (Chua Astro)	CHUA ASTRO
37	South American (Yacare)	YACARE
38	Tananarive Observatory 1925	TAN OBS 25
39	Timbali	TIMBALI
40	Tokyo	TOKYO
41	Voiral	VOIRAL
42	Special Datum Indian	INDIAN SP
43	SD LUZON special	LUZON SP
44	SD TOKYO Special	TOKYO SP
45	SD WGS-84 Special	WGS-84
46	WGS-72	WGS-72
47	Default Datum, WGS-84	WGS-84

Figure 1-169. Geodetic Datums (Sheet 2 of 2)

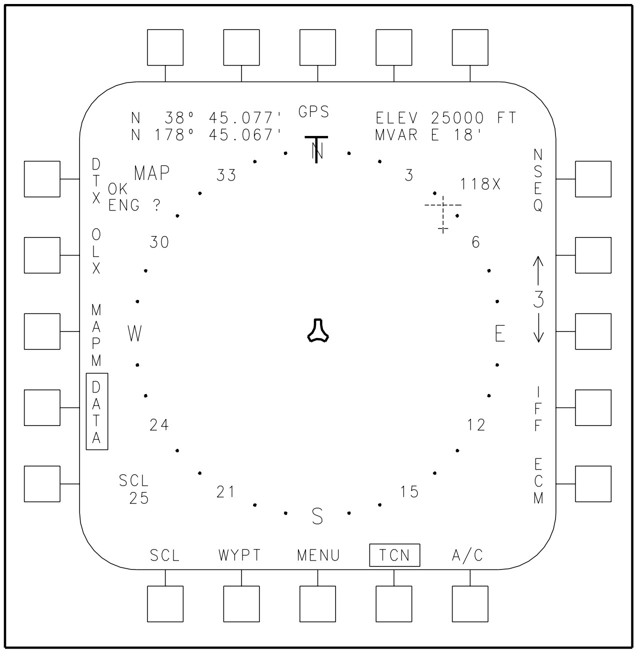

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Figure 1-170. Tacan Data Display

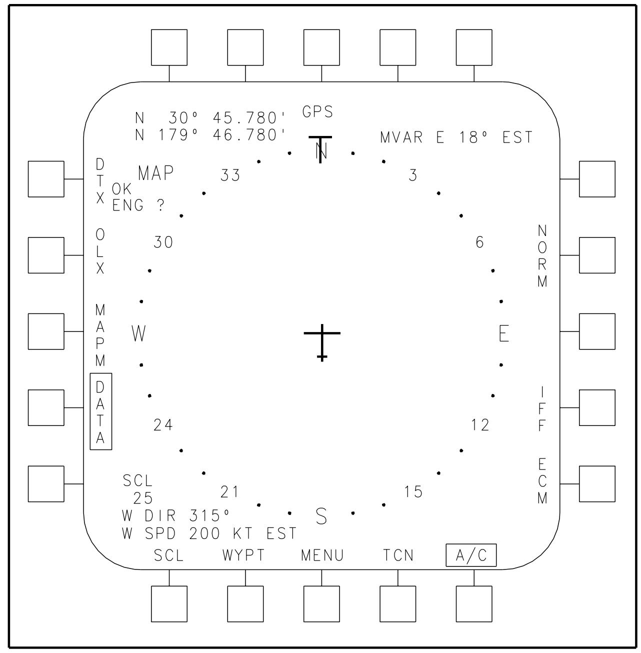

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Figure 1-171. Aircraft Data Display

1.12.6.4.6 Waypoint Offset Entry. The waypoint offset range and bearing can be entered to the nearest hundredth of a nautical mile (0.01 nm) and tenth of a degree (0.1), respectively. The ability to enter waypoint offsets using a magnetic reference is available. The waypoint offset bearing entered is interpreted as a magnetic reference if the map menu (MAPM) TRUE option is *not* boxed. If the TRUE option is boxed the waypoint offset bearing will be interpreted as a true bearing reference from the waypoint. If the waypoint offset bearing is entered in magnetic reference and then TRUE is boxed, the waypoint offset bearing will update as local magnetic variation changes.

1.12.6.5 Tacan Data. The tacan data display format has been modified as shown in Figure 1-170. The tacan channel legend has been moved below the tacan magnetic variation and the GPS option has been added at the top center pushbutton location. Tacan position is entered and displayed in degrees, minutes, and thousandths of minutes.

1.12.6.5.1 Tacan Offset Entry. The tacan offset range and bearing can be entered to the nearest hundredth of a nautical mile (0.01 nm) and tenth of a degree (0.1), respectively.

1.12.6.6 Aircraft Data. The aircraft data display format is modified as shown in Figure 1-171. The GPS flight mode selection option has been added and the GPS option is added at the top center pushbutton location. Aircraft position is entered and displayed in degrees, minutes, and thousandths of minutes. Aircraft position entry is not accepted when INS or GPS position keeping mode is valid.

1.12.6.6.1 GPS Flight Mode Selection. The GPS flight mode selections, approach (APPR) and normal (NORM) are available on the aircraft data display (POS/GPS, DATA, A/C, NORM, or APPR). See Figure 1-171. These options specify a corridor (navigation tolerance) about the desired aircraft course. If GPS position keeping is selected and the estimated error of the GPS exceeds the selected mode tolerance, a cockpit warning is provided by a GPS advisory and MASTER CAUTION light. The default flight mode selection at aircraft power-up with weight-on-wheels is normal mode. The flight mode selection option is only available in POS/ GPS and DGD/GPS position keeping modes.

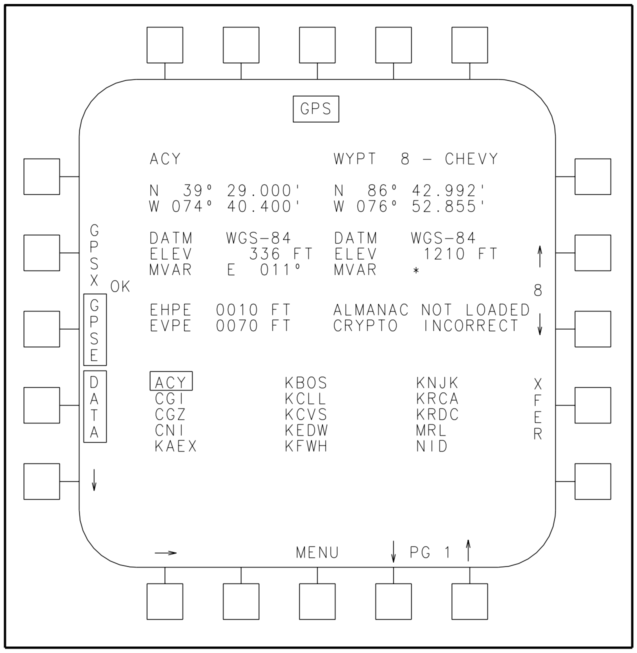

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Figure 1-172. GPS Data Display

Currently GPS in USN aircraft is for tactical use only and does not meet FAA standards for enroute or the terminal phase of flight. GPS will not be used as the primary means of navigation to file or fly in the National Airspace System. Reference CNO/N88/021214Z Aug 94.

1.12.6.7 GPS Data. The GPS data display format is enabled by selecting the GPS option from the EHSD-DATA display format. See Figure 1-172. The GPS data display format contains GPS and tactical waypoint / markpoint information, including the identifier, latitude, longitude, elevation, and magnetic variation. The GPS data display format is used to upload waypoints into the GPS from the DSU, to transfer waypoint data stored in the GPS into a tactical waypoint / markpoint, to examine the GPS almanac and crypto-key status, and to inspect the current estimated GPS position errors.

1.12.6.7.1 GPS Waypoint Data Upload. Selection of the GPSX option transfers the GPS waypoint database from the DSU to the GPS. ″OK″ indicates the transfer was successful. ″??″ indicates an error occurred during transfer. ″OK″ or ″?″ is displayed until another pushbutton is pressed.

1.12.6.7.2 GPS Waypoint Data Transfer. To transfer waypoint data from over 200 waypoints stored in the GPS into one of the tactical waypoints / markpoints (0 thru 24, MK1, MK2, MK3),

1. Select a tactical waypoint / markpoint.
2. Select GPS waypoint.
3. Select XFER option.

The tactical waypoints/markpoints are selected by scrolling to the desired waypoint / markpoint number using the increment or decrement arrow option on the right side of the display format. The GPS waypoint is selected by scrolling to the desired page using the page up or page down arrow option and then by using the down and/or right arrow option, the selection box is placed around the desired GPS waypoint. The transfer of the GPS waypoint data into the tactical waypoint / markpoint is accomplished by selecting the XFER option. An “OK” is displayed adjacent to the XFER option when the transfer has been successfully completed. The previous waypoint or markpoint offset data is lost when the GPS waypoint data transfer is completed successfully.

1.12.6.7.3 GPS Almanac and Crypto-Key Status. After aircraft power-up, the GPS-DATA display format should be selected to examine the almanac and crypto-key loading status. After communication with a satellite is established, the GPS reports whether the crypto-keys are correct. If the almanac data is not loaded in the GPS, the NOT LOADED legend is displayed adjacent to the ALMANAC legend. When the almanac data is loaded into the GPS, the LOADED legend is displayed adjacent to the

ALMANAC legend. If no almanac is loaded, the MAGR strips a complete almanac from the satellite signal once it finds any satellite. This takes approximately 12.5 minutes after a satellite is located. Once an almanac is loaded, the MAGR retains it even after shutdown. Whenever the MAGR is changed or batteries in the MAGR are changed, the MAGR should be run on ground power until a fix is obtained. There is no power switch or ON/OFF switch for the MAGR. The MAGR functions any time APU or main generator power is available. If the crypto keys are not loaded in the GPS, the NOT LOADED legend is displayed adjacent to the CRYPTO legend. When the crypto keys are loaded into the GPS and the GPS has not verified whether the keys are correct, the LOADED legend is displayed adjacent to the CRYPTO legend. The INCORRECT legend is displayed adjacent to the CRYPTO legend if the GPS determines that the loaded keys are incorrect. The "OK" legend is displayed adjacent to the CRYPTO legend after the GPS has determined that the loaded keys are correct. Crypto-key verification may take up to 12 minutes.

1.12.6.7.4 GPS Estimated Position Error Status. To inspect the current estimated horizontal and vertical position errors of the GPS, the GPSE option can be selected.

NOTE

It is especially important to monitor GPS position errors when using the GPS (POS/GPS or DGD/GPS) for low-level night navigation. GPS position errors are also displayed on the STRS display and on Day Attack aircraft on the EHSI displays.

If a GPS failure exists, the GPSX option, XFER option, cursor arrow options, and GPS waypoints are removed, and an asterisk (*) is displayed adjacent to the GPS waypoint data, position errors, almanac, and crypto-key status. See Figure 1-173.

1.12.7 CAS Format. On the CAS display format, the IP offset bearing and IP UTM bearing are displayed with a preceding T legend when true heading is selected, and without the T legend when magnetic heading is selected. The IP offset bearing and IP UTM bearing are updated when the magnetic variation of the IP is modified.

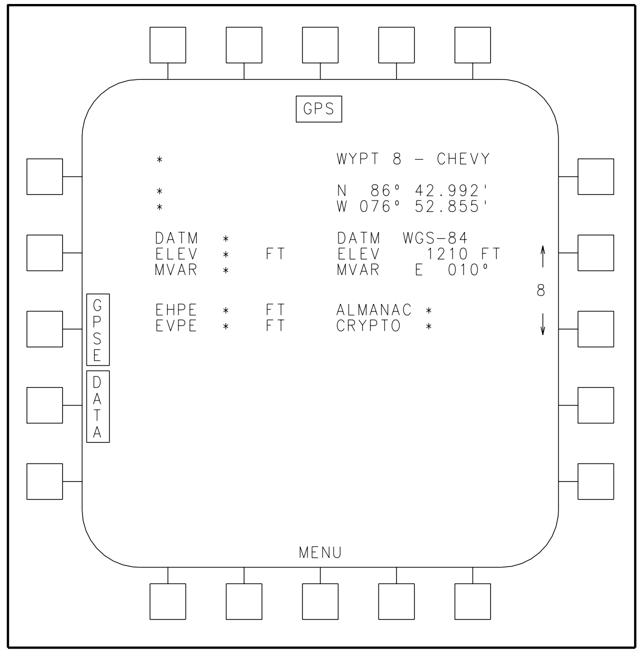
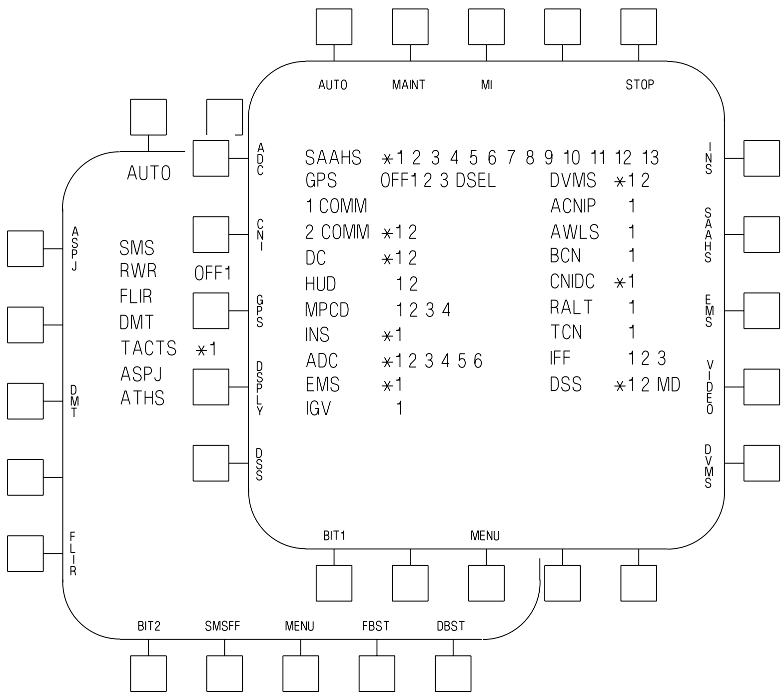


Figure 1-173. GPS Failure

1.12.8 Built-In-Test (BIT) Format. The GPS BIT reporting status can be inspected by selecting the BIT display format. On Night Attack and Radar aircraft the BIT display format is split into two display formats; Day Attack aircraft have only one display. See Figure 1-174. The BIT1 format contains the weapon and sensor subsystem BIT reporting and the BIT2 format contains the communication, identification, and navigation subsystem BIT information. The default BIT display format at power-up with weight-on-wheels is the BIT1 display format. The GPS BIT reporting information, found on the BIT2 format, includes receiver, battery, and communication status. The GPS can only be placed into initiated BIT with weight-on-wheels by selecting the GPS pushbutton option. The GPS option is not available with weight-off-wheels.

1.12.8.1 GPS BIT Reporting Status

GPS Asterisk (*) - GPS MAGR present but not communicating.



NOTE
NIGHT ATTACK AIRCRAFT DISPLAY SHOWN,
DAY ATTACK AND RADAR AIRCRAFT DISPLAYS ARE SIMILAR.

AHR607-504-1-013

Figure 1-174. GPS BIT

GPS Off - GPS MAGR not present or power off to it.

GPS 1 - GPS Receiver Fail

GPS 2 - GPS Battery Fail

GPS 3 - Velocity Reasonableness Test Failure.

GPS DSEL - GPS not position keeping source. GPS was deselected as the position keeping source during the last flight because GPS data did not meet quality/ sanity checks.

1.12.9 GPS Timer Functions. The GPS time, Universal Time Coordinated (UTC) - also referred to as Zulu and Greenwich Mean Time (GMT), is accurate to better than 1 millisecond. Using GPS time allows all GPS equipped aircraft and ground units to be synchronized to the same time. Refer to Time Data Programming, paragraph 1.15.

1.12.10 Update to Height Above Target Matrix

1.12.10.1 Using GPS Altitude. An option to use GPS altitude to derive the aircraft height above target has been added when the ALT option is selected on the UFC. When ALT is selected, a GPS option is displayed on the ODU in addition to the BOMB and PUC options. See Figure 1-175. GPS altitude is considered the second most accurate source of aircraft altitude following radar altimeter altitude and ahead of ADC baro-corrected altitude. If both the BOMB and GPS options are selected, radar altimeter, if valid, is used to determine height above target. The A/G weapon delivery mode legend in the HUD reflects that GPS altitude is being used by displaying GCIP in CCIP mode and GAUT in Auto mode. When using GPS altitude

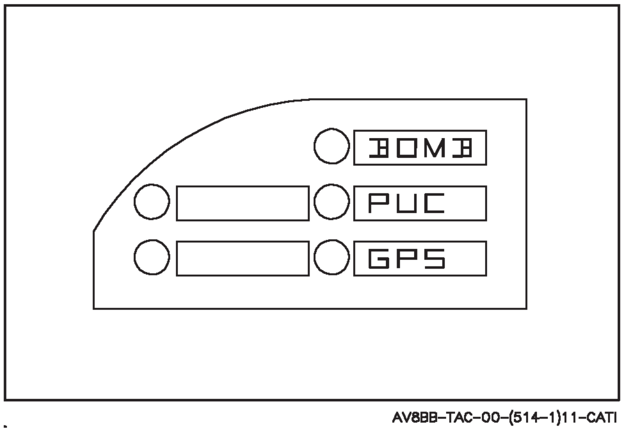


Figure 1-175. GPS Altitude Option

in CCIP mode, the waypoint / waypoint offset elevation is subtracted from GPS altitude to derive the height above target. When using GPS altitude in Auto mode to derive height above target, the MC uses a two phased approach. In the first phase, the GPS altitude is used directly; subtracting waypoint / waypoint offset field elevation from GPS altitude. In the second phase that begins at 15,000 feet slant range from the target, the height above target is computed by integrating aircraft vertical velocity.

If the GPS vertical error exceeds the threshold limits at any point during the attack, GPS altitude is no longer used. The GCIP or GAUT weapon delivery mode legend changes accordingly to reflect the new source being used to derive the aircraft height above target.

1.12.11 GPS and INS Cautions

1.12.11.1 GPS Caution Light. The GPS light on the CAUTION / ADVISORY panel, shown in Figure 1-176, is illuminated along with the MASTER CAUTION light, if a GPS failure has been detected or if the GPS horizontal error exceeds a specified tolerance. If the GPS is being used as the position keeping source and normal mode is selected, the GPS caution light is illuminated when the horizontal position error exceeds 333 meters for greater than 5 seconds. If the GPS is being used as the position keeping source, approach mode is selected, true airspeed is valid and less than 300 knots, the GPS caution light is illuminated when the horizontal position error exceeds 33 meters for greater than 5 seconds.

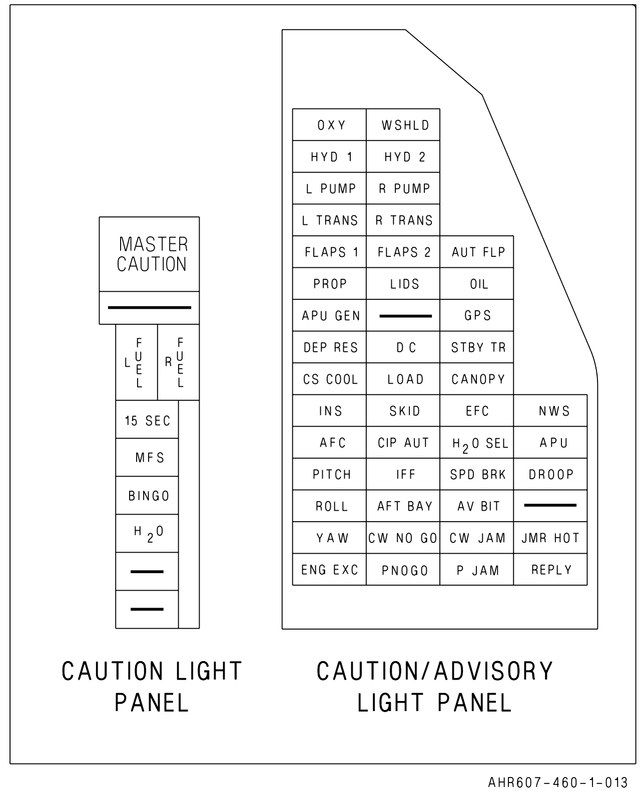


Figure 1-176. GPS and INS Cautions

1.12.11.2 INS Caution Light. The INS light on the caution/advisory panel, shown in Figure 1-176, is illuminated along with the MASTER CAUTION light, when the INS is aligning or failed. If the INS is aligning there is no action required. If the INS is not aligning when the INS caution light is illuminated (i.e., INS has failed) perform the following:

1. If the position keeping source is GPS, cycle the INS mode select switch to OFF then IFA.

2. If position keeping source is *not* GPS and pitch ladder is present, monitor GPS. When GPS becomes valid, cycle the INS mode select switch to OFF then IFA.

3. If position keeping source is *not* GPS and pitch ladder is *not* present, cycle the INS mode select switch to OFF then GYRO. When GPS becomes valid, cycle the INS mode select switch to IFA.

1.12.11.3 GPS and INS Caution Light. Both the GPS and INS caution lights along with the MASTER CAUTION light, are illuminated when the INS mode select switch is not in the IFA position. If cycling the INS mode select switch to IFA after completing an INS ground alignment does not extinguish the GPS and INS light, begin troubleshooting using previous procedures for the GPS and INS caution lights.

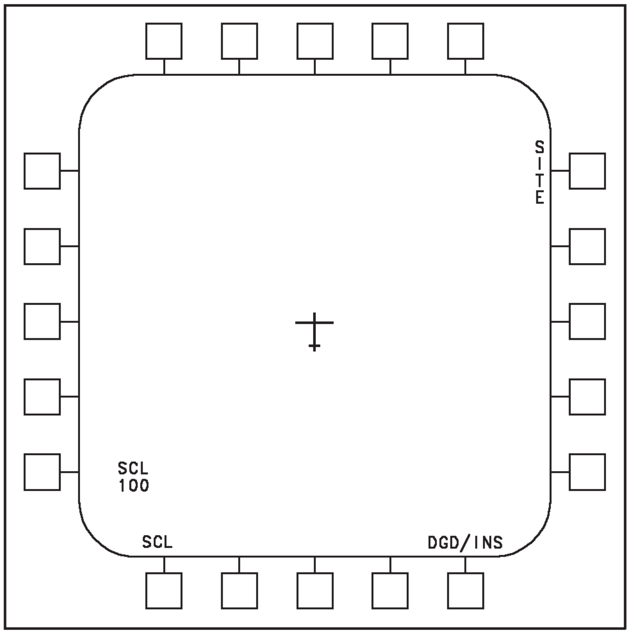


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Figure 1-177. Display Computer Backup

1.12.12 Reversions

1.12.12.1 Mission Computer (MC) Failure. In the event of a MC failure the Display Computer (DC) will take over as bus controller of the avionics multiplex bus. The navigation system will automatically enter uncoupled mode. The position keeping source is displayed on the backup digital map format and can be toggled between DGD/INS (default) and DGD/GPS. See Figure 1-177.

1.12.13 KYK-13. To obtain the best accuracy from the GPS, crypto-keys must be loaded into the MAGR using the KYK-13. After connecting a cable between the KYK-13 and the GPS, the KYK-13 switch is placed in the LOAD position. The "VERIFIED" LED (light emitting diode) on the KYK-13 will be illuminated from 0.25 to 0.50 seconds when the MAGR is successfully loaded.

1.12.14 Mission Planning System. To support the GPS integration, the Mission Planning System (MPS) has been modified to provide input and storage of the Digital Aeronautical Flight Information File (DAFIF) database, selection of waypoint and navigation aids from the DAFIF, and input and storage of the GPS almanac database. The mission planning station has also been modified to support entry and transfer of twenty-five waypoints (0 to 24) and three markpoints (MK1, MK2, MK3). The latitude / longitude of the waypoint can be entered to the nearest one thousandth of a minute. The waypoint offset range and bearing can be entered to the nearest tenth of a nautical mile and tenth of a degree, respectively.

The operator can select a combination of up to 200 waypoints and navigation aids from the DAFIF database to load into the DSU. Prior to writing the mission file information to the DSU, the operator has the option to also write the GPS almanac data to the DSU. The waypoints and navigation aids can be transferred from the DSU to the GPS by using the GPSX option on the GPS-DATA display format. The GPS is capable of storing up to 200 waypoints and navigation aids that can be transferred into the mission computer as a tactical waypoint (0 to 24) or markpoint (MK1, MK2, MK3) as mission requirements dictate.

Optical disks must be digitized in WGS-84. All latitude / longitude and UTM data is stored on the DSU as WGS-84 data.

1.12.15 GPS Position, Velocity, and Time Accuracy. The GPS calculates three-dimensional position to an accuracy of 16 meters SEP (Spherical Error Probable) and three-dimensional velocity to an accuracy of 0.1 meters per second. GPS time is accurate to within one millisecond. If the crypto-keys are not loaded in the MAGR, position is calculated to an accuracy of 100 SEP.

1.12.16 GPS Position Update. Aircraft position updates are not allowed in the tightly-coupled mode since updates in that mode are automatic. The waypoint overfly (WOF) update can be selected on the UFC when operating in tightly-coupled mode, however there is NO option to perform a position update of the INS, and therefore no temporary update of the aircraft symbol position on the EHSD display format. The other existing functions that are performed when the WOF option is selected are unaffected. All existing methods of performing position updates and an additional method,

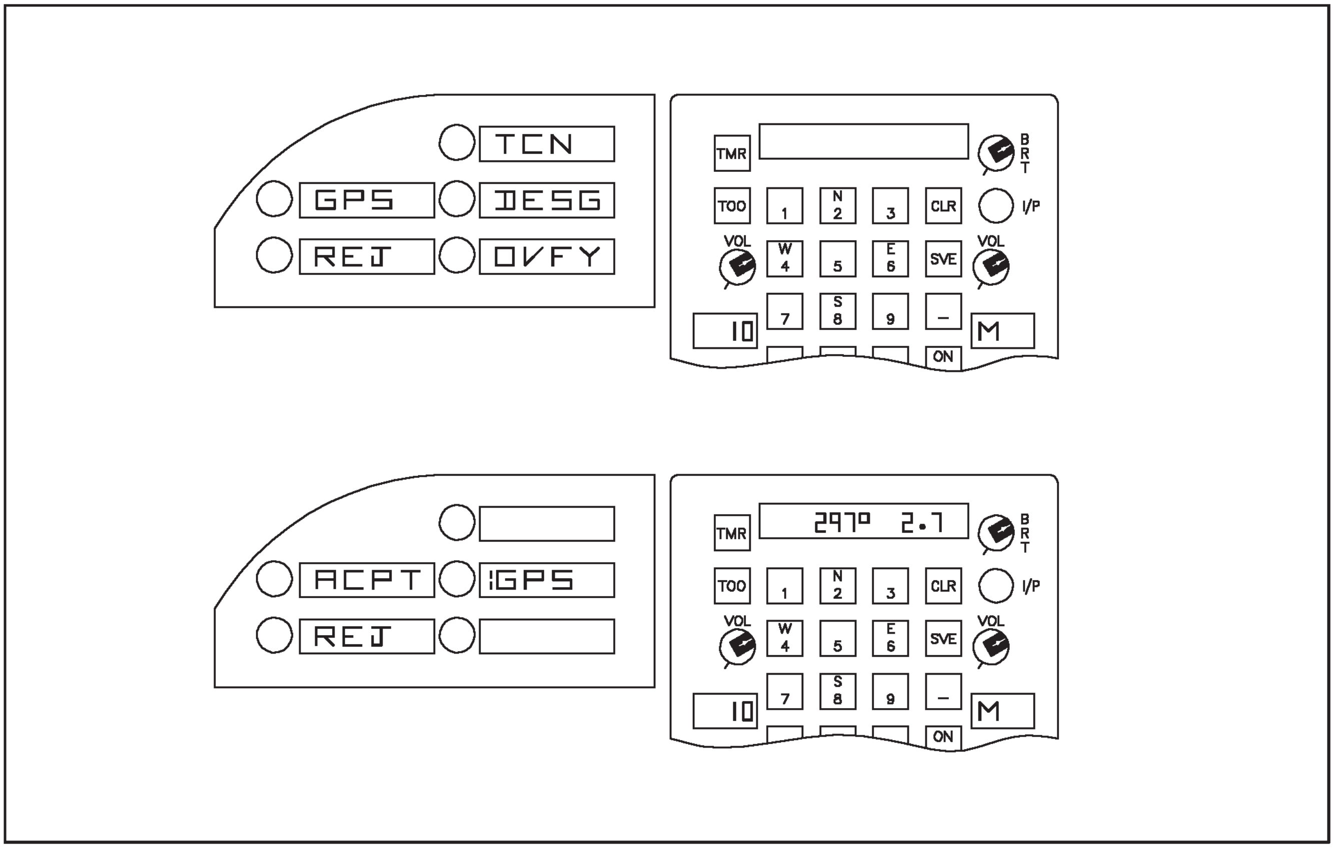

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Figure 1-178. GPS Update Option

GPS, are permitted when operating in either DGD/INS or DGD/ADC position keeping modes. When operating in DGD/GPS and INS position keeping is available, only the GPS update option is provided when the UPDT option is selected. The UPDT option is removed from the EHSD, FLIR, and DMT display formats when operating in DGD/GPS and INS position keeping is *not* available.

The GPS update option, shown in Figure 1-178, provides the capability to update:

1. The INS present position and aircraft present position when operating in DGD/INS.

2. The INS present position when operating in DGD/GPS.

3. The aircraft present position when operating in DGD/ADC.

When selected, a range and bearing error is displayed on the UFC scratchpad. Options to accept or reject the update are provided on the ODU. If the update is accepted, the MC sends the appropriate information to the INS to perform a Type-7 undefined update. A Type-7 Undefined update is a position-only bias to the Kalman filter output. If the update is rejected, the INS is not updated and the GPS update information is removed from the UFC and ODU.

1.12.17 GPS Employment Considerations. The GPS provides an unprecedented level of precision and accuracy to the navigation system. Accuracies of less than 16 meter SEP (50 percent) are possible if the system is utilized properly. GPS accuracy will reveal the limitations of maps, charts, and target coordinates that were previously masked by errors inherent in the INS. To obtain optimum performance, it is absolutely essential that the pilot understand the error sources resident in each part of the navigation system. Possible errors include:

(a) Using the wrong datum

(b) Map inaccuracies

(c) Incorrect target coordinates

(d) Incorrect system usage

These errors can be introduced into the system via the MPS, the aircraft data display, or the CAS display.

1.12.17.1 Datums. A datum is defined as ″something used as a basis for calculating or measuring″. In cartography, a datum defines the zero latitude/zero longitude point on earth from which all other latitudes and longitudes are referenced. In the past, cartographers developed maps based on the instruments and techniques available to them at that time. As a result, maps were accurate for the local region in which they were produced, but this accuracy did not remain constant worldwide. A cartographer in London and one in Tokyo might each create a map that would be locally accurate, but if the latitude and longitudes were extended to meet each other they rarely line up. These differences were generally the result of a lack of knowledge as to the actual shape of the earth and limitations in the accuracy of the surveying equipment available. Since GPS is intended for seamless worldwide use, a new and very accurate "earth model" was introduced. This earth model is the World Geodetic system 1984, or WGS-84. Because maps of the continental U.S. are generally accurate, only minor differences are noticeable when shifting to WGS-84. However, maps made in other regions of the world in the local datum (usually much older maps) may contain substantial differences when compared to WGS-84. Thus, the same target can have a different latitude/longitude/elevation in each datum it is measured in.

The WGS-84 system also redefined UTM coordinates. The zero/zero point of each 100,000 meter grid square has shifted a distance equal to the datum shift in latitude/longitude. Additionally, two-letter identifiers for each 100,000 meter grid square have been reordered by DMA. Each northing alpha was shifted 10 boxes. Thus, if the pilot attempts to enter an NAD 27 UTM on the CAS page with WGS-84 datum selected, huge errors may appear (up to 450 nm). A UTM derived from one datum *will not* transfer to another datum. The pilot must ensure that all coordinates, both latitude/longitude and UTM, remain datum consistent throughout the entire mission. This requires that the pilot be aware of the datum used in obtaining all coordinates, whether they are obtained by message, from S-2, or from the FAC.

The MAGR and the MPS are capable of translating coordinates between 47 of the most commonly used datums. These datums are listed in Figure 1-169. It is essential that the datum from which all latitudes and longitudes are derived be known. This will ensure optimum precision and reduce cockpit confusion. Both JOGAIR and TPC maps are of too small a scale to obtain precise coordinates .

A typical planning sequence may generally look like this: The pilot is given mission tasking. Target coordinates come in via message, and are given in datum A. The airspace control coordinates are in datum B. The coordinates are entered into the MPS. The MPS is capable of taking any of the 47 datums listed in Figure 1-169 and translating them into WGS-84. This is done by selecting the datum for the coordinate on the ENVIRONMENT page. Care must be taken to ensure that the correct datum is selected for each coordinate entered. Datum A is selected on the ENVIRONMENT page, then the target coordinate is entered in the ROUTE-DEFINE-WAYPOINT page. Datum B is then selected on the ENVIRONMENT page, and the airspace control points are entered on the ROUTE-DEFINE-WAYPOINT page. Once a coordinate is correctly entered, changing the datum on the environment page translates all coordinates previously entered into that datum. This allows the pilot to work in any of the 47 datums.

While able to display a coordinate to the pilot in any of the 47 datums, the MPS actually stores all coordinates in WGS-84 and uses WGS-84 for all distance and heading calculations. This is transparent to the user. The MPS also transfers all coordinates to the Data Storage Set (DSU) in WGS-84, regardless of which datum they are entered in.

From the DSU, the WGS-84 coordinated are transferred to the aircraft mission computer via data transfer (DTX). These coordinates can be displayed on the aircraft data page in whatever datum the pilot wishes to view them. Changing the datum on the aircraft data display will change the datum in which that coordinate is displayed, but the MC and MAGR will always maintain those coordinates as WGS-84 for all calculations.

Only aircraft with operating MAGRs are capable of this datum translation. The information goes from the MC to the MAGR, is translated, and then is displayed on the aircraft data display. Although not always possible, every effort should be made to work in WGS-84. This eliminates the possibility of error being introduced through inadvertent use of the wrong datum.

A moving map made in WGS-84 coordinates will correctly display all symbology and overlays from the MC and DSU over the intended point on the ground. However, if the moving map was scanned, or “warped”, onto the aircraft optical disk in a different datum the waypoint symbol and aircraft symbol will not be over the proper point on the ground. The magnitude of the error will be identical to the difference between WGS 84 and the datum the map was scanned in. Local control procedures should be developed to keep track of the datum each moving map disk is made in (ideally, WGS-84).

1.12.17.2 Map Inaccuracies. Chart coordinate accuracy is dependent upon the chart type, scale and skill of the person who performed the plot. The relative horizontal and vertical accuracy of various types of aeronautical charts is shown in Figure 1-179. The expected accuracy of a proficient pilot performing plots on these charts is also shown.

The source, and therefore accuracy, of a coordinate is determined by the mission requirements at that particular phase of the mission. DMA mensurated coordinates are not required for a tanker rendezvous point; a TPC plot will suffice. On the other hand, JOGAIR plot of a target will be insufficient.

SOURCE	SCALE	SOURCE CEP	PLOT CEP
ONC	1:1,000,000	6500 ft	3000 ft
TPC	1:500,000	3250 ft	2000 ft
JOG	1:250,000	810 ft	1000 ft
TOPO	1:50,000	160 ft	200 ft

Figure 1-179. Chart Coordinate Accuracy

1.12.17.3 Target Coordinates. DMA mensurated coordinates are the most accurate coordinates available. Point Positioning Data Base (PPDB) coordinates are derived form photographic materials and are also extremely accurate. A third source of highly accurate coordinates is a GPS survey, using a PPS receiver; this requires getting the receiver to the target location, something that is not always possible. coordinates derived from charts are the least accurate, as discussed earlier.

Target coordinates should be taken from the most accurate source available during the allotted planning time. If DMA, PPDB, or GPS surveyed coordinates are not readily available, then photographs should be used to assist the pilot in performing the chart plot and coordinate determination. Remember target elevation is a critical component of the target coordinate; both Baro and GPS bombing will be significantly degraded if correct target elevation in not used.

The integration of the MAGR into the AV-8B allows a high degree of precision in locating targets. Initial results have demonstrated CEPs better then those currently accepted by all-weather bombing systems (ASRAT and A6-E radar beacon bombing). The key to success is datum control, coordinate accuracy, and system management. Although the AV-8B is not an "all-weather" bomber, GPS introduces a capability for very accurate nonvisual deliveries that show much promise.

1.12.17.4 Incorrect System Usage. Proper system management will allow full utilization of the increased capabilities of the GPS system as integrated into the AV-8B. This system management begins with proper maintenance procedures, includes the mission planning process, and extends throughout the flight. Besides the proper preflight use of datums and coordinates, maximum accuracy depends on switchology, INS management, in-flight procedures, and in-flight data entry.

a. Maintenance Procedures. Essential to gaining the accuracy needed for target location is a PPS capable MAGR. This requires that the MAGR be keyed with the *correct* Cryptographic code daily; this is similar to the requirement to load the KY-58 for covered communications. If the correct crypto is not loaded into the GPS, the system will only operate to the SPS standard. This can be checked by the pilot on the GPS data display, as discussed earlier.

1.13 VIDEO RECORDING

The video recording system (VRS) provides recording of the entire HUD field of view and/or, if selected, the concurrent DDI video display (ARBS or Maverick video only, not the pushbutton legends or alphanumerics). Actual tracking and release conditions viewed on the HUD, DDI, or both are recorded on 0.25-inch magnetic tape for post flight removal and playback. If both the HUD and DDI presentations are recorded, a split screen presentation is used to show both displays at reduced size. Analysis as to why impacts missed on individual attempts can easily be made. Since the entire head-up display is recorded, all factors affecting weapons aiming and release are available for assessment. The HUD presents dive angle, airspeed, slant range (through target size/aspect measurement), release height, tracking technique, aim point at release, crosswind drift, and mil depression. This can be a valuable tool in training because it provides a "truth-telling" influence on pilots. Good techniques can be shown and exploited, while any bad tendencies can be corrected in a timely manner. See Figure 1-180 for VRS cockpit controls and components.

1.13.1 HUD Video Camera. The HUD video camera is mounted on the right side of the HUD, focused at infinity and set to monitor the HUD field of view. The camera lens has a field of view of 15.8° vertically and 21° horizontally. An automatic exposure control (AEC) adjusts for light level changes.

1.13.2 Video Recorder. The recorder is mounted in the right console and controlled by the recorder switch. Recording time is limited to 60 minutes.

1.13.3 Split Screen Unit. On some AV-8B aircraft, a split screen unit (SSU) is located below the left side of the windshield behind door 7L. The HUD only or DDI only video selections are full screen presentations. In the split screen (S/S) video selection, the SSU compresses both video displays at the same time in a side by side presentation. During playback HUD video is displayed on the left side and DDI video is displayed on the right side.

1.13.4 Radar Display Recording. The VRS (Video Recording System) provides a video and voice recording of the flight on 0.25 inch wide magnetic tape. Weapon video from the SMS, and video from the FLIR, RADAR, and EHSD may be recorded from the MPCD. HUD display video may be recorded directly from the HUD video camera which is an integral part of the HUD. The pilot controls basic VRS operation via the video record switch (REC - STBY - UNTHRD) on the video recorder on the right console, and the VRS Auto/Run switch on the miscellaneous switch panel. However, since the aircraft has two MPCDs, the pilot must be aware of recording priority so that the proper display is recorded.

1.13.4.1 Recording Priority. The two position VRS display select switch on the miscellaneous switch panel selects one of two output video display formats; HUD or MPCD. When HUD is selected, the HUD display is recorded directly, however, when MPCD is selected the mission

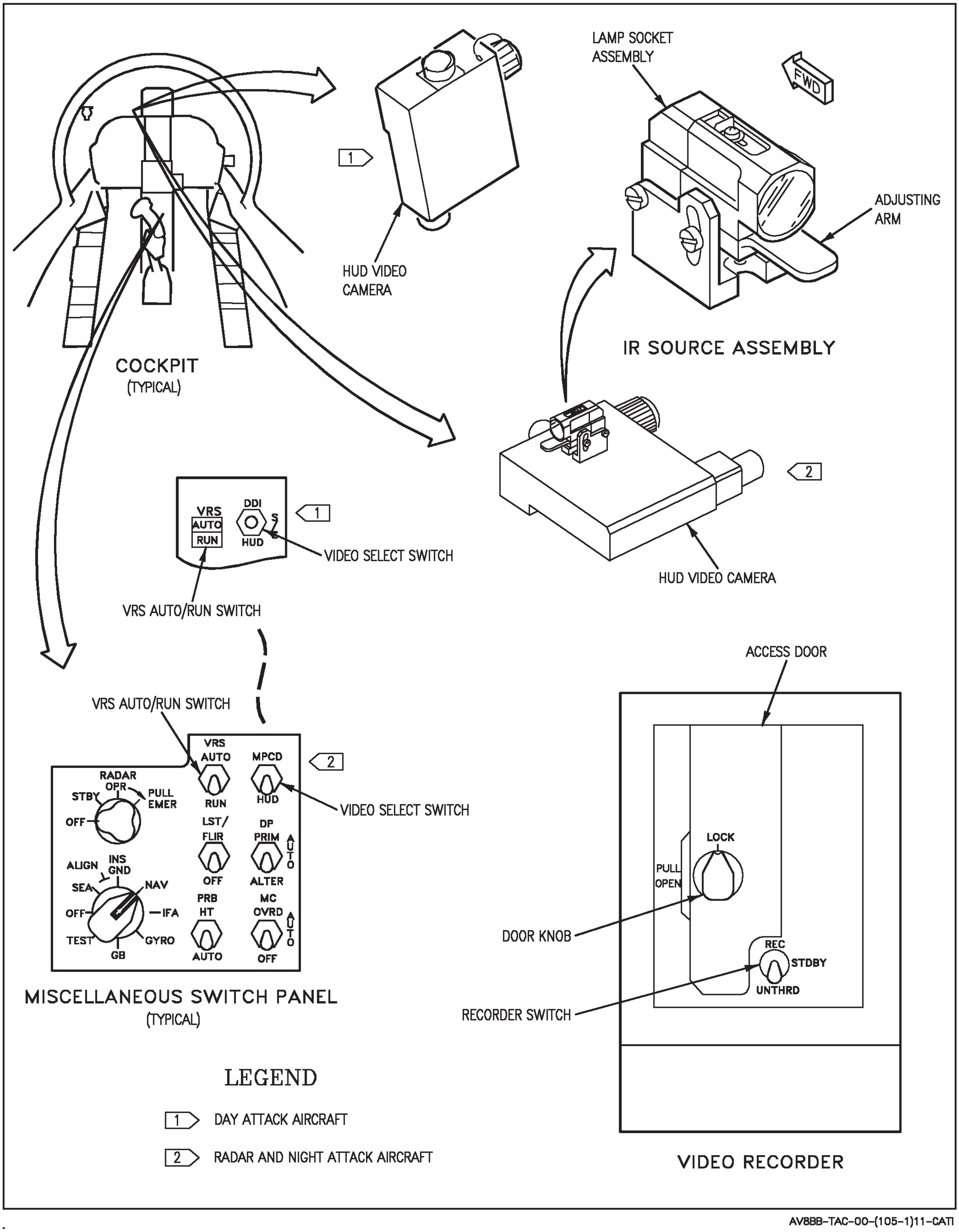

Figure 1-180. VRS Cockpit Controls and Components

computer selects video from either MPCD as determined in the following priority:

a. Day Attack aircraft:

(1) DMT

b. Night Attack aircraft:

(1) Weapon

(2) DMT

(3) FLIR (HUD FLIR takes priority over MPCD FLIR)

(4) EHSD

c. Radar aircraft:

(1) Weapon

(2) FLIR (HUD FLIR takes priority over MPCD FLIR)

(3) Air-to-surface radar

(4) EHSD

Another factor for the pilot to keep in mind is that the VRS is only capable of recording raster video. Stroke symbology can not be recorded. Basically, stroke symbology is displayed by an electron gun being positioned to the point where a symbol is to be placed and then turned on to write or paint the desired words or symbols. Raster data, on the other hand, is displayed by having electron guns continually scan the display from side to side and top to bottom, firing when they reach a position where something must bedisplayed, thereby drawing a portion of the image with each scan. This is the basic manner in which any TV display is created. The radar displays have a maximum of 512 lines with a maximum of 512 pixels per line (1024 pixels total).

All of the air-to-surface radar mapping modes can convert the radar video signal into a raster display. Generally speaking, only the track modes (and all the air radar modes) use stroke symbology. The MAP, EXP1, EXP2, EXP3, SEA, and GMT displays can be recorded, however, the FTT, GMTT, AGR, and PVU mode display symbology will not be recorded.

1.13.5 VRS Operation. The VRS is operated by three switches: the recorder switch, VRS AUTO/RUN switch, and video select switch. The pilot has the option to run the recorder continuously or only when A/A or A/G master modes are selected and to record either the HUD, DDI, or both displays. If the head-up display is recorded, an event marker will appear as a small black box in the upper left corner of the recorded HUD video when the bomb pickle button is pressed or the trigger is squeezed and remains there until the control(s) are released.

1.13.6 HUD Symbology Sizes. See Figure 1-181 for an illustration of the HUD weapon aiming symbols and their sizes.

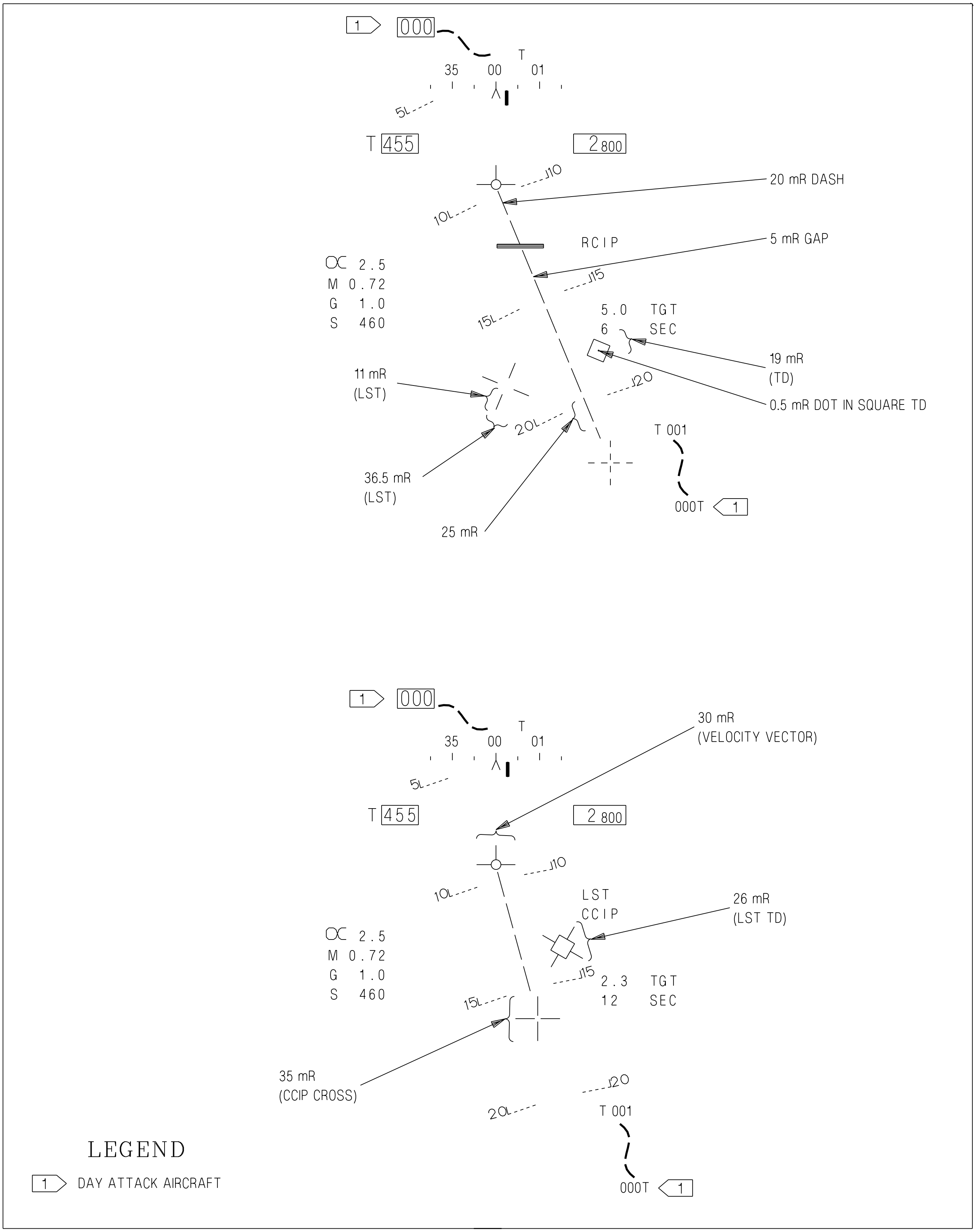

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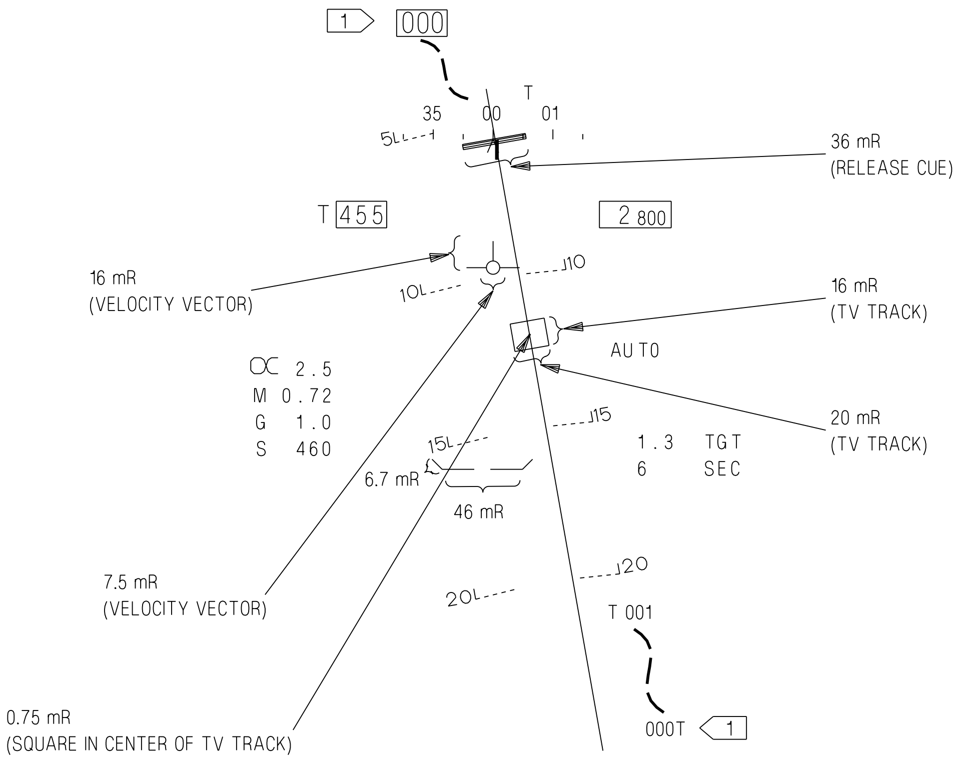
Figure 1-181. HUD Symbology Sizes (Sheet 1 of 10)



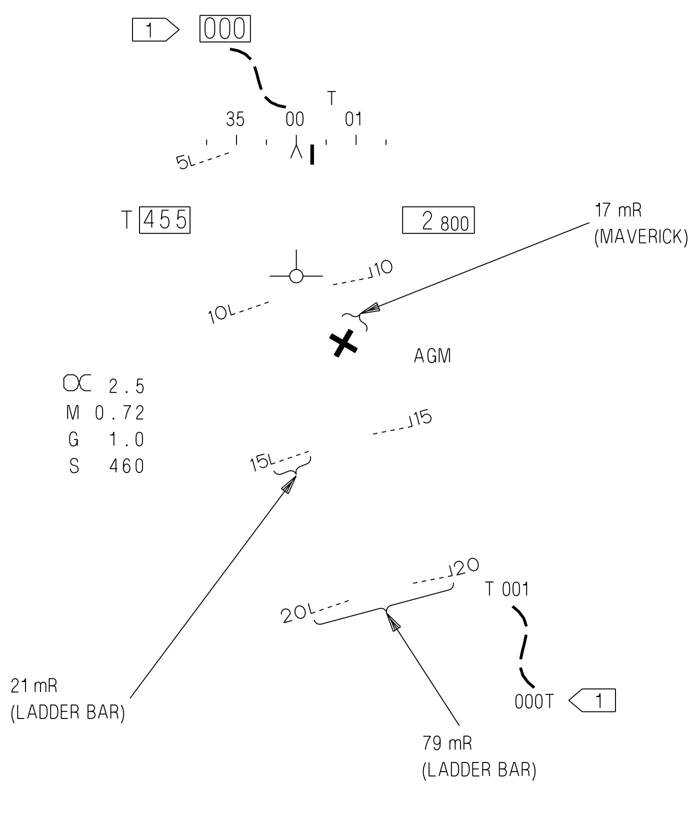


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Figure 1-181. HUD Symbology Sizes (Sheet 2 of 10)

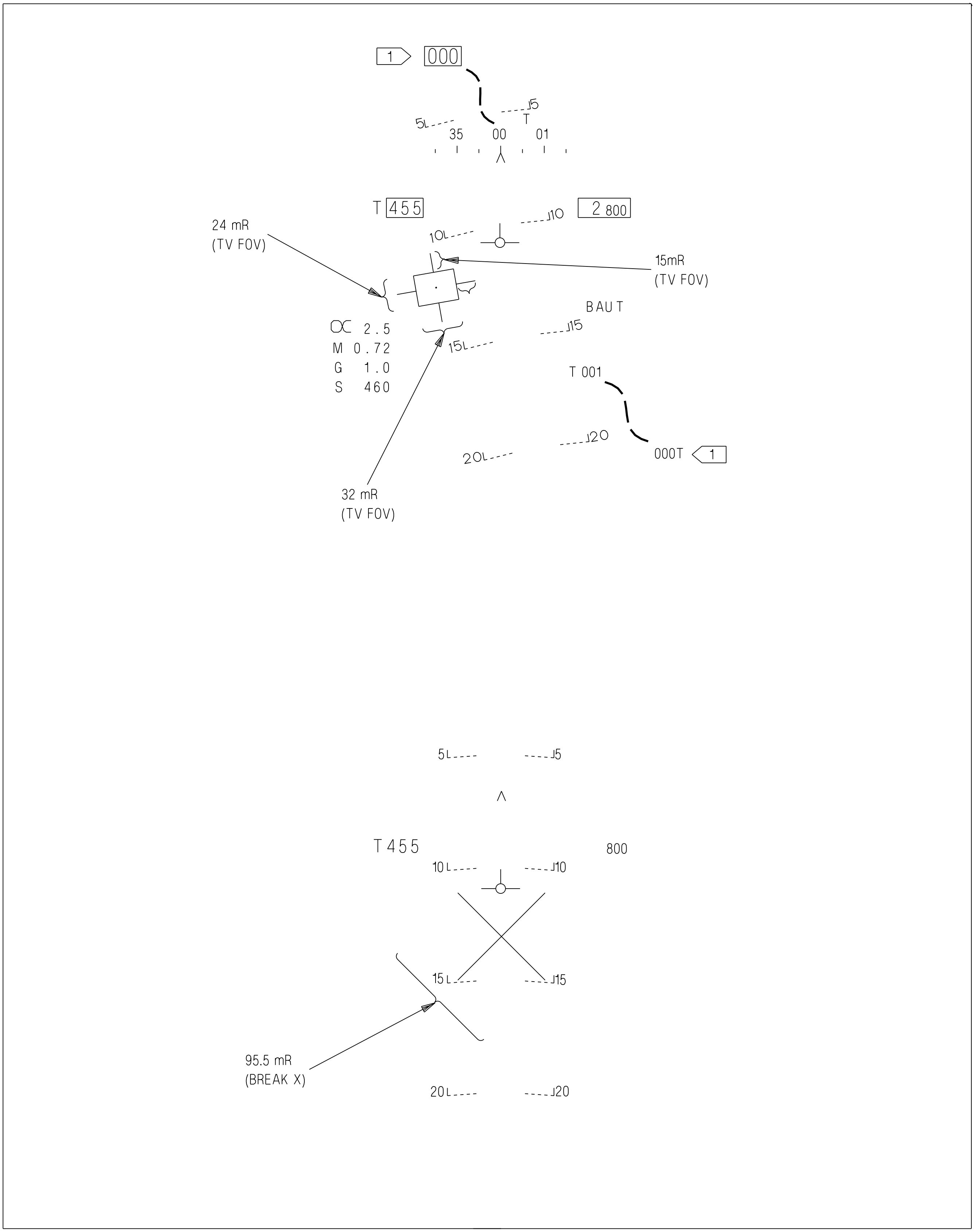

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Figure 1-181. HUD Symbology Sizes (Sheet 3 of 10)

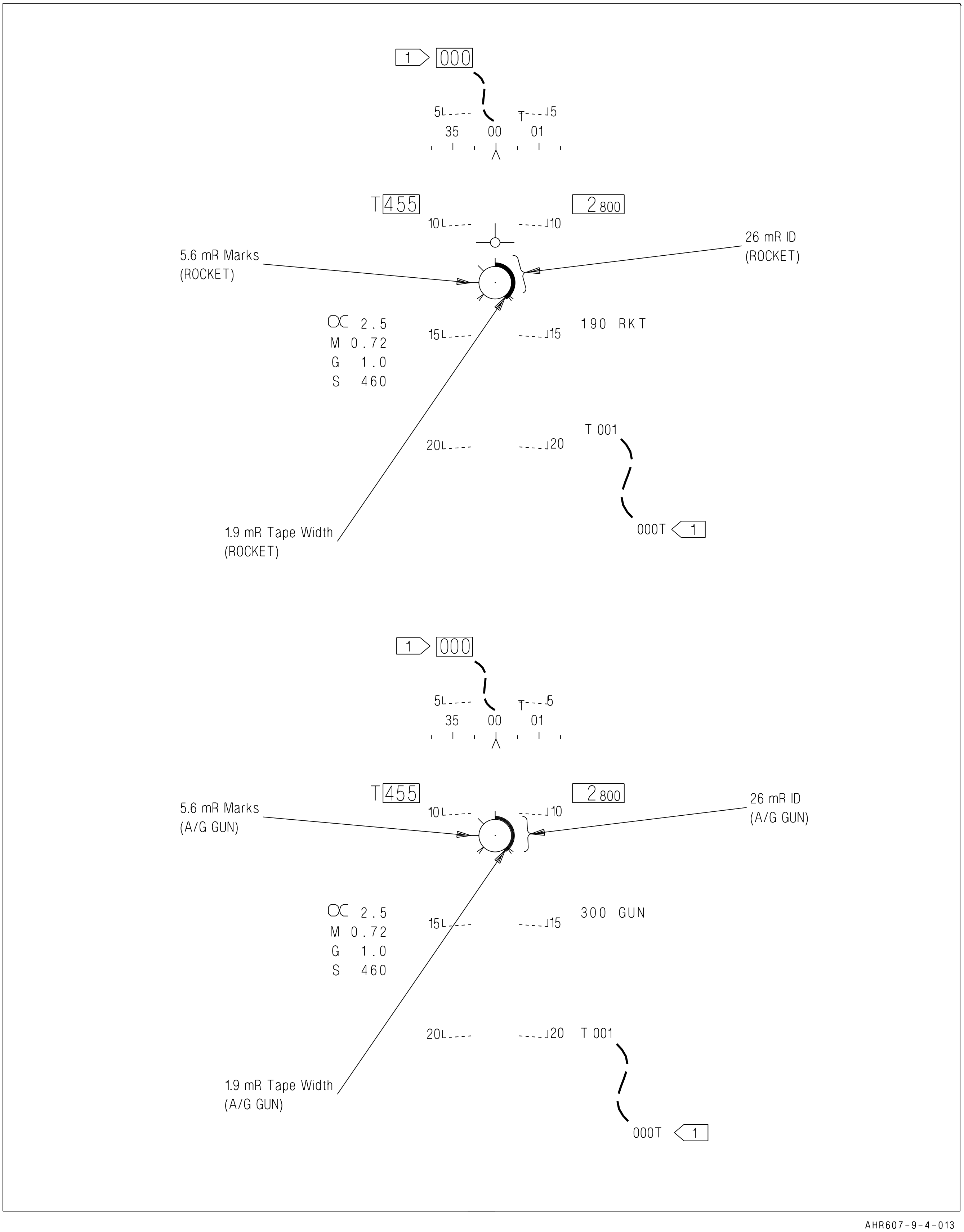

Figure 1-181. HUD Symbology Sizes (Sheet 4 of 10)

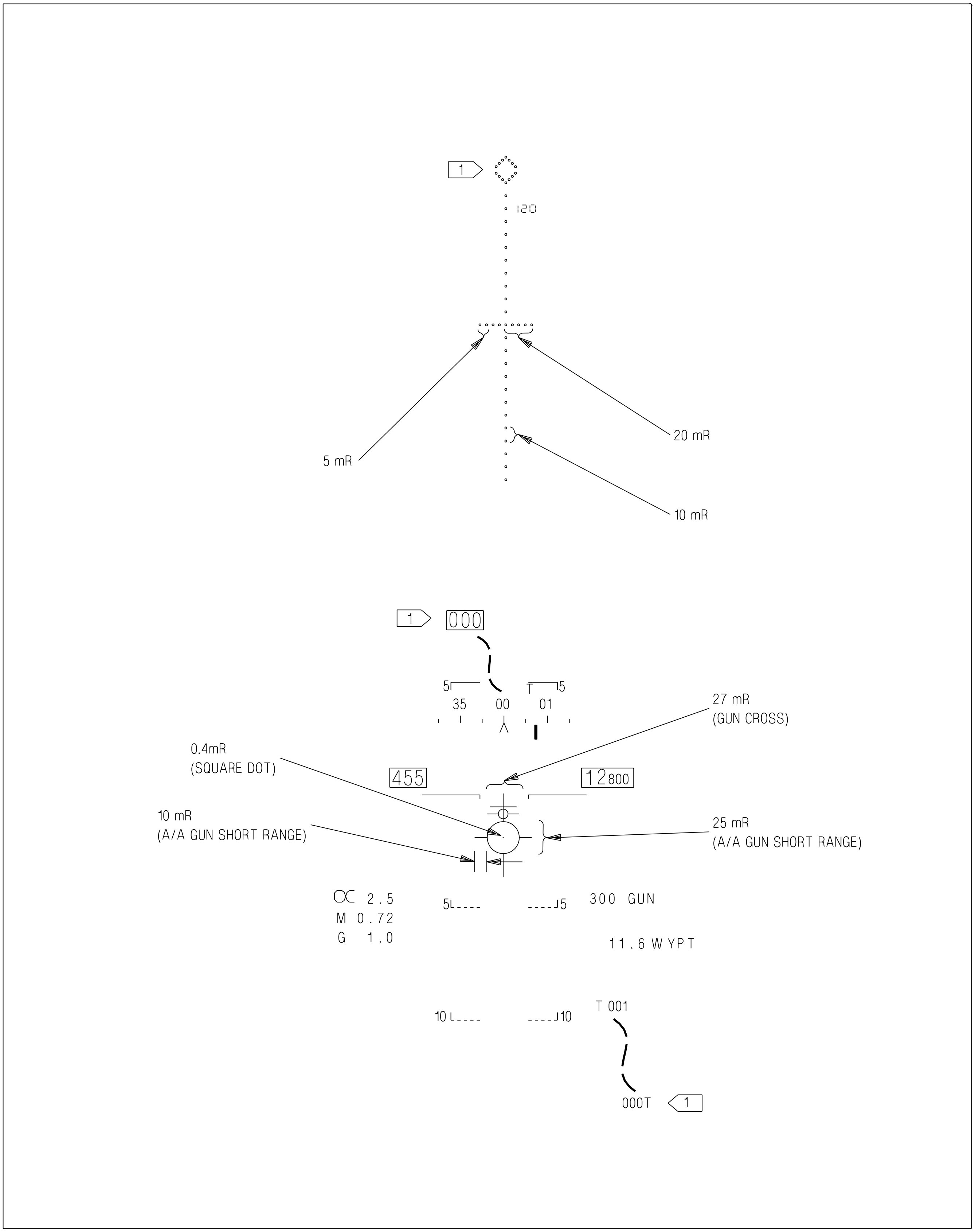

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Figure 1-181. HUD Symbology Sizes (Sheet 5 of 10)

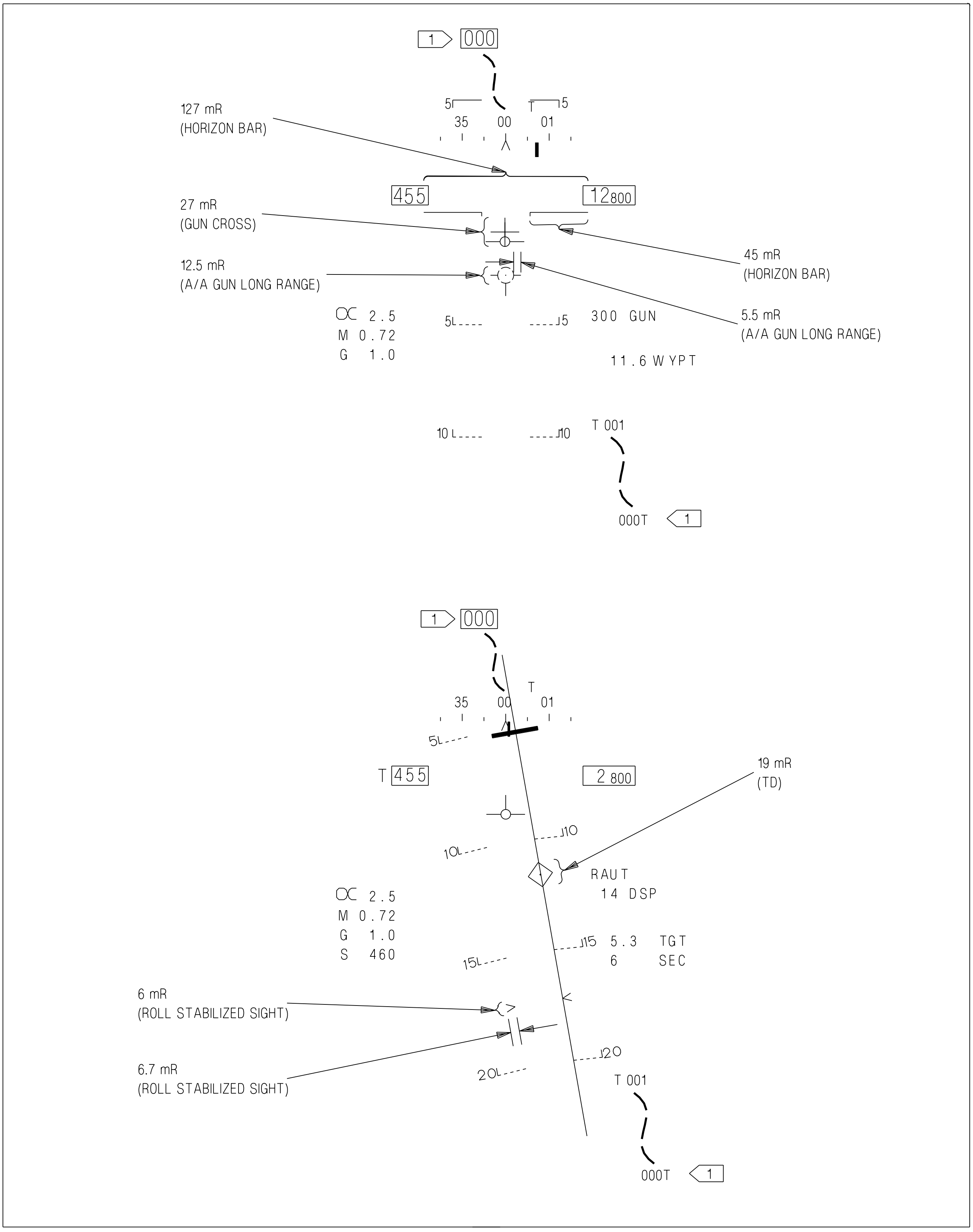

Figure 1-181. HUD Symbology Sizes (Sheet 6 of 10)

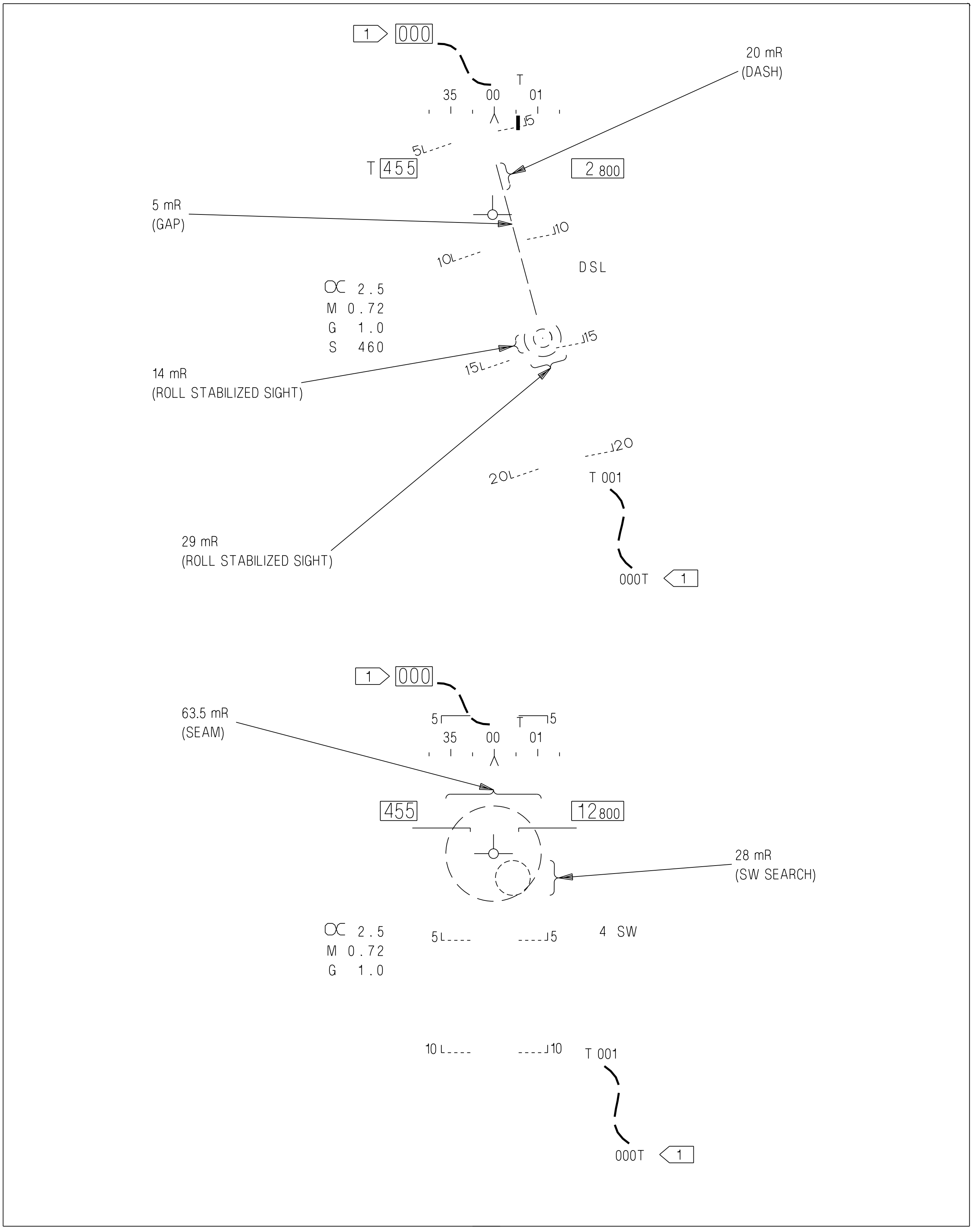

Figure 1-181. HUD Symbology Sizes (Sheet 7 of 10)

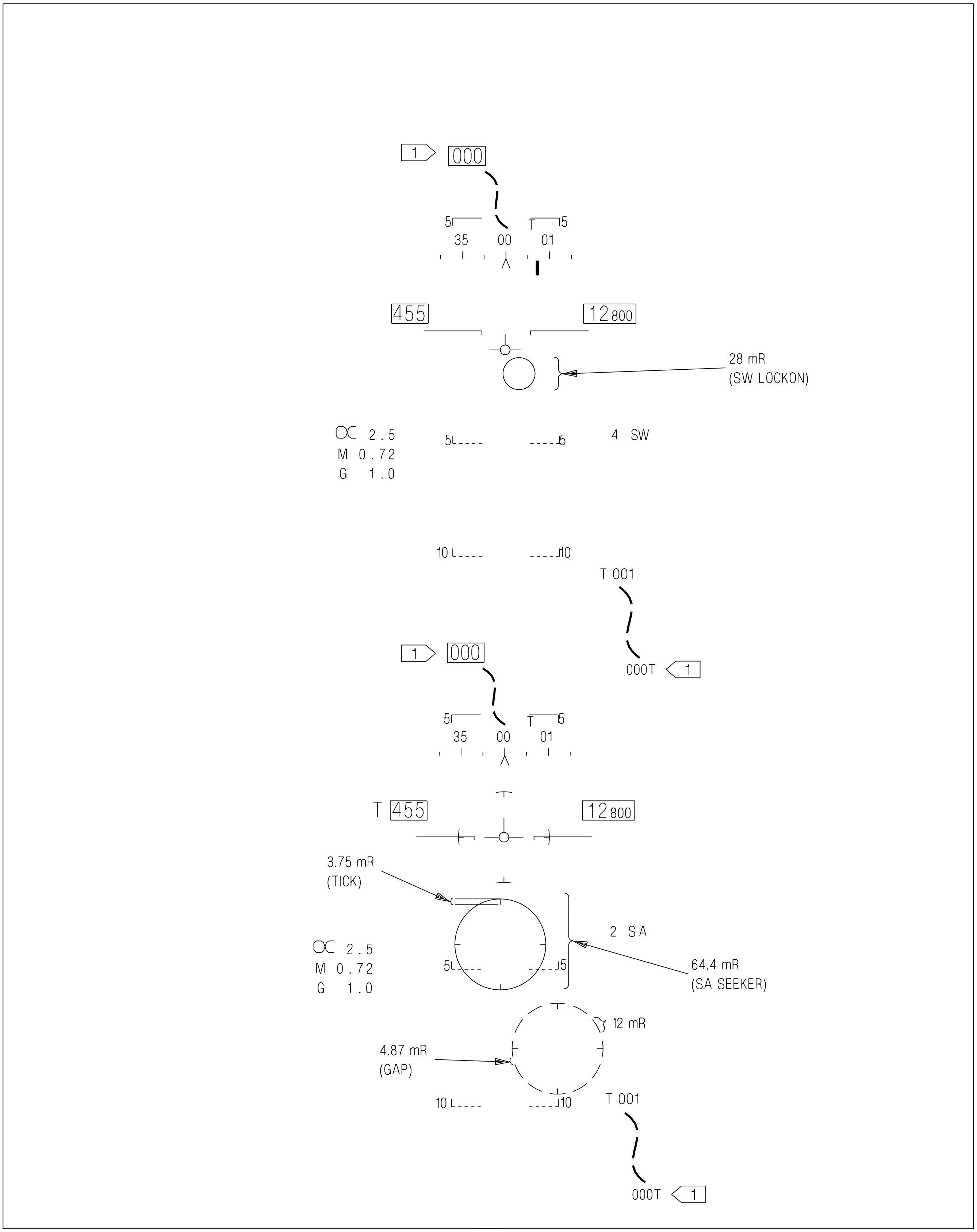

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Figure 1-181. HUD Symbology Sizes (Sheet 8 of 10)

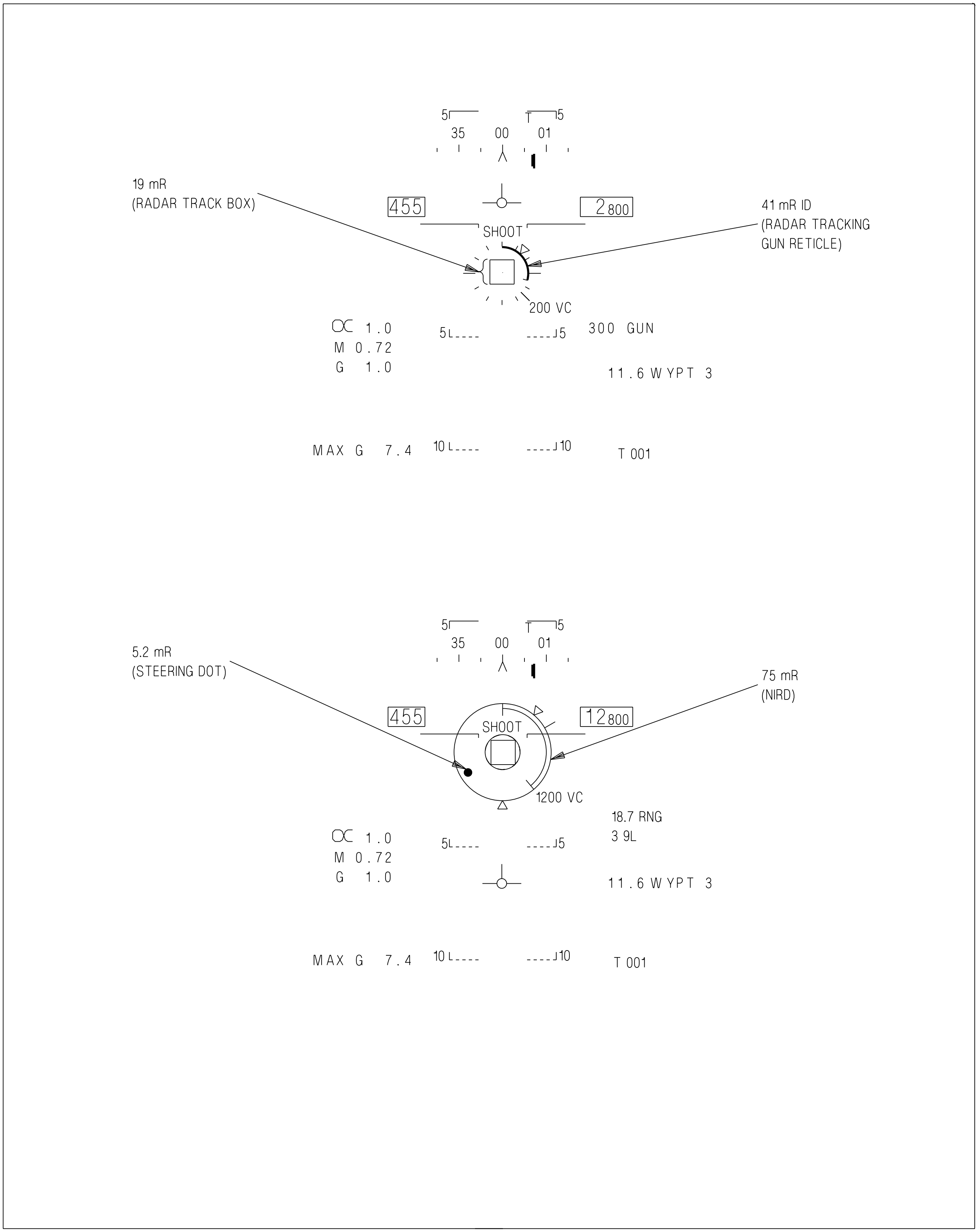


Figure 1-181. HUD Symbology Sizes (Sheet 9 of 10)

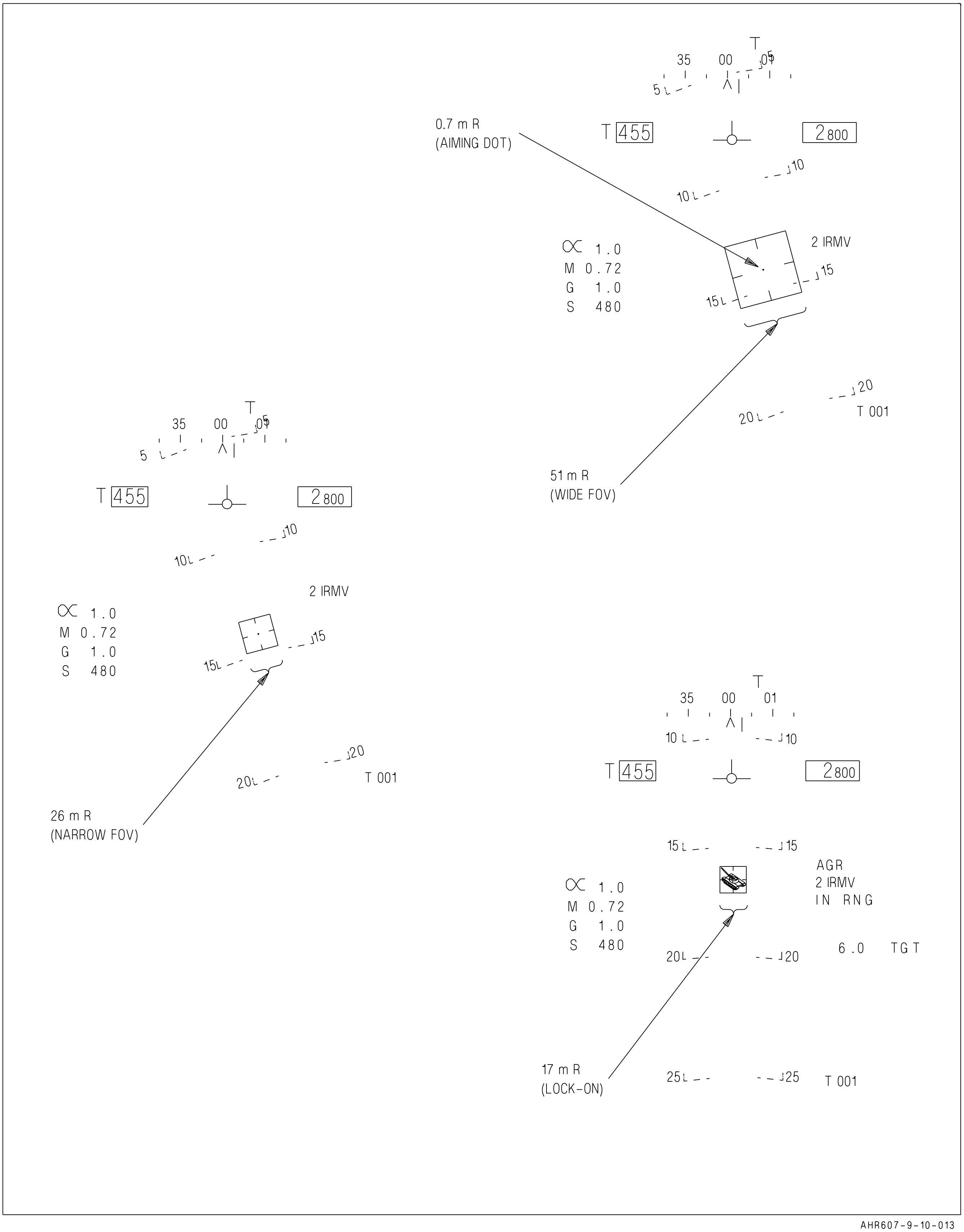


Figure 1-181. HUD Symbology Sizes (Sheet 10 of 10)

1.14 STORES MANAGEMENT SYSTEM

1.14.1 Stores Management Control Set (SMCS). The SMCS maintains an inventory of the loaded stores, monitors their status, and controls the release of the weapons. The SMCS is made up of a stores management computer with an integral weapon loadout panel, armament control panel, and seven stores station controllers.

1.14.1.1 Stores Management Computer (SMC). The primary component of the SMCS is the SMC. The SMC is a programmable digital computer that controls the SMCS. The front panel of the SMC is accessible in the main wheelwell. Thumbwheel controls are provided on the front panel or weapon loadout panel for inserting store codes for the stores loaded, fuzing codes for the fuzes on the weapons, and the quantity of weapons loaded at each station (for SMC loadout panel programming codes refer to NWP 3-22.5-AV8B, Vol. III, Chapter 5). With store codes inserted, the SMC supplies the applicable internally stored weapon ballistic coefficients to the MC when required for the weapon delivery computations in night attack aircraft. Ballistic coefficients are stored in the MC in day attack aircraft. The SMC stores the weapon delivery programs and provides selectable options for program modification. The SMC also generates and distributes the electric fuzing voltages for all electric fuzes. Backup delivery capabilities are provided by the SMCS when failures occur.

1.14.1.2 Stores Station Controllers (SSC). Seven identical SSCs are installed, one in each of the seven pylons. The SSC contains the normal selective jettison and backup release drivers required to off-load the pylon stores. It also contains the arming drivers for normal and backup release functions to mechanically arm the bombs.

1.14.1.3 Armament Control Panel (ACP). The ACP on the lower left main instrument panel contains controls and indicators for the SMCS. See Figure 1-182. The panel has display windows that indicate the weapon program that can be set by the pilot via the adjacent control

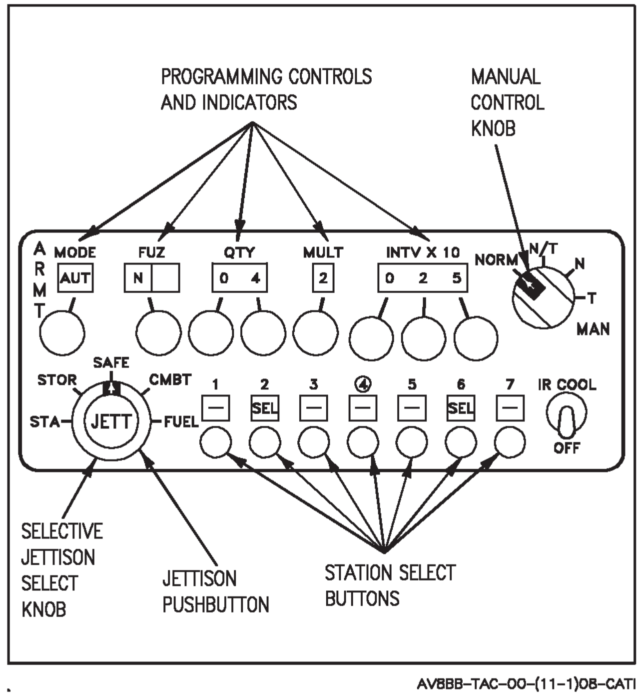


Figure 1-182. Armament Control Panel (ACP)

switches or the UFC and ODU. Regardless of which control is used to select the weapon delivery program, it is displayed in the windows on the ACP and in the stores display program block on the DDI. The windows contain a dash (−) for mode and fuzing and zero for other options when no weapon is selected. The dashes and zeros also appear when certain failures occur. In addition, the panel contains station select buttons, a switch for DSL(1) (manual) delivery mode selection, a Sidewinder IR coolant switch, and a selective jettison switch and jettison (JETT) pushbutton. Refer to Stores Management Preflight Programming, paragraph 1.14.5.1 for detailed weapon programming.

1.14.2 Hands on Throttle and Stick (HOTAS) Controls. HOTAS functions peculiar to the SMS are discussed in the following paragraphs. See Figure 1-183.

1.14.2.1 Throttle

1.14.2.1.1 Target Designator Control (TDC). The TDC is a force transducer with a 0.20-inch displacement and a discrete action switch. The force transducer provides outputs for the display cursor (TD diamond) and/or sensor control. The

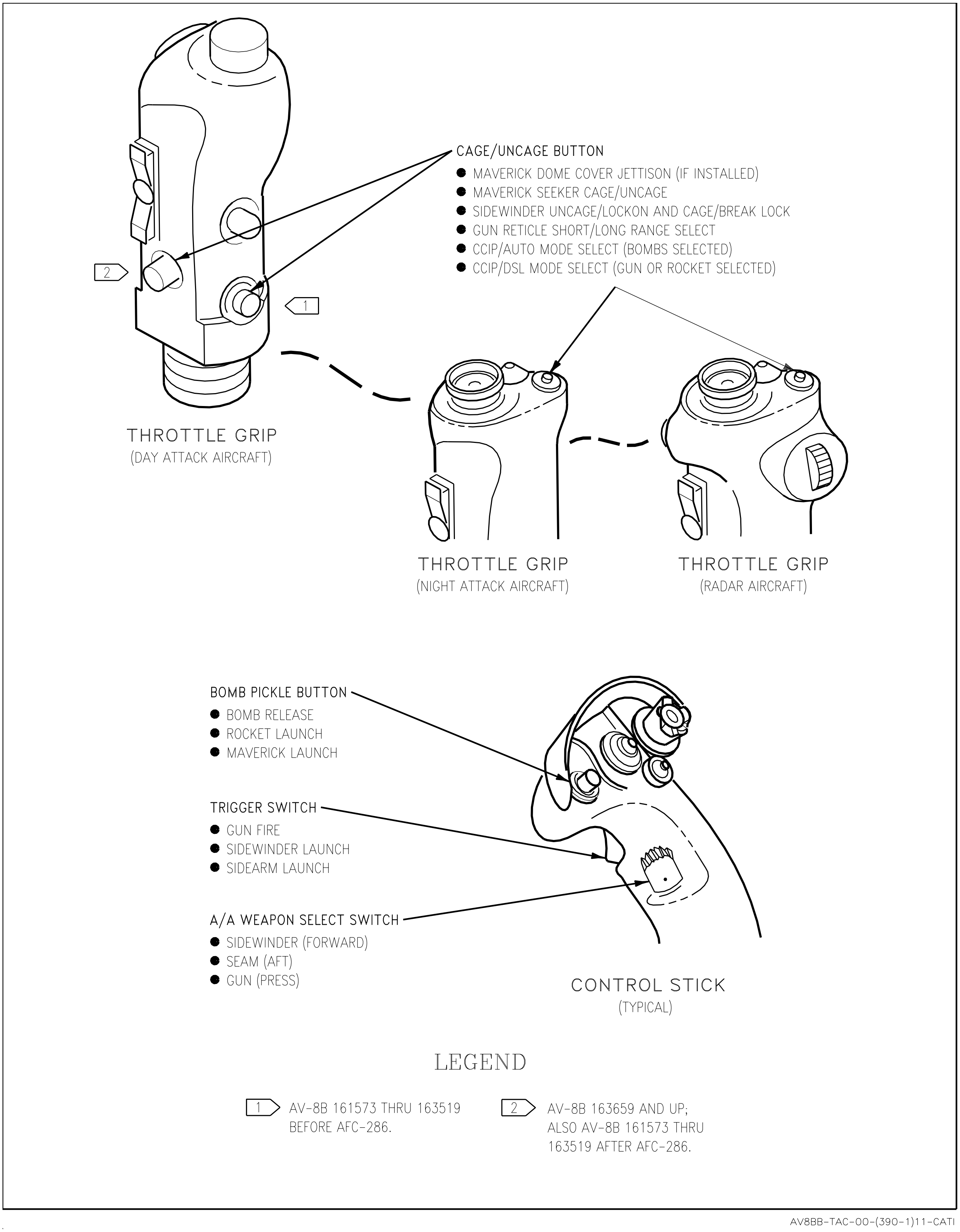


Figure 1-183. HOTAS Controls

TDC incorporates both action and no action slewing. Slewing without the TDC pressed (no action slewing) is used primarily for sensor control and “sweetening” of target track. Action slewing (TDC pressed) is used primarily in target acquisition and target designation.

1.14.2.1.2 Cage/Uncage. The cage/uncage button is a momentary pushbutton switch. In the A/A mode, the cage/uncage button is used to cycle the gun reticle between long and short range symbology when the fuselage gun is selected. When Sidewinder missiles are selected, this switch uncages the missile seeker and commands lock on. Reactuating the switch breaks lock and recages the missile. In the A/G master mode with Maverick missile(s) selected, pressing the cage/uncage button uncages the Maverick seeker head to initiate scan. If bombs are selected, successive actuations of the cage/uncage button alternates the selected computed delivery mode between CCIP and AUTO. If gun or rockets are selected, the cage/uncage button alternates between CCIP and DSL. If dispensers are selected, the cage/uncage button alternates between AUTO and DSL.

1.14.2.2 Control Stick

1.14.2.2.1 Trigger Switch. The trigger switch has two detents. The second detent fires the fuselage gun or Sidewinder missiles when in the A/A master mode, or fires the fuselage gun in the A/G master mode. In A/G master mode the trigger switch is also used to launch the Sidearm missiles. Detent 1 is unused.

1.14.2.2.2 Bomb Pickle Button. This switch is a momentary pushbutton switch that is active only in the A/G master mode. It is used for release of bombs, rockets, dispensers, and Maverick missiles.

1.14.2.2.3 A/A Weapon Select Switch. This is a three position (four on radar aircraft) momentary switch which automatically selects the A/A master mode when an A/A weapon selection is made. Pulling the switch aft selects Sidewinder expanded acquisition mode (SEAM), and pressing it selects fuselage gun. When released, it returns to the neutral position. Pushing forward selects Sidewinder boresight (SW) mode. Subsequent activations in either Sidewinder mode will step the station selected to the next station in priority. On radar aircraft, a right position is available but not functional.

1.14.3 Master Modes. The AV-8B weapon system is built around four master operational modes: navigation (NAV), vertical and short takeoff and landing (V/STOL), air-to-ground (A/G), and air-to-air (A/A). The master mode design allows a single pilot action to configure the aircraft avionics for takeoff and landing, navigation, or attack. The operation of the avionics subsystem and respective control/displays are tailored to the operating master mode.

As shown in Figure 1-184 NAV, V/STOL, and A/G master modes are selected by pressing the appropriate pushbutton on the master armament panel. These are momentary pushbuttons which illuminate when actuated. The A/G mode can also be selected by selecting waypoint overfly (WOF) or target of opportunity (TOO) on the UFC. The A/A mode is a HOTAS function. The three-position weapon select switch on the control stick allows the pilot selection of either Sidewinder, SEAM, or gun.

AV-8B master modes are mutually exclusive with the last selected mode being the current mode of operation. At power up, the system initializes to the V/STOL mode. Master modes are deselected by selecting another master mode.

Selection of a master mode automatically enables the programs and selections preset by the pilot and/or stored in the MC, and initializes the HUD to display appropriate system information.

1.14.3.1 A/G Master Mode. The A/G master mode is selected by actuating the A/G master mode button on the left side of the main instrument panel. It is automatically initiated with either waypoint overfly (WOF) or target-of-opportunity (TOO) pushbutton actuation on the UFC. Activation of the A/G master mode initializes the selected weapon and weapon program for delivery, provides attack symbology on the HUD, and turns on the HUD video recorder.

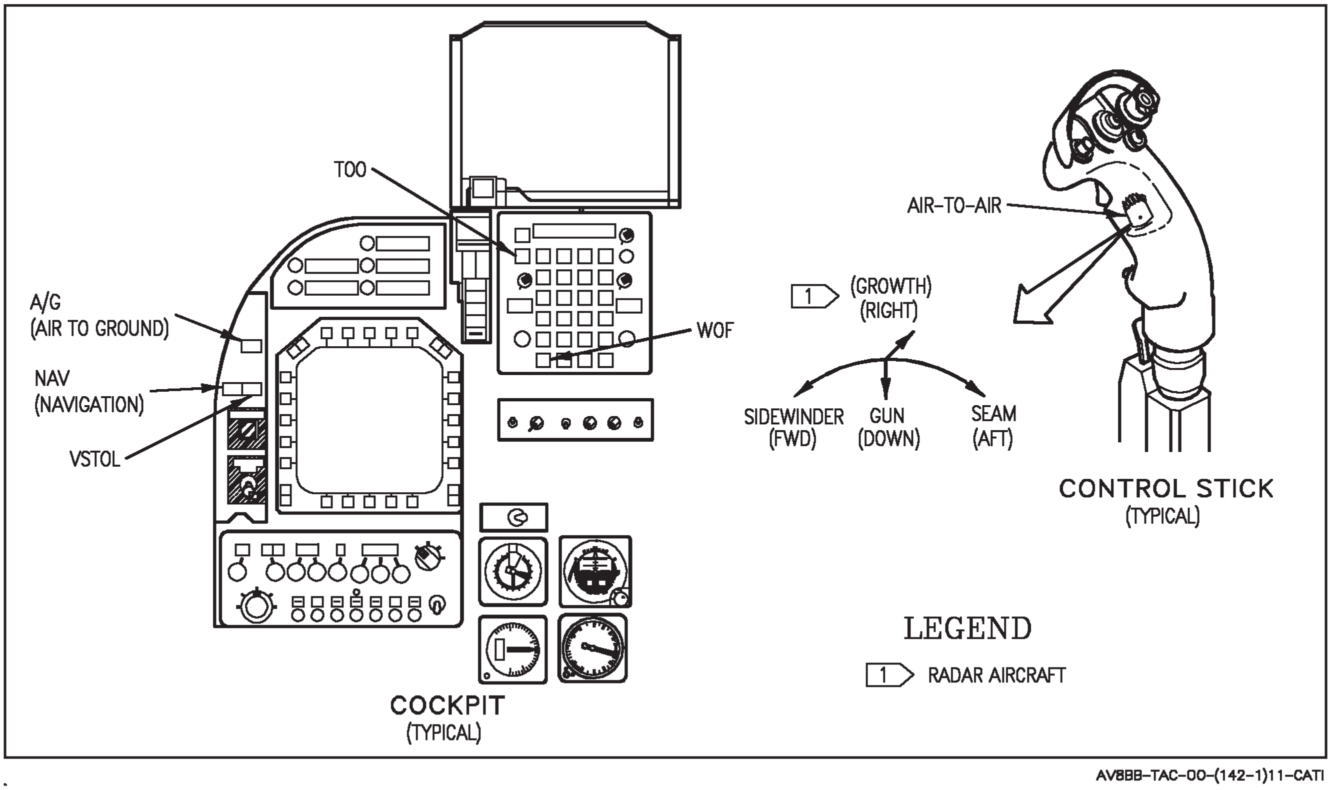


Figure 1-184. Master Mode Selection

In the A/G master mode, the pilot is provided with six A/G delivery modes, several methods of target designation, and a weapon delivery program for each of up to four weapon types loaded on the aircraft plus the fuselage gun. Aiming references are provided for the delivery of bombs, launching rockets, and firing guns. An AGM (air-to-ground missile) delivery mode is also provided.

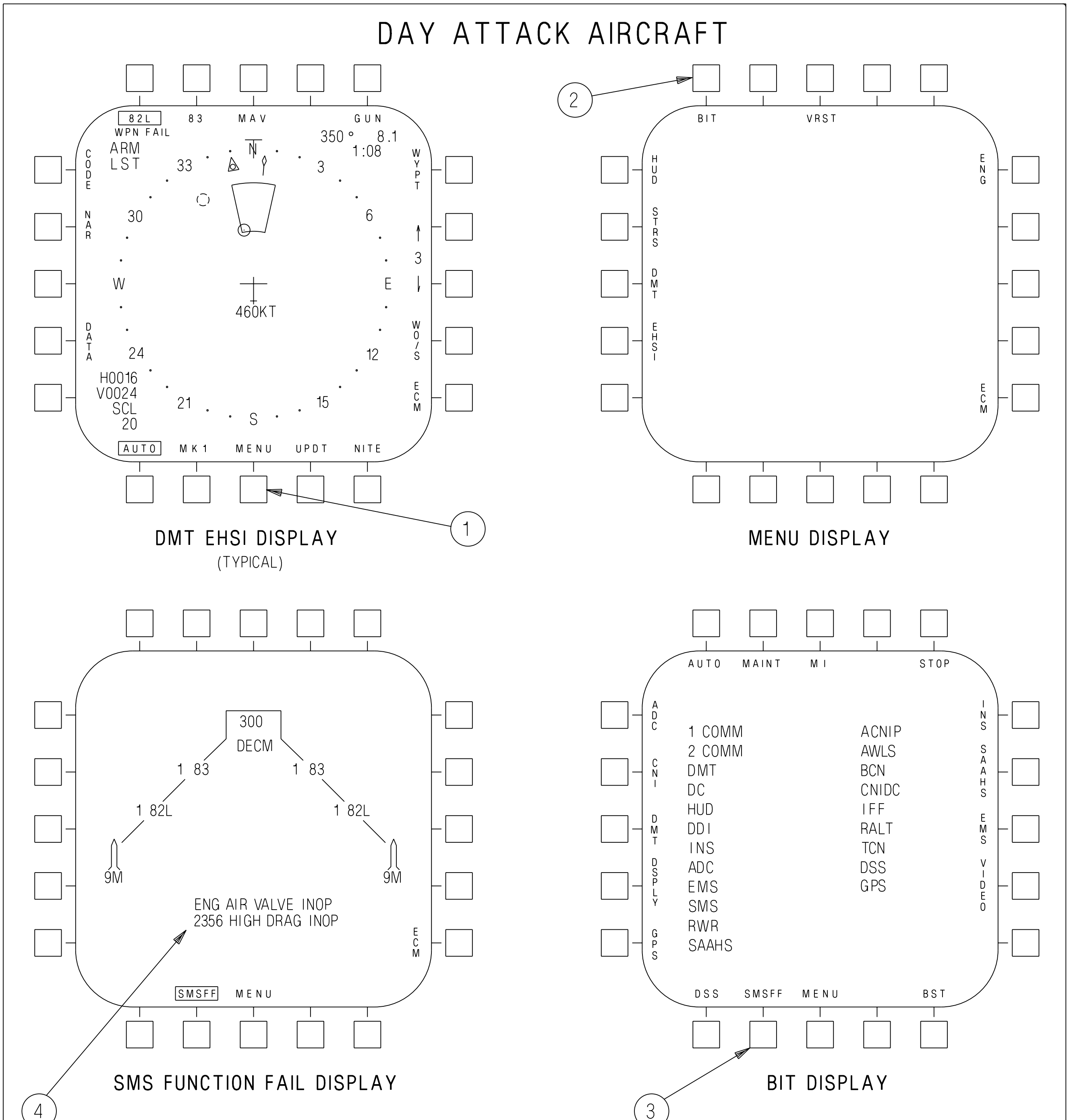
1.14.3.2 A/A Master Mode. The A/A master mode is automatically entered by selecting an air-to-air weapon via the A/A weapon select switch on the control stick. This switch is a momentary switch selecting the Sidewinder boresight mode (SW) when pushed forward, Sidewinder expanded acquisition mode (SEAM) when pushed aft, A/A gun when pressed down, and returning to a neutral position when released. Selecting one of these positions enables the A/A weapon for firing (with master ARM selected), commands the MC to compute and display associated A/A aiming symbology, and turns on the HUD video recorder.

1.14.4 Built-In Test (BIT)

1.14.4.1 In-Flight Failure Reporting. The BIT mechanization for SMS fault reporting displays a flashing WPN FAIL legend on the DDI above the ARM/SAFE legend when an SMS function failure is detected. The WPN FAIL legend can be displayed, in A/A or A/G mode, on any DDI display for which the weapon select options are present (i.e., stores display, Maverick display, EHSI, DMT, and RWR displays). The WPN FAIL legend will continue to flash until the pilot selects the SMSFF (SMS function fail) option from the BIT display.

Selecting the SMSFF option boxes the SMSFF legend and causes the wing plan form to be displayed with the current weapon loading. See Figure 1-185.

Below the plan form, the stores station number (if applicable) and the type of SMS function failure is displayed. For example, the legend 2356 HIGH DRAG INOP indicates that the high



1. SELECT MENU OPTION WHEN WPN FAIL LEGEND FLASHES.
2. SELECT BIT OPTION FROM MENU DISPLAY.
3. SELECT SMSFF OPTION FROM BIT DISPLAY.
4. UP TO FIVE FAILURES MAY BE DISPLAYED WITHOUT REGARD TO SEQUENCE.

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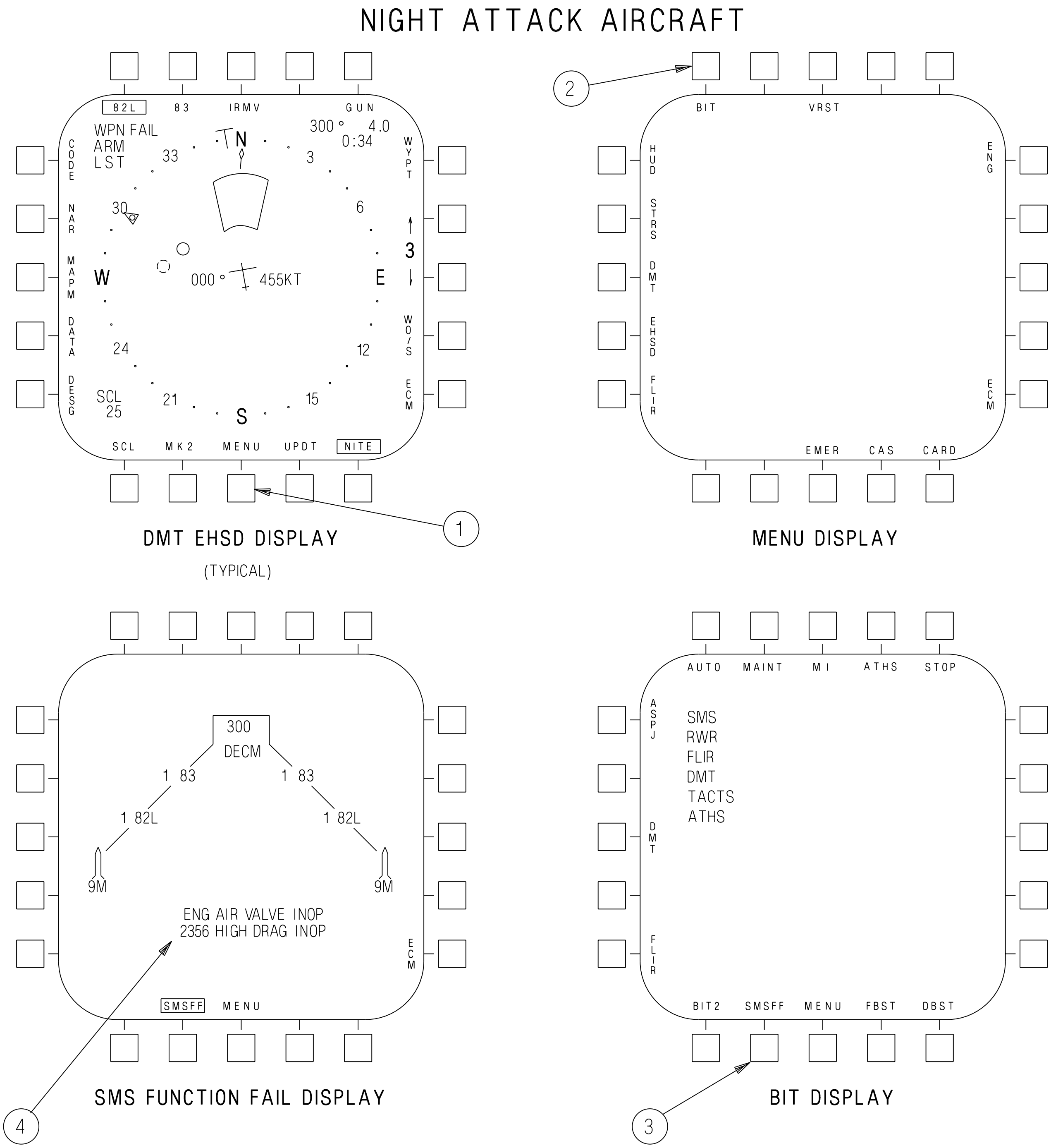
Figure 1-185. SMS Function Fail Option Selection (Sheet 1 of 3)



1. SELECT MENU OPTION WHEN WPN FAIL LEGEND FLASHES.
2. SELECT BIT OPTION FROM MENU DISPLAY.
3. SELECT SMSFF OPTION FROM BIT DISPLAY.
4. UP TO FIVE FAILURES MAY BE DISPLAYED WITHOUT REGARD TO SEQUENCE.

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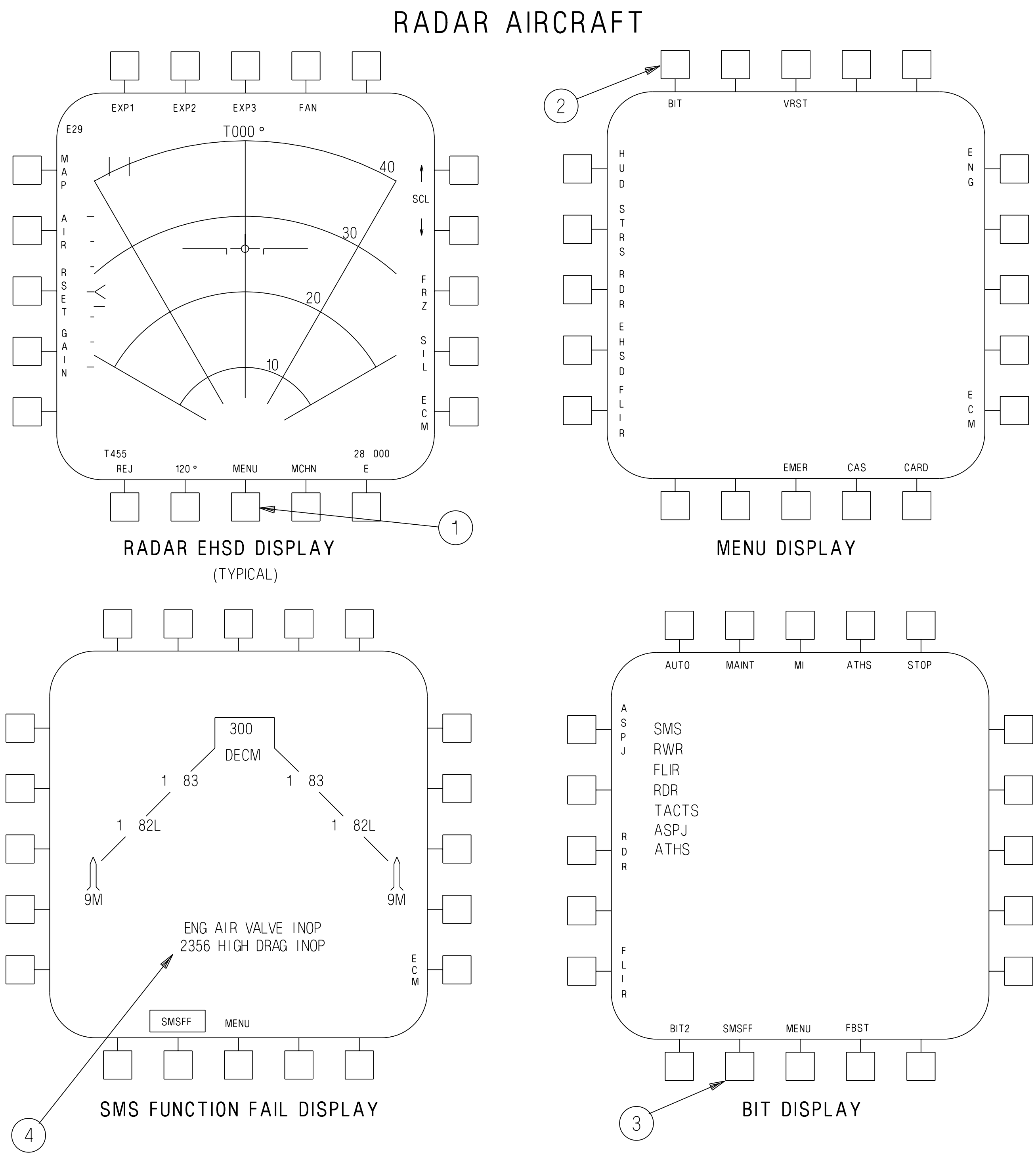
Figure 1-185. SMS Function Fail Option Selection (Sheet 2 of 3)



1. SELECT MENU OPTION WHEN WPN FAIL LEGEND FLASHES.
2. SELECT BIT OPTION FROM MENU DISPLAY.
3. SELECT SMSFF OPTION FROM BIT DISPLAY.
4. UP TO FIVE FAILURES MAY BE DISPLAYED WITHOUT REGARD TO SEQUENCE.

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Figure 1-185. SMS Function Fail Option Selection (Sheet 3 of 3) drag option for bombs on stations 2, 3, 5, and 6 is inoperative.

SMS function failures are reported for master operational modes, A/G weapon delivery modes, bombs, fuselage gun, Sidewinder missiles, master arm, ALE-39 flare/chaff/jammer dispenser, and stores jettison. See Figure 1-186 for a complete list of SMS to MC failures reported.

Deselecting the SMSFF option unboxes the legend and returns the DDI to the BIT display. SMSFF may also be deselected by selecting MENU or ECM. The WPN FAIL legend will not reappear until another SMS function failure occurs. All reported failures will be listed on the SMSFF display in the order of their occurrence.

Although fuselage gun failures are not an SMS function failure, they are reported by the BIT mechanization. SMS fault reporting is done to prevent the SMS of not reporting NOT CLEAR when armament bus power is lost or the stores display is deselected. The WPN FAIL legend flashes when fuselage gun not clear is detected and the MC displays a GUN NOT CLEAR legend on the DDI when the SMSFF option is selected. On Day and Night Attack aircraft, three failure indications can be displayed under the boxed GUN legend on the DDI, NOT CLEAR, MISFIRING and LIMITED.

CAUTION

When a flashing WPN FAIL legend appears on the DDI, the SMSFF option should be selected. If the SMSFF display indicates WEAPON PROGRAM FAIL for all pylon stations, the master arm switch should remain in the OFF (SAFE) position. With a WPN FAIL indication, selection of master ARM may cause inadvertent release of stores. If any JETTISON FAIL indication is displayed, external stores may be jettisoned with weight-off-wheels (i.e., upon takeoff).

SMS FUNCTION FAIL CUE SUMMARY (WPN FAIL DISPLAYED FLASHING)		
ITEM	DDI DISPLAY INDICATION (SMSFF OPTION SELECTED)	
	STORES STATIONS REPORTED	FUNCTION FAILURE LEGEND
Master operational modes (NAV, VSTOL, A/G, A/A)	Not applicable	MASTER MODE LIGHT
A/G Weapon delivery modes	Not applicable 2, 3, 5, and/or 6 1, 2, 3, 4, 5, 6, and/or 7 1, 2, 3, 4, 5, 6, and/or 7 1, 2, 3, 4, 5, 6, and/or 7	CIP/AUT MODES INOP AGM MODE INOP DSL MODE INOP DIR MODE INOP DSL 1 MODE INOP
Weapon programming	1, 2, 3, 4, 5, 6, and/or 7	WEAPON PROGRAM FAIL
Bombs	Not applicable 1, 2, 3, 4, 5, 6, and/or 7	ELEC FUZING INOP HIGH DRAG INOP
Fuselage gun	Not applicable Not applicable Not applicable Not applicable Not applicable Not applicable Not applicable Not applicable Not applicable	FUS GUN NOT CLEAR ENG AIR VALVE INOP FUSELAGE GUN INOP FUS GUN NORM INOP FUS GUN B/U INOP FUS GUN FIRE ON FUS GUN SELECT ON 1 1-20 RND BURST ONLY 1 LIMITED-20 RND BRSTS
Sidewinder	1, 2, 6, and/or 7 Not applicable Not applicable	SIDEWINDER MODE INOP SEAM MODE INOP SIDEWINDER B/U INOP
Master arm	Not applicable Not applicable	MASTER ARM BUS ON MASTER ARM FUS FAIL
ALE-39	Not applicable Not applicable Not applicable	ALE-39 NORM INOP ALE-39 RWR INOP ALE-39 B/U INOP
Stores jettison	Not applicable 1, 2, 3, 4, 5, 6, and/or 7 Not applicable Not applicable	SELECT JETT ON SELECT JETT INOP EMER JETT FAILED ON EMER JETT INOP
LEGEND: 1 Day and Night Attack aircraft		

Figure 1-186. SMS to MC Failures Reported

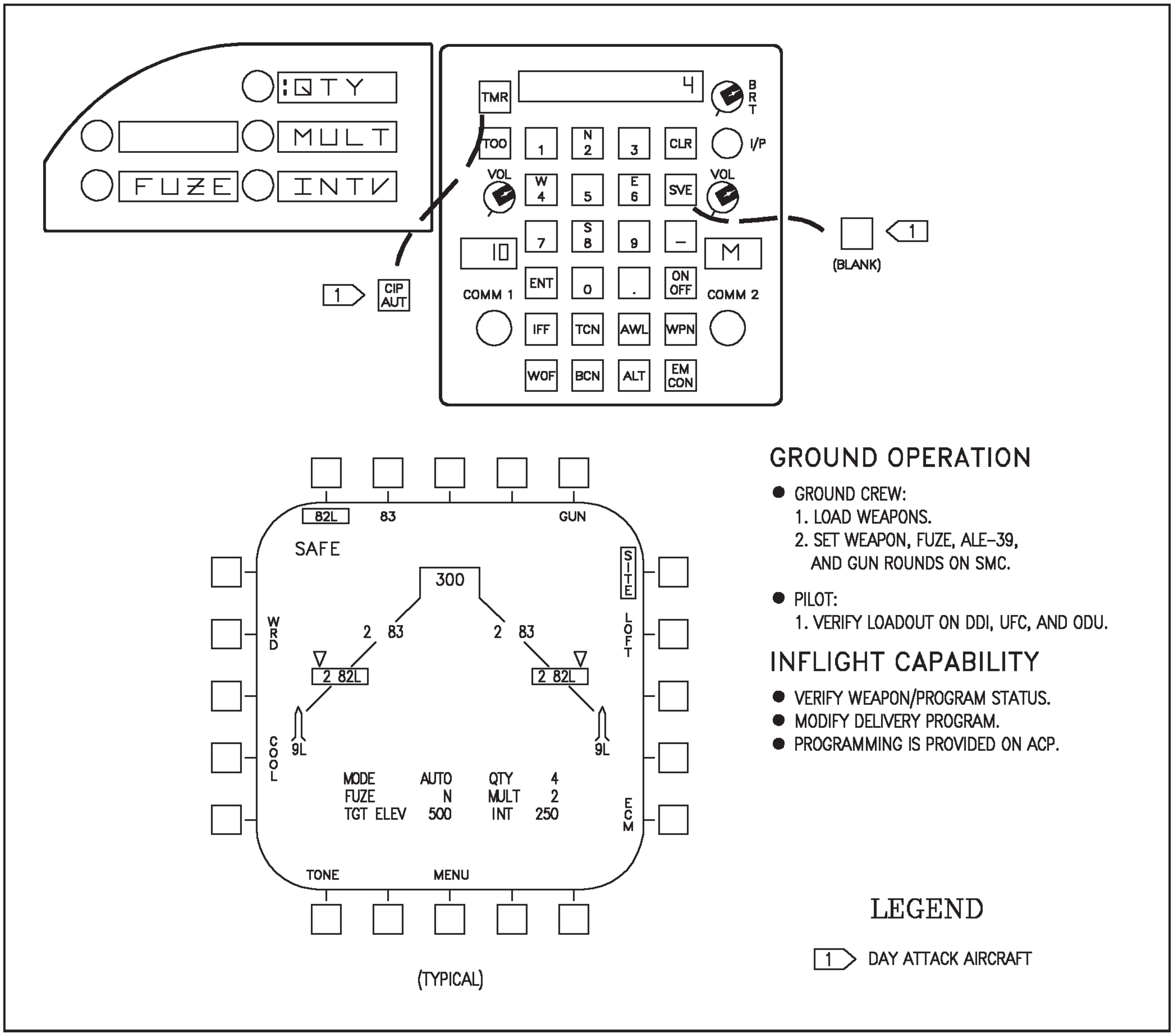

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Figure 1-187. Weapon Management

1.14.5 Preflight System Management

1.14.5.1 Stores Management Preflight Programming. Weapon loading is entered by the ordnance ground crew via the SMC loadout panel in the main wheelwell. As shown in Figure 1-187, the pilot can verify the weapon inventory from the crew station via the stores display on the DDI. Weapon programming may use programs loaded via the data storage set or the pilot can select and program weapon delivery parameters using either the UFCS or the armament control panel (ACP).

Prior to flight the ground crewman enters weapon loading data into the SMC. A numerical code for the weapon/store type and nose/tail fuzing is entered for each weapon station. For non-fuzed weapons (rocket pods, and SUU-25/F dispensers), the same switches used for fuze code entries are used to enter quantity at each station. Fuselage gun rounds and ALE-39 dispenser loading are entered separately. Refer to Chapter 3 for a complete list of codes and a complete description of the SMC loadout panel.

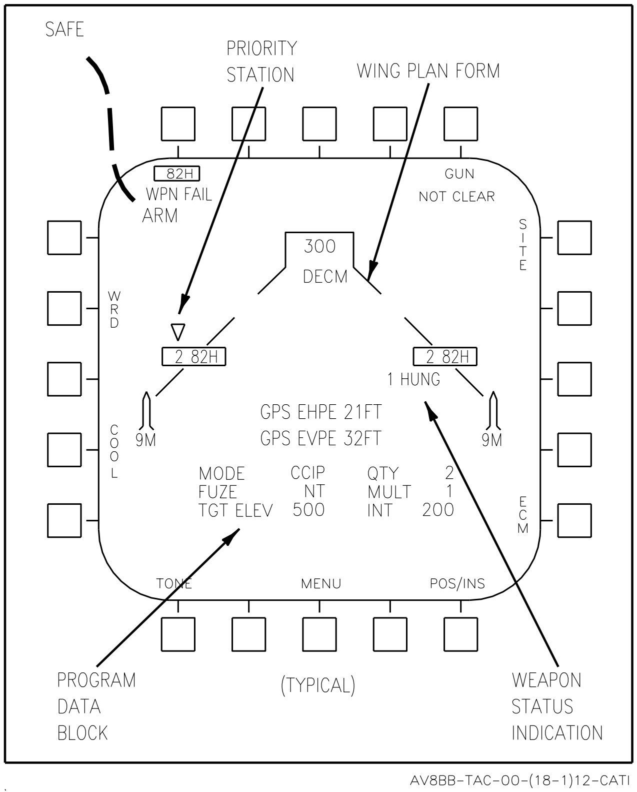


Figure 1-188. Stores Display

1.14.5.2 Stores Display. The stores display called up by actuating the STRS pushbutton on the DDI presents the type, number, and status of all weapons loaded on the aircraft. See Figure 1-188. It also presents the weapon delivery program data which is programmed by the pilot via the UFC and ODU or the ACP.

1.14.5.2.1 Wing Form Display. The weapon load entered on the weapon loadout panel by maintenance personnel appears on the stores display wing form as alphanumeric legends.

Figure 1-188 shows Sidewinder AIM-9M (9M) missiles loaded on outboard wing pylon stations 1 and 7, two Mk 82 high drag (82H) weapons on intermediate wing pylon station 2, two Mk 82 high drag (82H) weapons on intermediate wing pylon station 6, and a defensive electronics countermeasures pod (DECM) on centerline station 4. The number of rounds remaining in the 25 mm fuselage gun is denoted by the numeral 300 at the top center of the wing form display. The numerals preceding the other weapon legends denote the number of weapons loaded on that station. In the case of a rocket pod with the launcher switch set to SINGLE (for example 61S), the numerical load count denotes the number of rockets remaining in the pods on that station. Conversely, if the pod(s) is set to RIPPLE (61R), the numerical count denotes the number of pods on that station. For dispensers such as the SUU-25/F, the numerical load count denotes the number of flares or sonobuoys remaining in the dispensers on that station.

If the SMC identifies a fault which it cannot resolve (indicated by four asterisks), the weapon loaded on that station will not be selectable. However, if the fault is resolvable, the SMC will display the actual weapon loading if the weapon has ident capability. If the weapon does not have ident capability, the SMC will display the type entered on the loadout panel.

1.14.5.2.2 SAFE/ARM Indication. A SAFE legend appears in the upper left corner of the DDI stores display when the master arm switch is OFF. Placing the master arm switch to ARM enables weapon release/launch/firing and the SAFE legend on the DDI is replaced by an ARM legend. (This legend also appears on the A/G EHSI and DMT displays).

1.14.5.2.3 Weapon Release Station Status and Priority Stations. The stations from which the selected weapons will be released with the next push of the bomb pickle button are denoted by a box around the wing form weapon load legend. The inverted triangle above the boxed weapon load legend denotes the priority station from which the first release will be made. In the case of a multiple release, more than one inverted triangle is displayed to denote all the stations from which the first release will be made. A HUNG legend, as shown beneath the weapon load indication on station 6 appears when release of a weapon from the station has been attempted and the store is sensed as being still onboard. See Figure 1-188. A count of both hung and not hung weapons is displayed for the parent rack and ITER carriage. The SMC will again send release pulses to HUNG stations after all other weapons of the same store code have been released. The legend ASYM will be displayed where the HUNG legend is displayed, if an asymmetrical load condition exist. When an asymmetrical load condition exists, the bomb(s) cannot be dropped; therefore, no weapon load will be displayed at that station.

1.14.5.2.4 Program Data Block. The program data block appears when a bomb, rocket pod, A/G gun (with no other weapon selected), or dispenser is selected with one of the weapon select pushbuttons. The list contains the mode of delivery, fuzing (bombs, AGM), target elevation (TGT ELEV; waypoint, mark, or waypoint/mark offset elevation), and the delivery parameters used for computing the release points consisting of quantity (QTY), multiple (MULT), and interval (INT). Delivery mode and target elevation are also displayed if the fuselage gun is selected unless it is a hot gun. In that case, the program for the primary weapon is displayed. Exclusive selection of fuselage gun, or rockets displays the maximum (MAX) and minimum (MIN) range cue setting programmed for the A/G gun/rocket reticle below the target elevation.

1.14.5.2.5 NOT CLEAR Legend. A NOT CLEAR appears below the GUN indication when the system determines that unfired rounds have not been successfully reversed from the 25 mm fuselage gun breech. LIMITED and MISFIRING are additional failure indications that appear under the boxed GUN legend on the DDI. MISFIRING is displayed if the gun senses a misfiring barrel (i.e., barrel warpage, etc.) Under this condition only one 20 round burst remains. Subsequent actuation of the trigger will not fire the gun. LIMITED is displayed if the gun detects a projectile sensor failure during the gun clearing cycle. Under this condition firing is limited to 20 round bursts for each actuation of the trigger switch.

1.14.5.2.6 WPN FAIL Legend. A flashing WPN FAIL legend appears above the ARM/SAFE legend when an SMS function failure is detected or if unfired rounds have not been successfully reversed from the 25 mm fuselage gun breech. The WPN FAIL legend continues to flash until the pilot selects the SMSFF (SMS function fail) option from the BIT display. Once the SMSFF option is selected the WPN FAIL legend is removed until another SMS function failure occurs. The WPN FAIL legend appears on any display on which the A/G weapon options appear.

1.14.5.3 Stores Display Controls. The DDI contains 20 pushbuttons whose functions vary with the mode selected from the MENU. Figure 1-189 shows three store displays with most of the pushbutton control options that can be presented. The function of any particular pushbutton is indicated by the adjacent legend. For example, selecting the STRS option from the MENU causes the menu display legends to disappear and new legends to appear indicating different pushbutton functions.

1.14.5.3.1 Weapon Select Pushbuttons. The top row of option pushbuttons on the stores display selects the desired weapon type for delivery programming and weapon delivery. The wing form in the top display of Figure 1-189 shows a load of three different types of A/G weapons: Mk 82 bombs (82H), two Maverick missiles (MAV on Day Attack aircraft) (IRMV on Night Attack/ Radar aircraft), and a loaded fuselage gun (300 rounds). Weapons with the in-flight selectable option are initially depicted on the wing form as a weapon with two drag option (e.g., 82HL) as shown in the bottom left display of Figure 1-189. Actuating the desired weapon select pushbutton selects the applicable delivery program and drag option for that weapon and boxes the applicable weapon legend. Day Attack aircraft utilize a single pushbutton for both high and low drag options. Consecutive activations of the 82HL pushbutton scrolls through 82L (boxed), 82H (boxed) then 82HL (unboxed). Night Attack/ Radar aircraft utilize two pushbuttons, the first selects 82L and the second selects 82H. The pushbutton legend of the selected weapon is boxed as is the selected option on the wing form. The display at the top of Figure 1-189 shows that the Mk 82 bomb with a high drag option (82H) has been selected.

The bottom left display in Figure 1-189 shows the selection of the fuselage gun (no other weapon selected). The delivery mode and target elevation are presented for a gun selection. The maximum and minimum range for the A/G gun

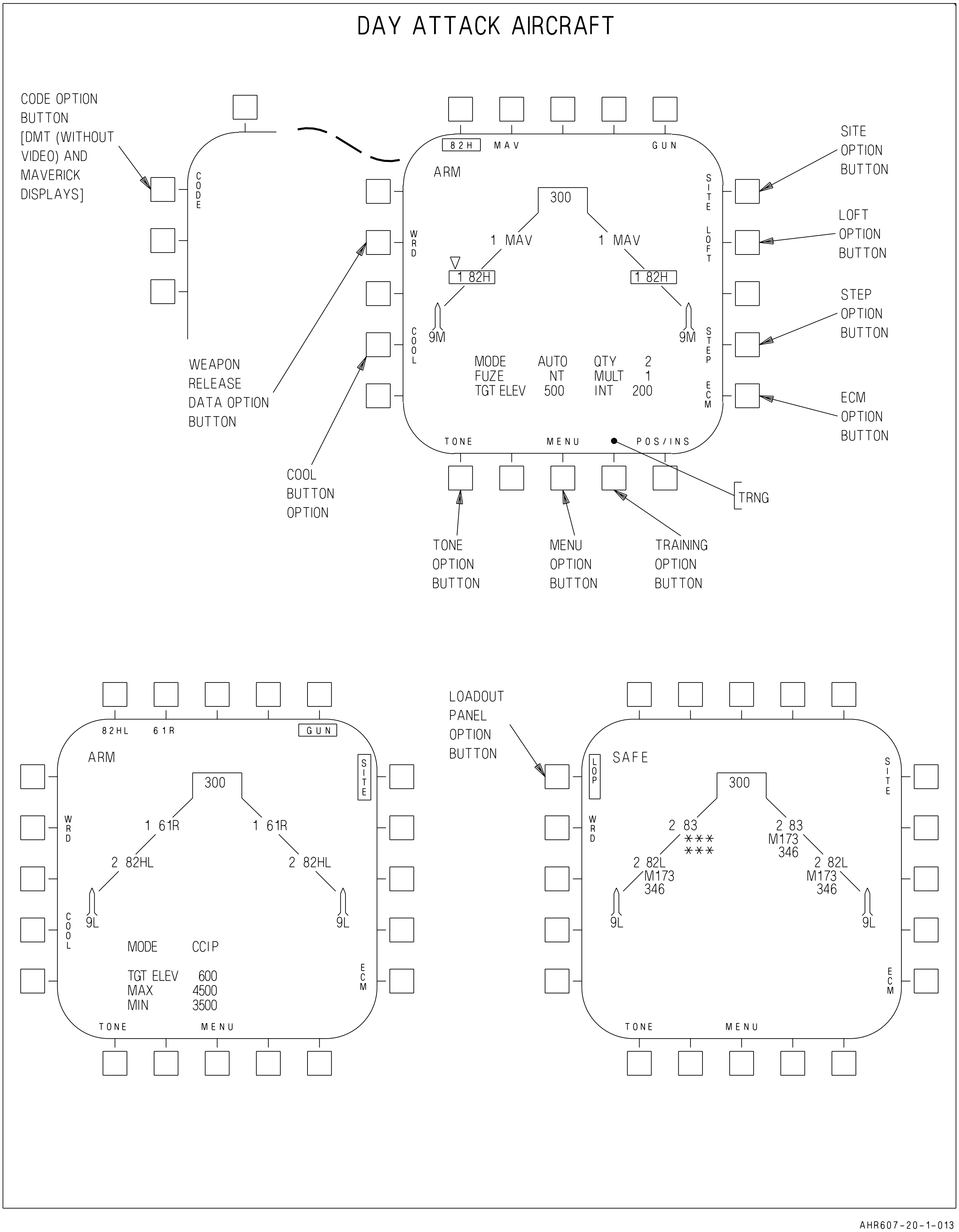


Figure 1-189. Stores Display Controls (Sheet 1 of 2)

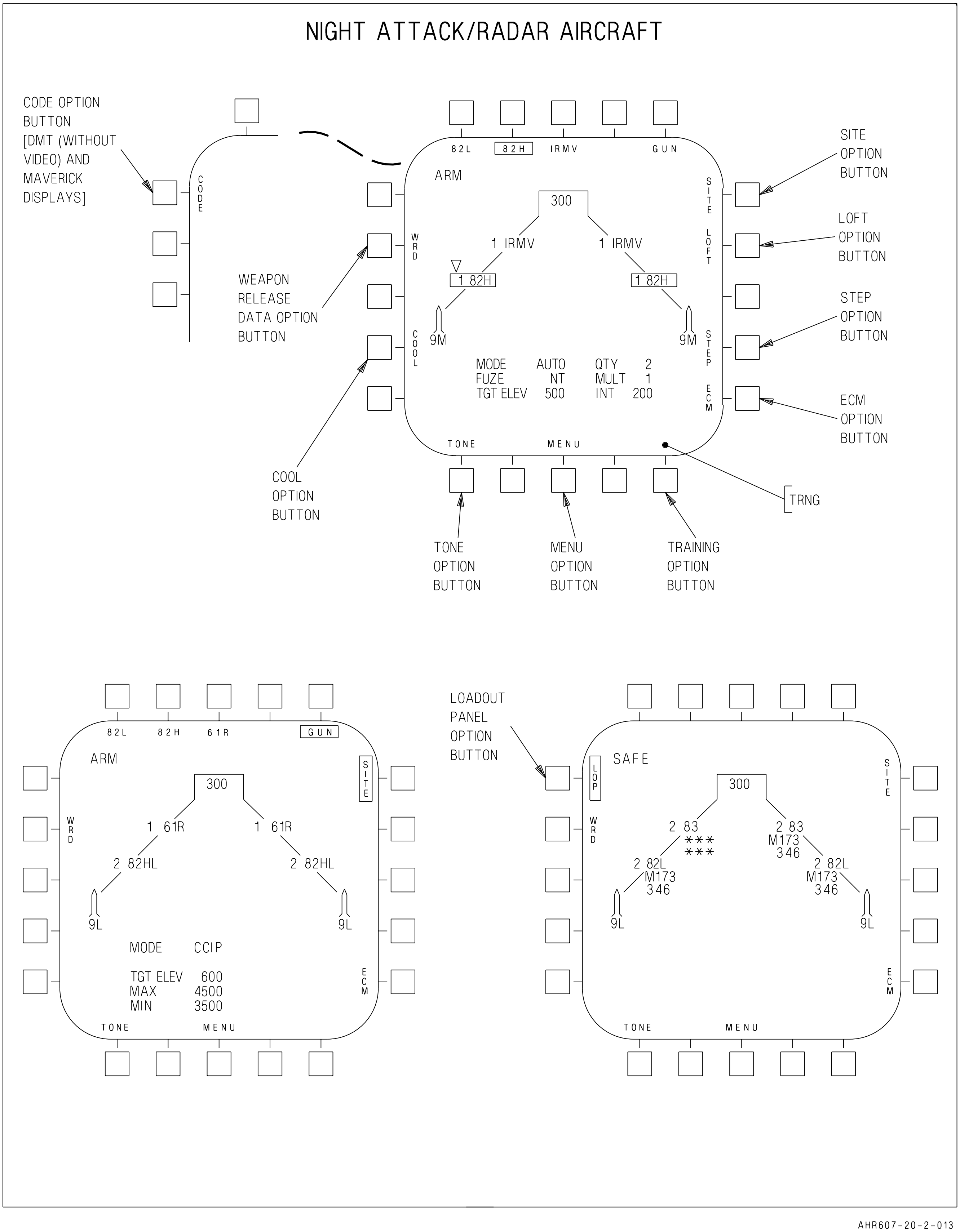


Figure 1-189. Stores Display Controls (Sheet 2 of 2)

reticle is displayed below the target elevation. Reactuation of the GUN weapon select pushbutton would result in no weapon selection.

The fuselage gun can be selected in conjunction with another A/G weapon to provide a “hot gun” capability while delivering another weapon. The hot gun is obtained by selecting the fuselage gun option (GUN) as well as selecting another primary A/G weapon. Gun firing can then be initiated with the trigger, and bomb release/ rocket launch can be initiated with the bomb pickle button. The hot gun is indicated on the HUD by display of a gun cross in addition to the attack symbology for the primary weapon. On the stores display, the primary weapon legend and gun legend are both boxed.

1.14.5.3.2 Site Option Pushbutton. The SITE option appears on the DDI whenever the stores display is selected. Actuating the site option pushbutton boxes the SITE legend. This brings up the SITE option on the ODU. The last entered depression angle is displayed on the scratch pad and the UFC is enabled for entry of a new depression angle. If the SITE option is cued, the roll stabilized sight/carets appear on the HUD in the A/G master mode. See Figure 1-190. If not cued, the sight is removed from the HUD. The SITE option is automatically deselected when transitioning from weight-off-wheels to weight-on-wheels.

1.14.5.3.3 Loft Option Pushbutton. A loft mode is available when an A/G weapon is selected and the delivery mode is AUTO. In the top half of Figure 1-189 actuation of the LOFT option boxes the LOFT legend and initiates the loft delivery mode displays and logic. Successive activations of the pushbutton alternate between AUTO and LOFT delivery modes.

1.14.5.3.4 Step Option Pushbutton. The STEP option is provided when the weapon selected is available for release from more than one station if the selected weapon is not loaded on an ITER. The STEP option is not available if an ITER is loaded with the selected weapon. Each successive actuation of the step option pushbutton causes the SMCS to change the priority to the next station in the normal station priority sequence which contains the selected weapon. In the top half of Figure 1-189 actuation of the step option pushbutton would result in the inverted triangle symbol shifting from station 2 to station 6. A second actuation of the step option pushbutton would result in reselection of station 2 since only two stations are loaded with Mk 82 bombs.

1.14.5.3.5 ECM Option Pushbutton. Actuating the ECM option pushbutton selects the ECM display on the DDI and boxes the ECM legend. Refer to NWP 3-22.5-AV8B, Vol. III, Chapter 6 for information on the ECM display. Reactuation of the ECM option pushbutton results in reselection of the former display and the ECM legend is unboxed.

1.14.5.3.6 Training Option Pushbutton. The TRNG (training) option appears when no weapon/store is selected and the fuselage gun or one or more stations are available for training. The fuselage gun is available for training if the rounds count is zero or the gun is not installed. A station is available for training if it contains no weapons but has a valid weapon code dialed in the SMC. This can occur either after depleting the weapon load on a station during a mission, or by having maintenance personnel insert weapon loadout codes in the SMC but never actually loading any weapon (hooks open) on the station.

Actuating the training option pushbutton enables the pilot to perform an A/G training mission with a simulated weapon load. When the pushbutton is actuated, the wing form on the DDI stores display reinitializes as follows:

1. If the fuselage gun is available for training, the rounds count is set to 300.

2. If a station is available for training, its weapon count (QTY) is set to the maximum number loaded in the loadout panel for that station.

3. All non-weapon stores (DECM pod, fuel tanks, and external baggage containers) are displayed on the wing form.

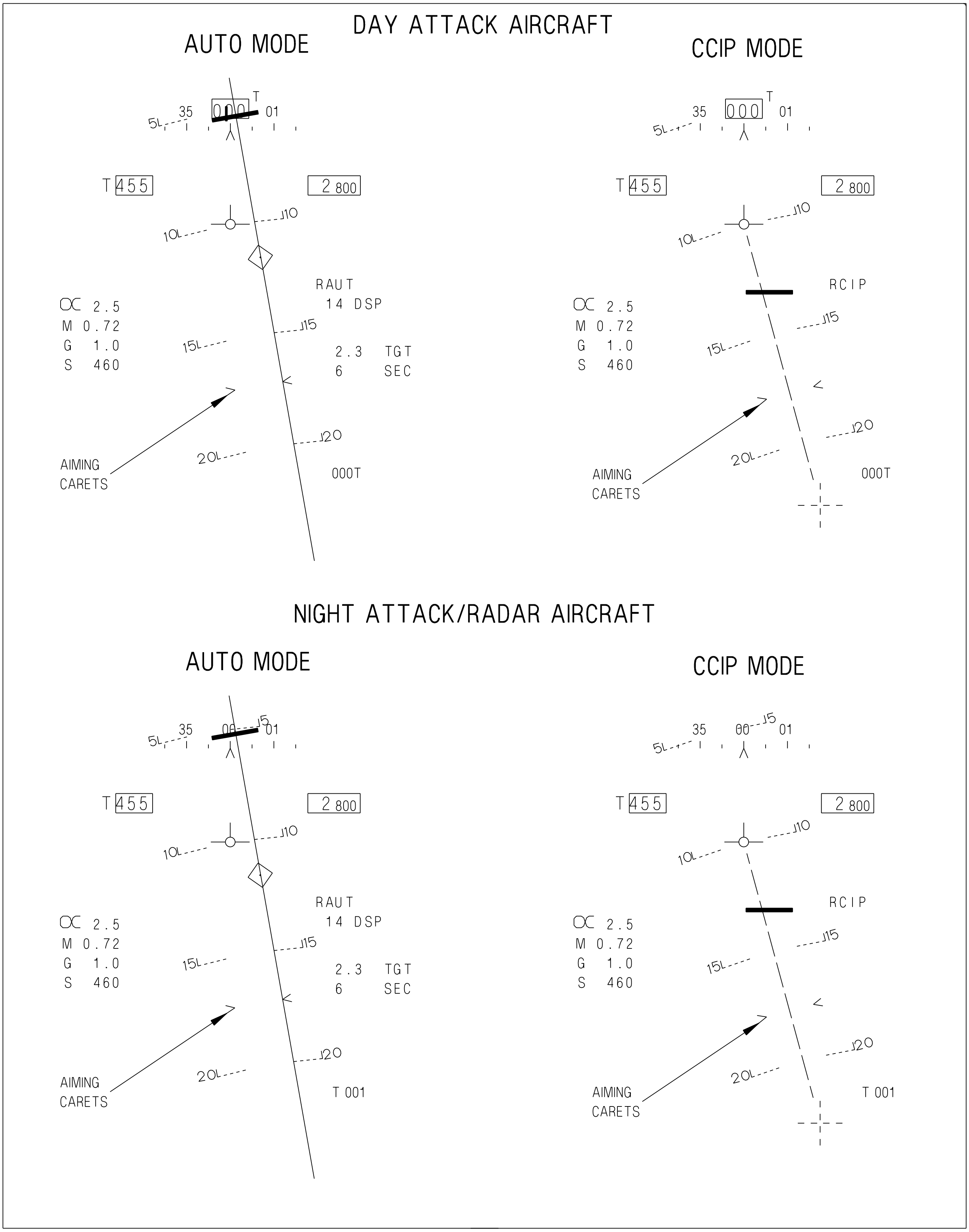


Figure 1-190. Roll Stabilized Sight Carets

4. All stations not available for training are reported as empty.

The simulated weapon load can be released/launched/fired with full attack symbology and control functions as with a real weapon load. It can also be reinitialized as many times as desired by pressing the training option pushbutton. Normal procedures including master ARM selection must be followed to release/launch/fire the simulated load. The AUTO, CCIP, and DSL delivery modes are available, but the DIR delivery mode is inhibited.

Also, weapon selection using the A/A weapon select switch (SW, SEAM, or GUN) is disabled. To provide a safety factor, no release/launch/firing pulses are provided to the weapon stations. Simulated releases are, however, denoted on the stores display.

WARNING

External stores can be emergency or selective jettisoned with training mode selected.

1.14.5.3.7 Tone Option Pushbutton. Actuating the tone option pushbutton boxes the TONE legend and enables the COMM 1 and 2 ARC-182 receiver-transmitter to transmit a weapon release tone at weapon release (on selected channel(s)).

1.14.5.3.8 Cool Option Pushbutton. The COOL option is available whenever an AIM-9 weapon code is loaded into the SMC loadout panel. This option functions only with weight-off-wheels. The COOL option may be preselected (boxed) while on the deck, however cooling will not be provided to the sidewinder stations until weight-off-wheels is achieved.

1.14.5.3.9 Loadout Panel Option Pushbutton. The LOP (loadout panel) option appears when no weapon is selected and weight is on the wheels. Selecting the LOP option (boxed) causes the wing form to display loadout panel data. The nose and tail fuze codes are displayed below the loadout data for the stores station. If a fuzing fault exists, three asterisks are displayed in place of the fuze code. If applicable, fuze arming time is indicated next to the fuze legend. See Figure 1-191 for an explanation of the fuze legends.

Deselection of the LOP option displays the actual weapon load on the wing form. The LOP option gives the pilot, the opportunity to check the SMCS weapon loading against the actual aircraft weapon loadout after engine start.

LOP OPTION SELECTED ON STORES DISPLAY					
NOSE FUZE CODE ON SMS	FUZE LEGEND ON WING FORM	FUZE DESCRIPTION	TAIL FUZE CODE ON SMS	FUZE LEGEND ON WING FORM	FUZE DESCRIPTION
0	Not applicable	None	0	Not applicable	None
1 1	904 2	Not Authorized	1	11701	FMU-139/U series
1 2	904 6	Not Authorized	2		Not Authorized
2 3	904 10	M904E4	3	42	Mk 42
4	339	Mk 339 Mods	4	344	Mk 344 Mods
5	13	Mk 13 Mod 0	5	13	Mk 13 Mod 0
6	***	Not assigned	6	***	Not assigned
3 7	140	FMU-140	7	346	Mk 346 Mod 0
8	43E	Mk 43 Mod 0 (Electric)	8	376	Mk 376 Mod 0
9	43M	Mk 43 Mod 0 (Mechanical)	9		Not Authorized
10	32	Mk32	10	***	Not assigned
11	***	Not assigned	11	***	Not assigned
12	***	Not assigned	12	***	Not assigned
13	***	Not assigned	13	***	Not assigned
14	***	Not assigned	14	***	Not assigned
15	MECH	Mechanical	15	MECH	Mechanical

LEGEND:

1 Although the LOP shows a legend of ″904 2″ or ″904 6″, these nose fuze codes are not authorized.

2 The LOP legend shows ″904 10″ regardless of the actual fuze arm time set on the M904E4 fuze.

3 Tail fuze codes used in conjunction with nose fuze code 7 designates altitude (HOF).

Figure 1-191. LOP Option Fuse Legends

1.14.5.3.10 Code Option Pushbutton. The CODE option appears on the DDI when either a DMT display (without video) or AGM-65E Laser Maverick missile display is selected. Actuating the code option pushbutton boxes the CODE legend and enables the UFC for code entry via the keyboard for 30 seconds. Completion of timing, or actuating the code option pushbutton unboxes the CODE legend and deselects the CODE option. The Laser Maverick display initializes with the code option boxed. The same code is used by the AGM-65E Laser Maverick and the LST. The code needs to be entered only once.

1.14.5.3.11 Weapon Release Data Option Pushbutton. Actuating the weapon release data (WRD) option pushbutton boxes the WRD legend and enables the weapon release data display. The weapon release data display shows the release data at pickle for a CCIP delivery and release data at the moment the release cue touches the velocity vector for an AUTO delivery. See Figure 1-192. The release data for ripple is calculated for the first bomb in the stick.

The values of the various parameters are shown as they were during the last weapon release. The speed values (aircraft airspeed and wind) are in knots, altitude is in feet MSL, flight path is in degrees, normal acceleration is in g's, time-of-fall is in seconds, steering error is in mils (AUTO mode only), and ranges are in feet. The X, Y, and Z parameters are defined as follows:

1. Range X - horizontal range in direction of flight
2. Range Y - cross range in direction of flight
3. Range Z - altitude (AGL) at release
4. Wind X - head/tail wind component
5. Wind Y - crosstrack wind component

Each subsequent release replaces the currently recorded data. Weapon release data is not stored in the A/A master mode, backup delivery modes (DSL, DSL (1), DIRECT), or in a "hot gun" condition. Deselecting the weapon release data option unboxes the WRD legend and returns the display to the previous stores display.

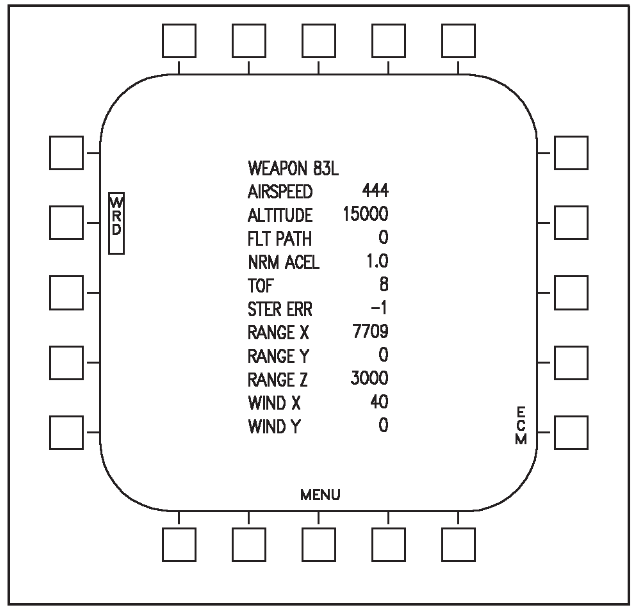


Figure 1-192. Weapon Release Data Display (Weapon Selected)

On Day/Night Attack aircraft, WRD data is automatically stored in the DSU for each weapon release. The DSU requires down loading following the flight to retrieve this data as it is not stored in a data file.

1.14.5.4 Armament Control Panel. The armament control panel (ACP) contains controls and indicators for the SMCS. See Figure 1-193. The panel has display windows that indicate the weapon program for the selected weapon. The programming can be done by the pilot via the adjacent control switches or the UFC and ODU. Regardless of which control is used to select the weapon program, it is displayed in the windows on the ACP and in the DDI stores display program block. The ACP windows contain a dash (–) for mode and fuzing and zero for other options when no weapon is selected. The dashes and zeros also appear when certain failures occur. In addition, the panel contains station select buttons, a switch for DSL(1) (manual) delivery selection, a Sidewinder IR coolant switch, and a selective jettison switch and jettison pushbutton. Refer to Chapter 2 for a description of the jettison functions.

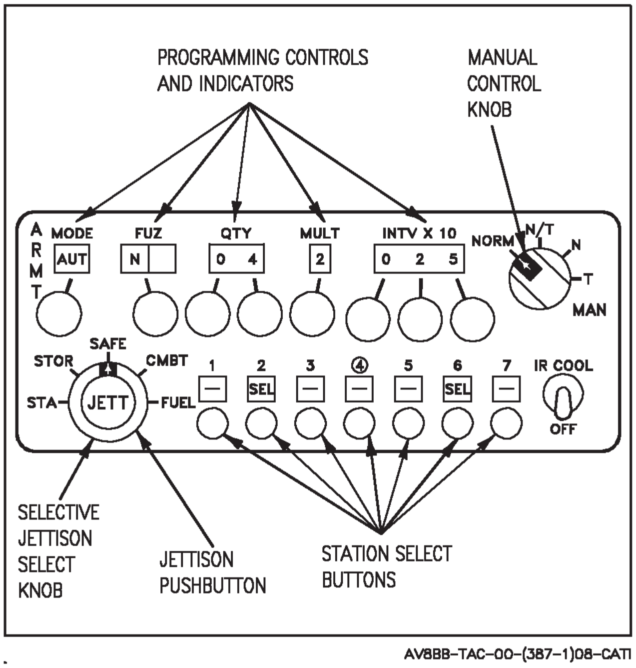


Figure 1-193. Armament Control Panel (Weapon Selected)

1.14.5.4.1 Mode Control. The mode control is a three-position switch with two momentary positions of UP and DOWN and a center OFF position. The control selects the weapon delivery mode: AUT (automatic), CIP (continuously computed impact point), DSL (depressed sight line), and DIR (direct). The window above the control displays the selected delivery mode. Momentarily placing the control UP advances the mode selection to the next acceptable mode for the selected weapon. Momentarily placing the control DOWN advances the mode selection in the reverse direction to the next acceptable mode. Only mode selections applicable to the selected weapon are available. AGM can be displayed in the mode window but not selected with the mode control. On Day Attack aircraft, AGM is displayed only after MAV (Maverick) or SA (Sidearm) has been selected on the DDI or a Maverick or Sidearm station select button has been selected on the ACP. On Night Attack aircraft AGM is displayed only after IRMV or LMAV has been selected on the DDI or a station carrying a Maverick missile is selected on the ACP. The DIR (direct) mode is available for selection only when no weapon or station is selected and the training mode is not enabled. The DIR mode is automatically selected when the SMC fails. The DIR mode can be programmed with backup delivery parameters for one type of bomb. The ACP selects and displays the backup program when the DIR mode is selected. If the ACP momentarily loses power or a backup program was not inserted, the pilot must enter weapon programming after the DIR mode is selected.

1.14.5.4.2 Fuzing Control. The fuzing control is also a three-position switch. The control selects the weapon fuzing options in the following order as they apply to the selected weapon and associated fuzes:

1. IN	9. ND1	17. TV2
2. D1	10. ND2	18. NT
3. D2	11. T	19. NTIN
4. V	12. TIN	20. NTD1
5. V1	13. TD1	21. NTD2
6. V2	14. TD2	22. PR
7. N	15. TV	23. OP
8. NIN	16. TV1	24. SAFE

The window above the control displays the selected fuzing option. Momentarily placing the control UP advances the fuzing option selection to the next acceptable fuzing option. Momentarily placing the control DOWN advances the fuzing option selection in the reverse direction to the next acceptable fuzing option. Only fuzing options applicable to the selected weapon are available. In some weapon cases, there may not be any fuzing options available for pilot selection. For example, even though fuzing is applicable to rockets, the fuzing is preset and rocket fuzing options are not presented to the pilot. In this case, a dash (–) is displayed in both fuzing option windows.

1.14.5.4.3 Quantity Control. The quantity control consists of two three-position switches. The controls select the quantity of weapons to be released during a sequence. The two windows above the controls display the selected quantity. A quantity greater than the number of the selected weapons aboard cannot be selected.

1.14.5.4.4 Multiple Control. The multiple control is also a three-position switch. The control selects the number of stations from which weapons will be simultaneously released in the sequence. The window above the control displays the selected multiple.

The multiple cannot be set to a number greater than the number of stations carrying the selected weapon or the quantity value, whichever is less. The SMC may override the multiple selection in some cases. However, the total number of weapons selected will eventually be released. For example, suppose quantity is set to 12 and multiple to 4. The SMC may have to drop the 12 weapons in a 2, 3, 4, 3 pattern in order to satisfy minimum release interval restrictions. The interval between the bombs will be automatically reduced to retain the same stick length providing minimum average safe interval requirements can still be met. If these requirements cannot be met, stick length will increase.

1.14.5.4.5 Interval Control. The interval control consists of three three-position switches. The controls select the release interval for a multiple release sequence (quantity greater than multiple). The interval selected represents the ground impact spacing in feet when operating in the AUT and CIP modes. In the DSL mode, the interval selected represents the weapon release interval in milliseconds. The selected interval is displayed in the three windows above the three control switches. The number is actually multiplied by 10 as indicated by the ×10 label to obtain the correct interval. In the AUT, CIP, and DSL modes, the SMC may override the pilot selected interval without changing the release pattern. The override function operates automatically to satisfy minimum release interval restrictions even though an average safe interval was selected. If the SMC recognizes that an unsafe interval exists between two bombs on ITERs, the interval between the two bombs will be increased to the minimum authorized.

1.14.5.4.6 Manual Control Knob. The manual (MAN) control knob places the SMCS in the DSL(1) (manual) delivery mode and selects backup arming. It enables the pilot to select mechanical fuze arming for bombs selected with the station select buttons. Positions of NORM (normal), N/T (nose/tail), N (nose), and T (tail) are provided. The knob is normally left in NORM. Placing the knob to N/T, N, or T causes the SMCS to enter the DSL(1) (manual) mode which overrides the computed release modes. An electrical signal is sent to a solenoid at all stations selected with the station select buttons and mechanically arms the applicable fuzes (nose/tail, nose, or tail) at weapon release. No electrical fuzing is available in the DSL(1) mode. One release pulse is applied to each selected station for each bomb pickle button actuation. If the weapons are aboard an ITER, successive actuations of the bomb pickle button step the release pulses through the ITER stations, but only one weapon per selected station is released with each actuation.

1.14.5.4.7 Station Select Buttons. Seven station select buttons are provided along the bottom of the ACP, one for each armament station. Indicator windows above the buttons indicate station selection (SEL) and deselection (−). The buttons enable the pilot to select weapons for release in all modes.

When in the AUT, CIP, or DSL modes, selecting a station on the ACP causes that type of weapon to be selected, but not necessarily that station. Station priority for weapon release is determined by the SMCS. Actuating a station select button for a station not currently selected and carrying a different weapon than the one presently selected causes the SMCS to deselect the currently selected weapon and select the type of weapon that is aboard the station just selected. Actuating a station selector for a station that is carrying the same type of weapon as that presently selected is ignored by the SMCS. Actuating a station selector for a station that is currently selected causes the SMCS to deselect the currently selected weapon.

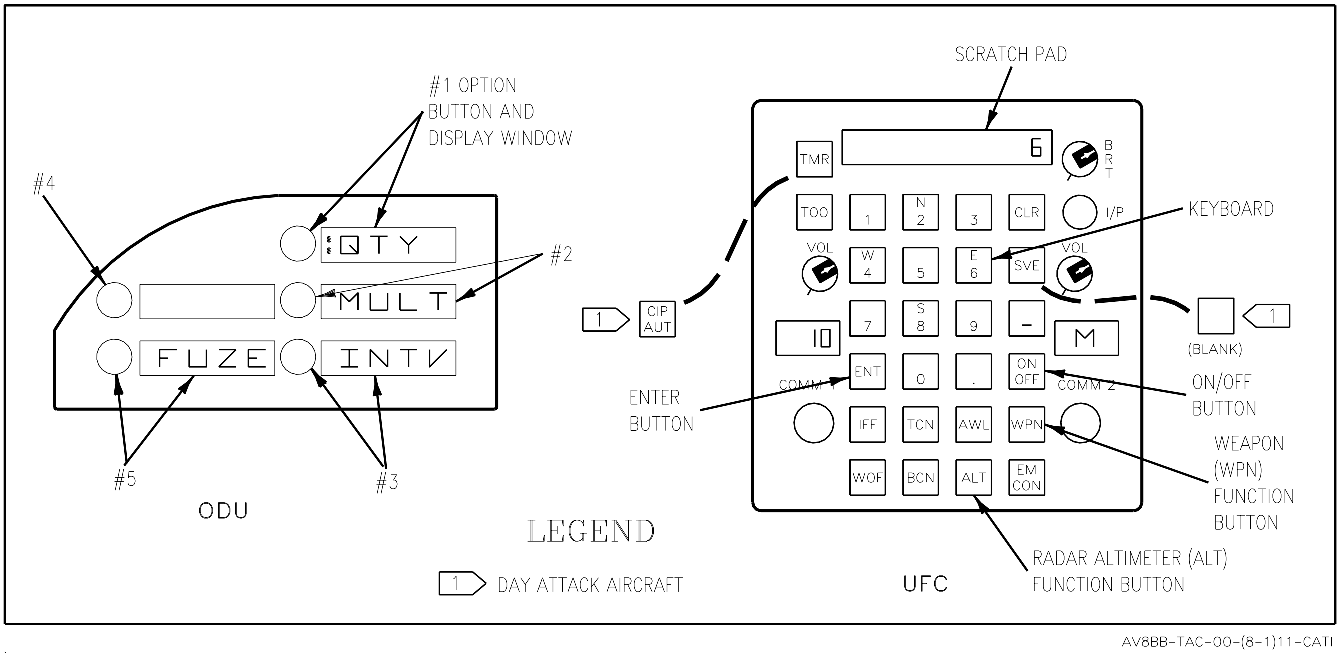


Figure 1-194. Option Display Unit/Upfront Control Stores Functions (Weapon Selected)

In AGM mode, actuating a station select button of another station with the same type of weapon aboard will deselect the original station and select the new station as the priority station. Actuating a station select button of an already selected station will deselect the station and exit the AGM delivery mode. On day attack aircraft with a Maverick selected, actuating a station select button of a Sidearm station will deselect the Maverick and select the Sidearm with the selected station being the priority station. Likewise, selecting a Maverick station with a Sidearm selected will deselect the Sidearm and select the Maverick with the selected station becoming the priority station.

In the DIR and DSL(1) (manual) delivery modes and in the selective jettison modes of STOR and STA, selection of a station causes a SEL legend to appear in the adjacent window. The stations selected are the priority stations and weapons will be released from the pilot selected stations instead of the SMCS determined station priority. Actuating a station selector for a previously selected station deselects that station.

1.14.5.4.8 IR COOL Switch. The IR COOL switch is a two position switch with positions IR COOL and OFF. The switch enables the pilot to manually apply IR detector cooling to the sidewinder seekers for pre-flight operation or in backup mode in case of a stores management computer failure. Positioning the switch to IR COOL applies cooling to all sidewinder stations with a sidewinder or sidearm loaded. Positioning the switch to OFF deselects IR cooling. The IR COOL switch must be returned to the OFF position prior to flight.

On aircraft with Sidearms loaded the IR COOL switch should not be positioned to IR COOL except for preflight check of sidewinders. In the IR COOL position the seeker hardware in the sidearm will uncage and the seeker will free-float, however, the movement will terminate at the gimbal stops. Excessive and uncontrolled contact with the gimbal stop can cause seeker damage.

1.14.5.5 UFC and ODU. The UFC and ODU contain controls that are applicable to the stores management programming. See Figure 1-194. The keyboard and scratch pad are employed in conjunction with the ODU for weapon delivery programming. In addition, the following controls are directly applicable to weapon programming.

1.14.5.5.1 Weapon Function Select Pushbutton. After a weapon is selected, the WPN (weapon) function select pushbutton is actuated to enable the UFC and ODU for weapon delivery parameter insertion. The ODU always initializes with the quantity option (if quantity is an option) and the selected quantity is displayed in the UFC scratch pad.

1.14.5.5.2 Option Select Buttons and Displays. After actuating the weapon function select pushbutton on the UFC, the delivery program options for the selected weapon appear in the ODU display windows. Figure 1-194 shows the programmable delivery parameters for a bombing run: QTY, MULT, INTV, and FUZE. Some options are not applicable to all weapons.

1.14.5.5.3 Radar Altimeter Function Select Button. On the UFC, actuating the radar altimeter (ALT) function select pushbutton enables power to be applied to the radar altimeter via the power ON/OFF pushbutton. With the ALT function selected, BOMB is displayed in option window 1 and PUC is displayed in option window 2 on the ODU. See Figure 1-195.

The BOMB option allows the radar altimeter to be used as the source for elevation data when the MC performs weapon delivery calculations. Selecting the BOMB option by pressing the adjacent pushbutton causes a colon to be displayed in the option window and the last selected LAW altitude to be displayed in the UFC scratch pad. With weight on wheels the system will initialize with the BOMB option selected (cued) so that radar altitude will be used for ballistic computations, unless radar altitude becomes invalid. Pressing the option button will uncue the BOMB option and enable barometric altitude for ballistic computations.

The PUC (pullup cue) option, when enabled, provides cuing to the pilot to pull out of a dive to avoid flying into a weapon's fragmentation envelope or to release a weapon by a given altitude to insure sufficient arming time prior to impact.

Selecting the PUC option by pressing the adjacent pushbutton causes a colon to be displayed in the option window and the UFC keyboard and scratch pad to be enabled for data entry. The colon displayed in the option window indicates the function is selected. The UFC scratch pad initializes with zero altitude displayed at power up; else, it initializes with the last entered altitude. The pilot enters the desired MSL altitude using the keyboard. In the A/G master mode, the pullup cue is displayed on the HUD 5° below the velocity vector 9 seconds prior to reaching the entered altitude. The cue will start to move up with 6 seconds to go, and when it approaches the velocity vector the pilot must apply 4g's to be able to bottom out at no lower than the inserted altitude.

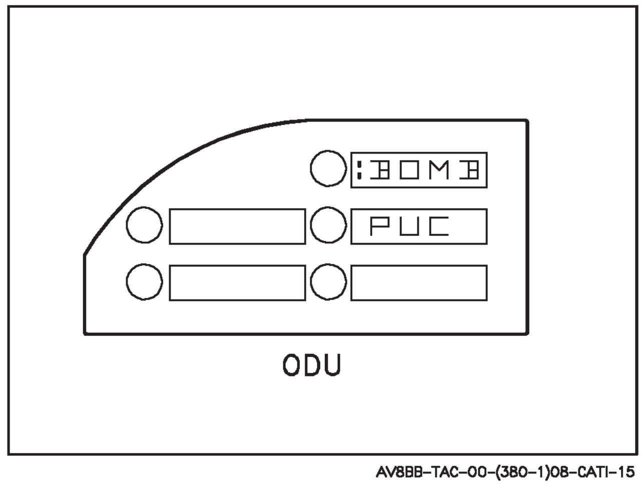


Figure 1-195. Option Display Unit (Bomb and Pullup Cue Options) (Weapon Selected)

1.14.5.6 Standby Reticle Controls. The HUD standby reticle is only available on day attack aircraft. The standby reticle brightness and depression controls for the HUD standby reticle are located on the HUD control panel. See Figure 1-196.

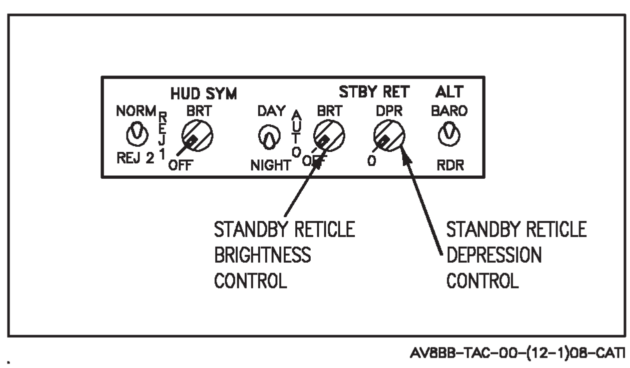


Figure 1-196. Standby Reticle Controls (HUD Control Panel)

1.14.5.6.1 Standby Reticle Brightness Control. Rotating the brightness control clockwise out of OFF turns the reticle on for display on the HUD. Further clockwise rotation of the control increases the reticle brightness.

1.14.5.6.2 Standby Reticle Depression Control. The reticle depression control sets the standby reticle cursor depression angle. Setting the control to 0 places the cursor at the waterline or zero depression. Rotating the control clockwise increases the cursor depression from the waterline; the range of the cursor depression is 0 to 240 mils below the waterline in 20-mil increments. The actual setting is numerically displayed on the HUD near the standby reticle diamond symbol.

1.14.6 Weapon System Programming. Before actually starting the programming sequence, the pilot should verify the SMC loadout entries by selecting the stores display on the DDI and pressing the LOP pushbutton. The stores display wing form should display the weapon type, quantity, fuzing, and station location as observed on his preflight walk-around and also as displayed on the stores display, with the exception of fuze legend and arming time without LOP selected. SMS loading via the DSS must be done after engine start or with generator power applied.

1.14.6.1 Weapon Selection. Weapon selection is a prerequisite for programming. Selection of A/G weapons can be made either using the DDI or the station select buttons on the ACP. Weapon selections (unlike weapon programs) are not stored between flights. Therefore, on power up, both the DDI and ACP initialize with weapons deselected.

A/G weapon options are presented on the DDI stores display in all master modes except A/A. In the A/G mode, weapon options are also presented on the EHSI, DMT, and ECM displays. The ACP can be used in all master modes. The desired weapon is selected by pressing the appropriate pushbutton. The selection is boxed, and the stored weapon program values, fuzing option, and selected delivery mode for the weapon selected are presented on the stores display data block. See Figure 1-197.

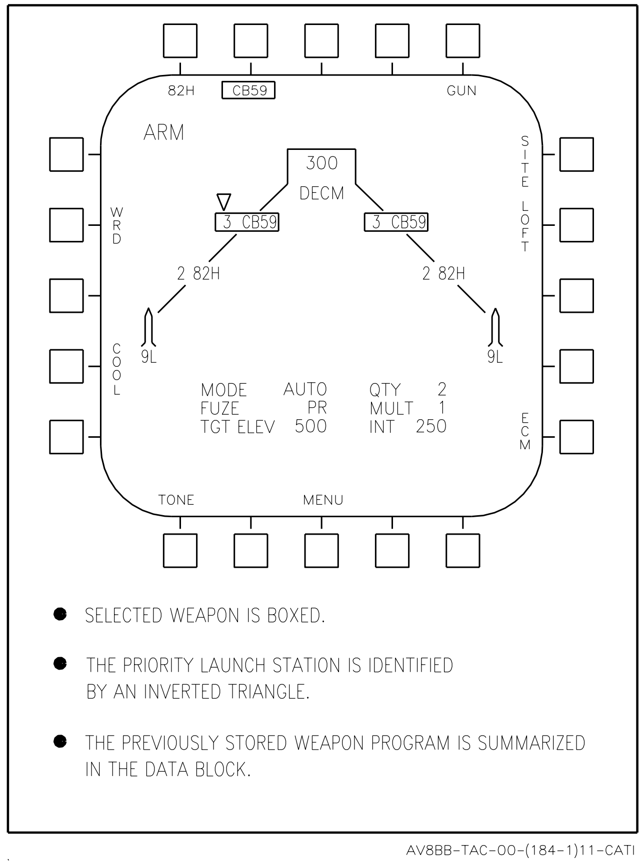


Figure 1-197. Stores Display (Weapon Selected)

The ACP is also driven to display the weapon program for the selected weapon on the DDI stores display. See Figure 1-198. Those stations that participate in the drop will display the SEL legend in the respective station windows. Priority stations are not identified on the ACP.

The pilot also has the option to select the weapon for programming on the ACP by selecting the station carrying the desired weapon. When a station is selected, the stored program is automatically brought up in the program windows on the ACP and all participating stations will display SEL. The DDI stores display also changes to display ACP weapon selection.

1.14.6.2 Weapon Programming. The pilot enters A/G weapon delivery programming using either the UFCS or the ACP. One delivery program for each of up to four weapon types loaded can be entered and stored in the SMC (plus fuselage gun). The stored delivery program is

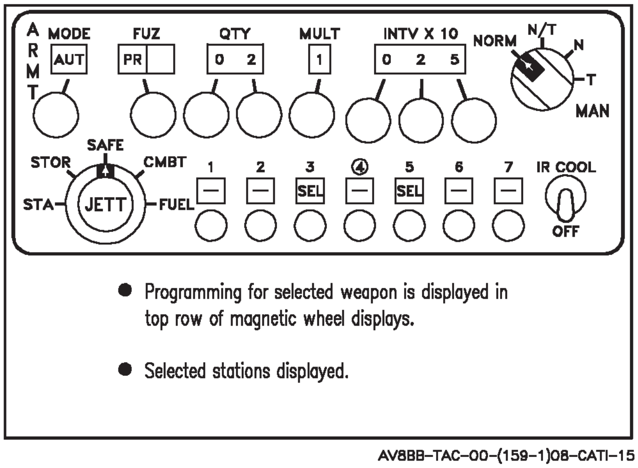


Figure 1-198. Armament Control Panel (Weapon Selected)

automatically recalled when the weapon is selected for delivery.

WEAPON	QTY	MULT	INTV	FUZE	MAX/ MIN*
Bomb	X	X	X	X	
Gun					X
Dispensers	X	X	X	X	
AGM	X			X	
Rocket	X	X			X
* Maximum and minimum range cue.					

Figure 1-199. Delivery Programming Options

1.14.6.3 UFCS Weapon Programming. The UFCS is enabled for weapon programming by pressing the WPN function select pushbutton on the UFC. The WPN pushbutton is functional only when a weapon is selected, and only in the A/G, NAV, and V/STOL master modes. When WPN is pressed, the allowable programming options for the selected weapon are displayed on the ODU. Programming options available for the various weapon types are listed in Figure 1-199. The ODU always initializes with quantity (QTY) selected when available and the stored value displayed on the scratch pad. See Figure 1-200.

ODU options are mutually exclusive with respect to UFC keyboard/scratch pad usage. Selecting an option displays the last entered value on the scratch pad. The selected option on the ODU is cued by a colon in the respective display window. An option is deselected by selecting another option. When in the A/G master mode, the automatic 30-second timeout feature of the UFCS is disabled. The weapon display is deselected by reactuating the WPN option or selecting another function switch on the UFC. Option selection characteristics are as follows:

a. Quantity. The quantity entered equals the total number of stores to be released during the release sequence. Values of 1 thru 99 may be entered. Entry of a third digit will not be accepted. Leading zeros are not required. Since the UFCS initializes with the current program quantity on the scratch pad, keying in the new quantity and pressing ENT enters the change. If the QTY option has been deselected (colon removed), it may be reselected by pressing the QTY option pushbutton. To change the quantity to 95, the pilot presses 9, 5, and ENT keys on the UFC. See Figure 1-201.

If the entered quantity exceeds the available inventory, the system automatically displays the number onboard preceded by an asterisk to cue the pilot that the SMS has overridden his selection. The quantity on board and the asterisk (*) are also displayed on the stores program data block (DDI), indicating the override. See Figure 1-202.

When the Maverick missile is selected, the QTY option initializes to 1. The QTY can then be changed to a value not to exceed the number of missiles aboard (maximum of four). When this option is set to 2 or more, the next highest priority missile is selected and uncaged after launch of the first missile. When flares or sonobuoys are selected, the QTY option entered equals the total number of flares or sonobuoys to be released with one actuation of the bomb pickle button.

The QTY option for rockets depends on whether ripple (R) or single (S) firing modes are

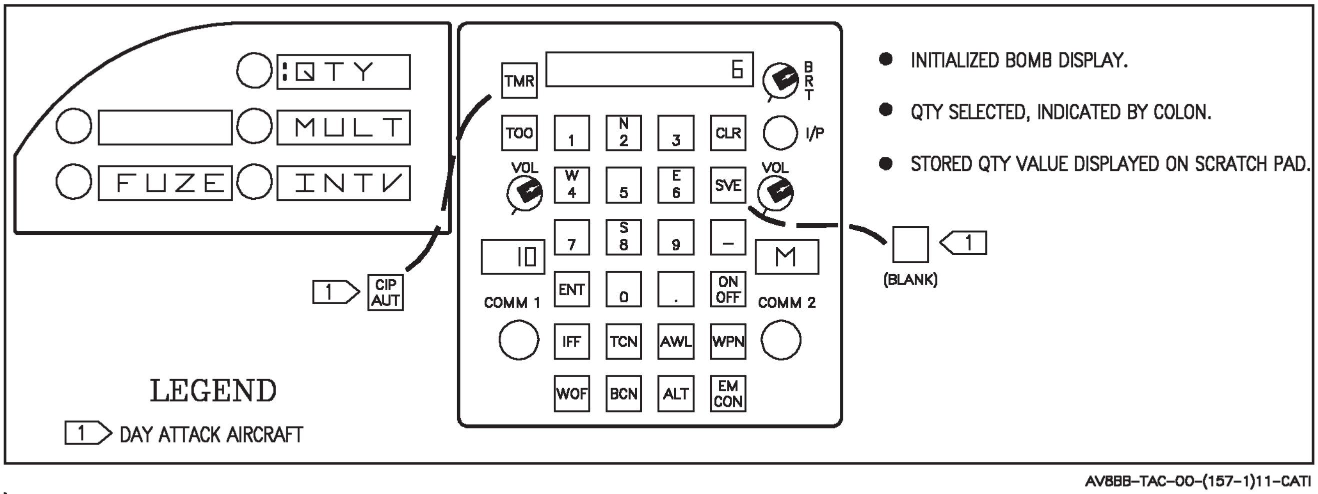


Figure 1-200. Weapon Options (WPN Selected)

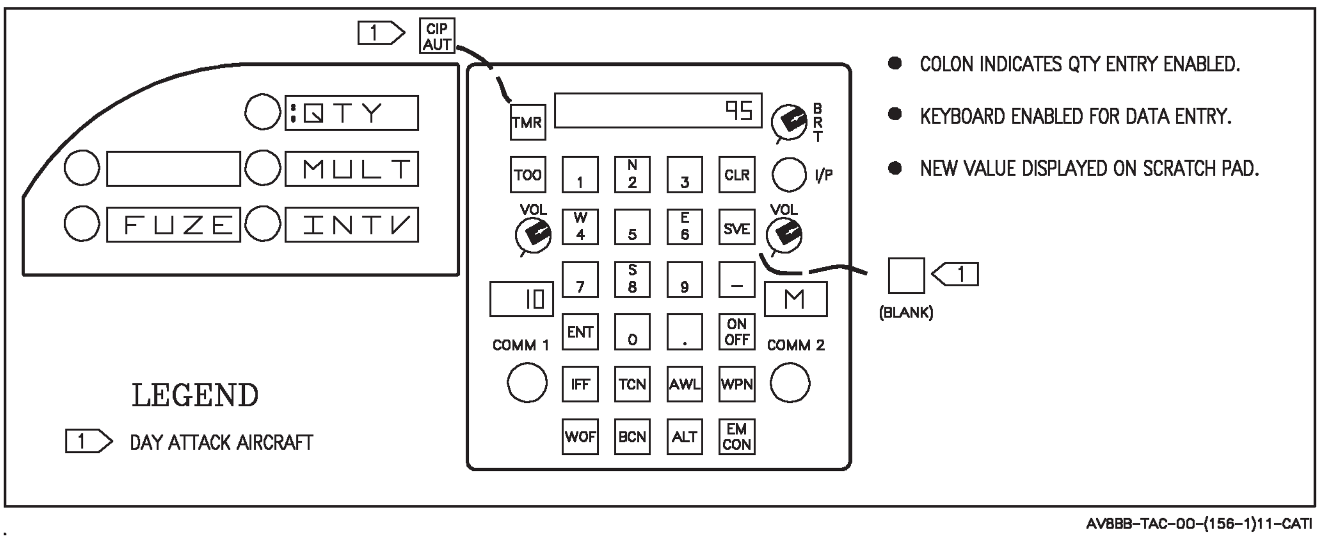


Figure 1-201. Quantity (QTY Selected)

selected on the rocket launchers. When set to R, QTY equals the total number of rocket launchers (pods) to be fired and is limited to the maximum number loaded. When set to S, QTY equals the total number of rockets to be fired and is limited to the maximum number loaded. The QTY option is not available for the fuselage gun. Gun rounds are set in by the ground crew.

b. Multiple. The multiple (MULT) is the number of stores to be released simultaneously at each interval during the release sequence. MULT can have values from 1 thru 6 but is limited to the number of stations containing the selected weapon. The MULT option is enabled by pressing the MULT option pushbutton on the ODU. See Figure 1-203.

The multiple may be changed whenever it is enabled on the keyboard. To select a new multiple, the pilot keys in the change and presses the ENT key on the UFC. If the multiple exceeds the entered quantity, the available stations, or the quantity for safe release, the SMS will override the selection to equal the quantity or available stations whichever is less. To cue the pilot that the SMS has overridden his selection, the new multiple value and an asterisk are displayed on the scratch pad and in the stores program data

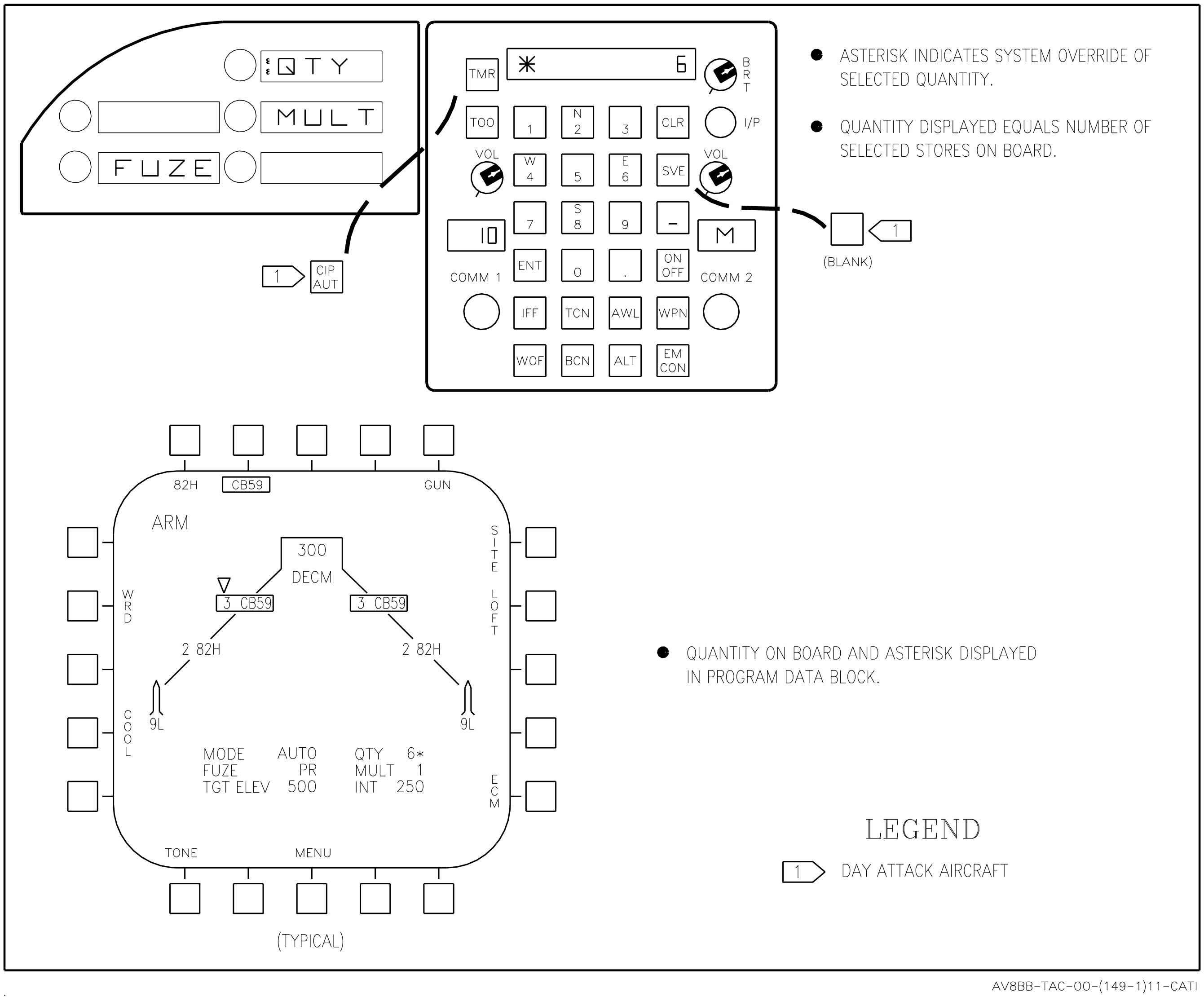


Figure 1-202. Excessive Quantity Entered

block on the DDI stores display. This is similar to the quantity override shown in Figure 1-202.

For the Maverick missile, the multiple value is automatically set at 1. Since it cannot be changed, the MULT option is not displayed. For the SUU-25F dispenser (flares), the MULT entry equals the number of tubes to be released at any given interval and cannot exceed the total number of stations loaded with the selected weapon type. Each dispenser tube contains two flares or sonobuoys. For rockets, the entered MULT value cannot exceed the total number of stations loaded with a particular rocket type. MULT is not available with guns.

c. Interval. In AUTO and CCIP bomb delivery modes, interval (INTV) is the ground spacing between multiple releases. It may range from 0 to 9,990 feet. (The last digit is always truncated to display 0.) In depressed sightline (DSL) modes, the range is from 10 to 9,990 milliseconds. The interval option is selected by pressing the INTV option pushbutton on the ODU. See Figure 1-204.

The interval option is not displayed if it is not applicable, i.e., the entered quantity and multiple are equal. The INTV is changed by keying in the new value and pressing the ENT key. The pilot may enter the actual interval to the units

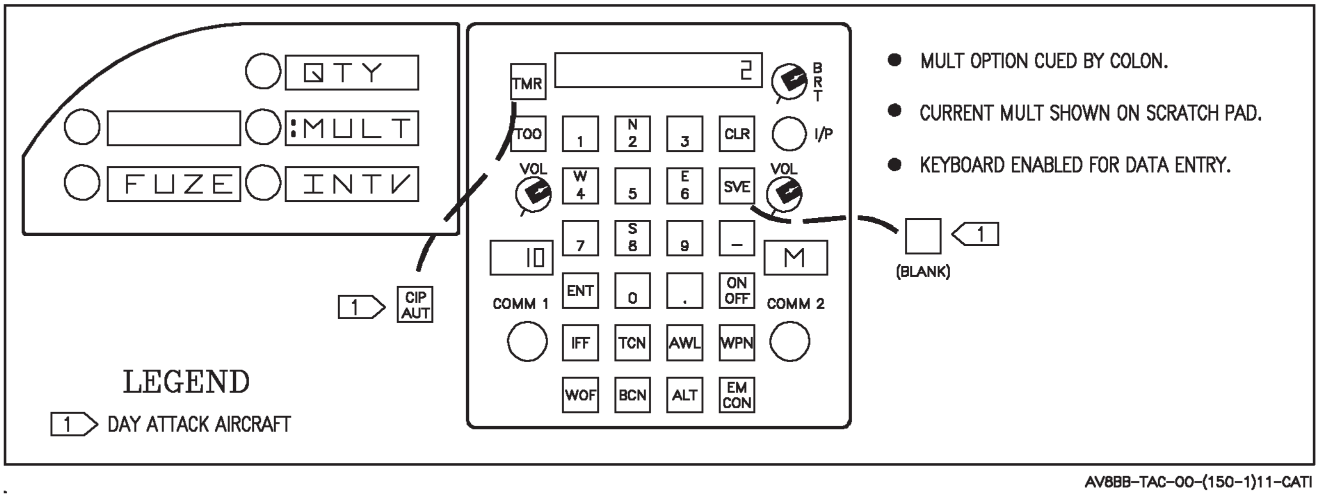


Figure 1-203. Multiple (MULT Selected)

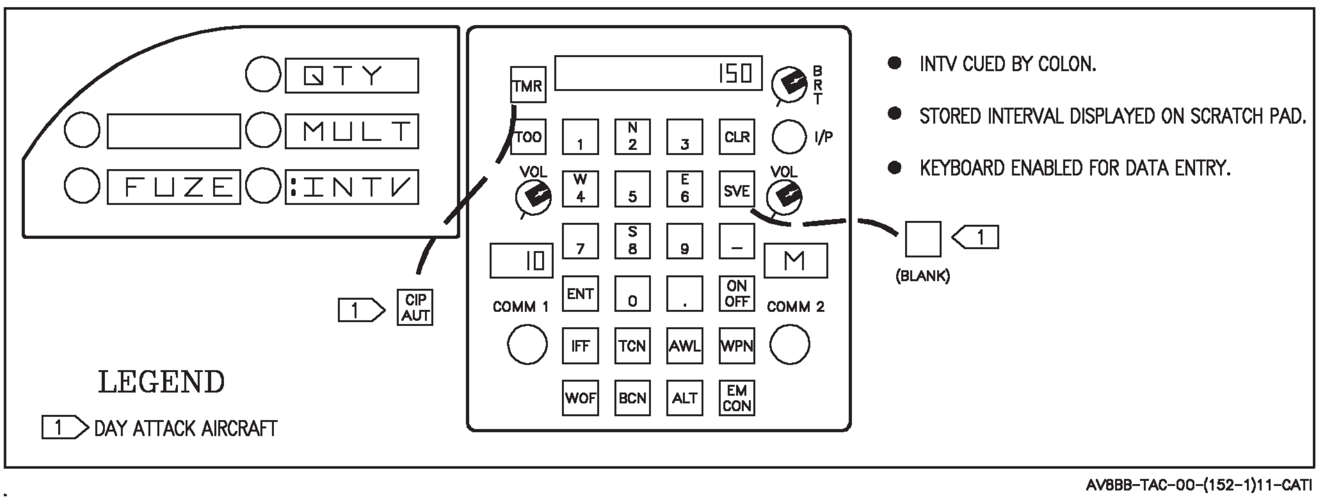


Figure 1-204. Interval (INTV Selected)

digit. This value will be initially displayed on the scratch pad. After pressing ENT, the units digit is replaced by zero. If the pilot enters an invalid interval (i.e., less than the safe minimum release interval), the system responds by displaying the minimum release interval, on the scratch pad, preceded by an asterisk indicating that the interval value entered has been overridden. The minimum release interval and the asterisk (*) are also displayed in the stores program data block on the DDI stores display, indicating the override.

When entered in flight, interval is computed based on current flight conditions and may display an asterisk with a value different than that entered. The interval will then continually change with changes in airspeed, dive angle, etc. to more closely agree with pilot entered values when approaching release conditions. The INTV option is not displayed if Maverick missiles or rockets are selected since it cannot be changed. For dispensing sonobuoys or flares, the INTV is selected in feet for the AUTO mode and milliseconds between releases for the DSL mode.

d. Fuzing. Fuzing options are available for bombs, flares, and Maverick missiles. They are displayed on the ODU by pressing the FUZE option pushbutton. There are 24 bomb fuzing options available in total:

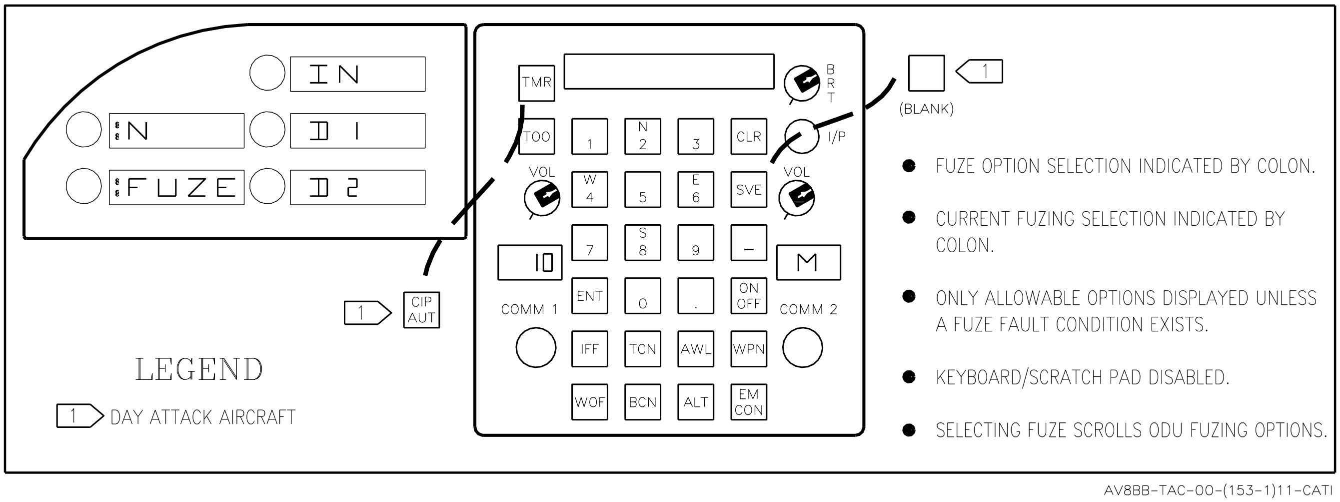


Figure 1-205. Fuze (FUZE Selected)

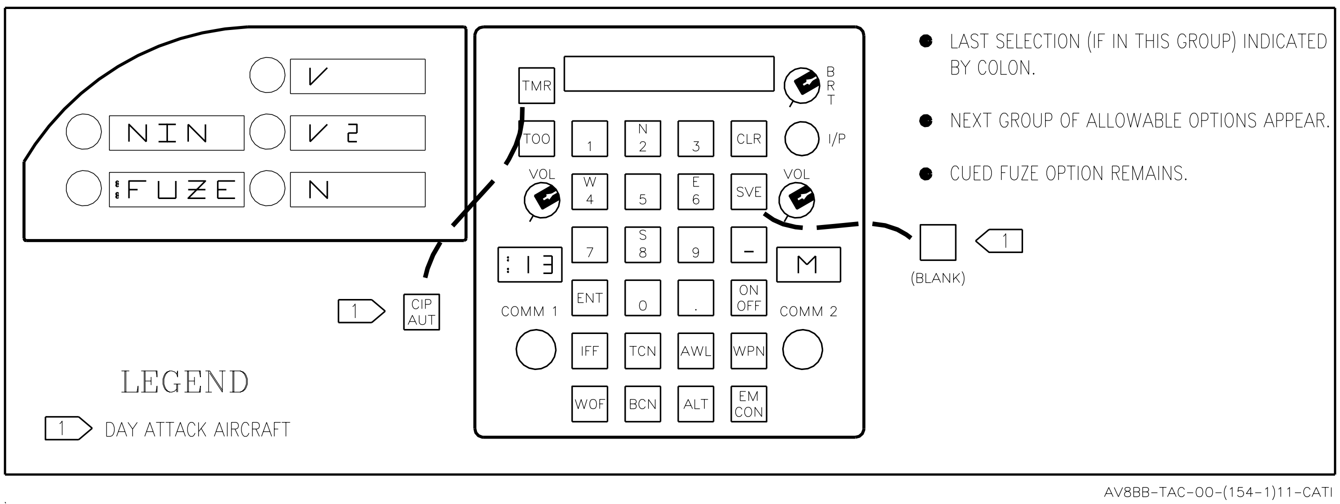


Figure 1-206. Fuze Options

IN	V1	ND1	TD1	TV2	NTD2
D1	V2	ND2	TD2	NT	PR
D2	N	T	TV	NTIN	OP
V	NIN	TIN	TV1	NTD1	SAFE

Only the allowable fuzing options for the selected weapon are displayed for selection. For example, cluster bombs (CBUs) use only the PR, OP, and SAFE options. The Maverick missiles use only the IN, D1, D2, and the SAFE options.

The last selected fuzing option for the selected weapon is indicated by a colon in the option window. If the stored fuzing option is no longer allowable, the SAFE fuzing option will be cued. Figure 1-205 displays bomb fuzing options.

If more than four fuzing options are available for the selected weapon, reactuating the FUZE pushbutton scrolls the display to the next set of available options.

As shown in Figure 1-206, the FUZE option always remains displayed and cued when FUZE options are on the ODU. After scrolling through available option sets, reactuating FUZE calls up the original option set. A new fuzing option is selected by pressing the associated pushbutton. This removes the colon from the current FUZE option window (or from SAFE if the current option was not allowable), and cues the new selection. Two seconds after FUZE option selection, the ODU reverts to the initial condition (QTY cued). In the A/G mode, if there is no selection after 30 seconds, the QTY display will be reinitialized. In all other master modes the UFCS will blank after 30 seconds.

If the pilot selects a fuze option and that fuze option becomes invalid due to current flight conditions, e.g. dive angle or g's outside of fuze limits, the system responds by selecting an appropriate fuze option or SAFE. An asterisk (*) will be displayed next to the new fuze data in the stores program data block on the DDI stores display, indicating the override.

e. Maximum/Minimum Range Cue. The computed reticle range cue options are provided on the ODU for the A/G fuselage gun and rockets. The range cue options allow the pilot to set the position of the maximum (MAX) and minimum (MIN) range cue carets displayed on the circumference of the computed A/G gun and rocket reticles. The position of the carets on the reticles denotes the MAX and MIN range selected by the pilot to begin and end weapon firing/launching. The current values for the MAX and MIN range cues are shown in the program data block on the stores display for the weapon selected.

If rocket is selected QTY, MULT, MAX, and MIN legends are displayed on the ODU. See Figure 1-207. MAX and MIN must be selected. If gun is selected, only the MAX and MIN options are available and MAX is initialized selected. See Figure 1-208. Pressing the pushbutton adjacent to the legend selects the option, displays the last entered value on the scratch pad, and enables the UFC for change. The option cued is changed by keying in the new value and pressing the ENT key. The values selectable depend on the weapon selected. Range values are zero and 2,000 feet to 10,000 feet for rockets, zero and 1,500 feet to 6,000 feet for the gun. Entry of leading zeros is not required.

f. Elevation. The elevation display in the program data block is the target altitude used by the MC (with default of ARBS or radar altitude capability) for BARO determination of aircraft height above the target. It is the same as the selected waypoint, mark, or waypoint/mark offset elevation. The pilot must develop the habit of always entering an accurate elevation for all waypoints, marks, or waypoint/mark offsets. This becomes imperative when delivering weapons in the BARO mode or designating, which is discussed in detail in Chapter 2 of this volume.

1.14.6.4 ACP Weapon Programming. Programming control/displays on the ACP include MODE, FUZ, QTY, MULT, and INTV. See Figure 1-208. Only the allowable options for the selected weapon will appear in the associated display windows. Options are changed using the controls below the display windows. All controls are three position toggle switches with momentary positions of up and down, and a center OFF position. Momentarily placing the control UP advances the option selection to the next acceptable option. Momentarily placing it down advances the options in the reverse direction. For MODE and FUZ options, and numerical options such as QTY, MULT, and INTV, only acceptable values can be selected.

a. Mode Control. This control selects the weapon delivery mode. Selectable options are AUT (automatic), CIP (continuously computed impact point), DSL (depressed sight line) and DIR (direct). AGM (Maverick) can be displayed in the mode window but is not selectable by the mode control. AGM is displayed only if MAV has been selected on the DDI or a station with a Maverick missile loaded is selected on the ACP. The DIR mode is available for selection only when no weapon or station is selected and training mode is not enabled. It is automatically selected when the SMC fails.

b. Fuzing Control. Fuzing options are the same on the ACP as on the UFCS. Acceptable options are selected by momentarily placing the FUZ control up or down. When no fuzing options are applicable for the selected weapon, a dash (- -) is displayed in the fuzing option window.

c. Quantity Control. The quantity control consists of two momentary controls. These controls select the quantity of weapons to be released during a sequence. The quantity value

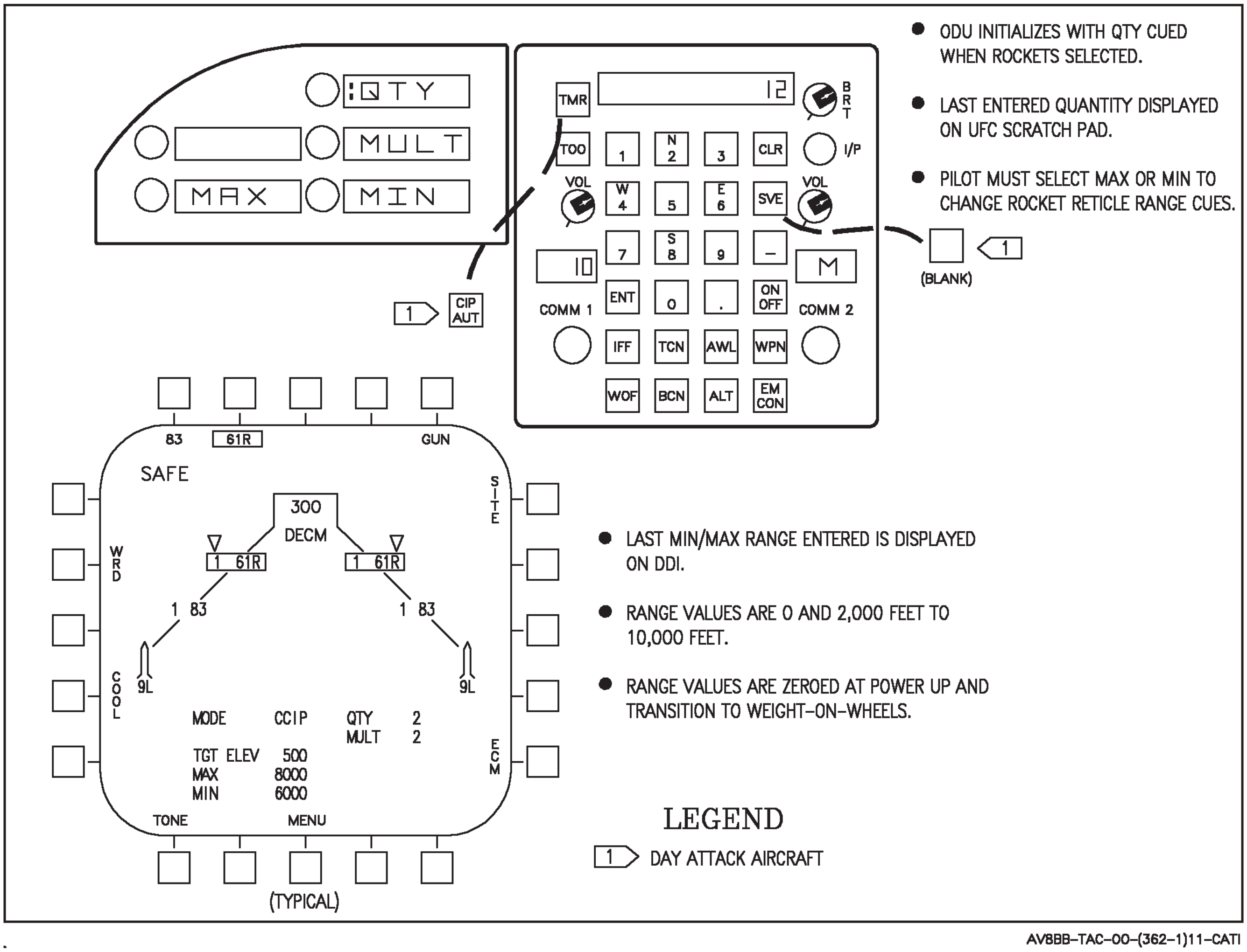


Figure 1-207. Rocket Reticle Range Cue Programming

cannot be set to exceed the number of onboard weapons of the type selected.

d. Multiple Control. The multiple control switch selects the number of stations from which weapons will be simultaneously released in a release sequence. It cannot be set to a number greater than the number of stations carrying the selected weapon or the quantity value, whichever is less.

e. Interval Control. The interval control consists of three switches. It controls the release interval in a multiple release sequence (quantity greater than multiple). In AUT and CIP delivery modes, the interval entered represents ground spacing in feet. In the DSL mode, it represents the weapon release interval in milliseconds.

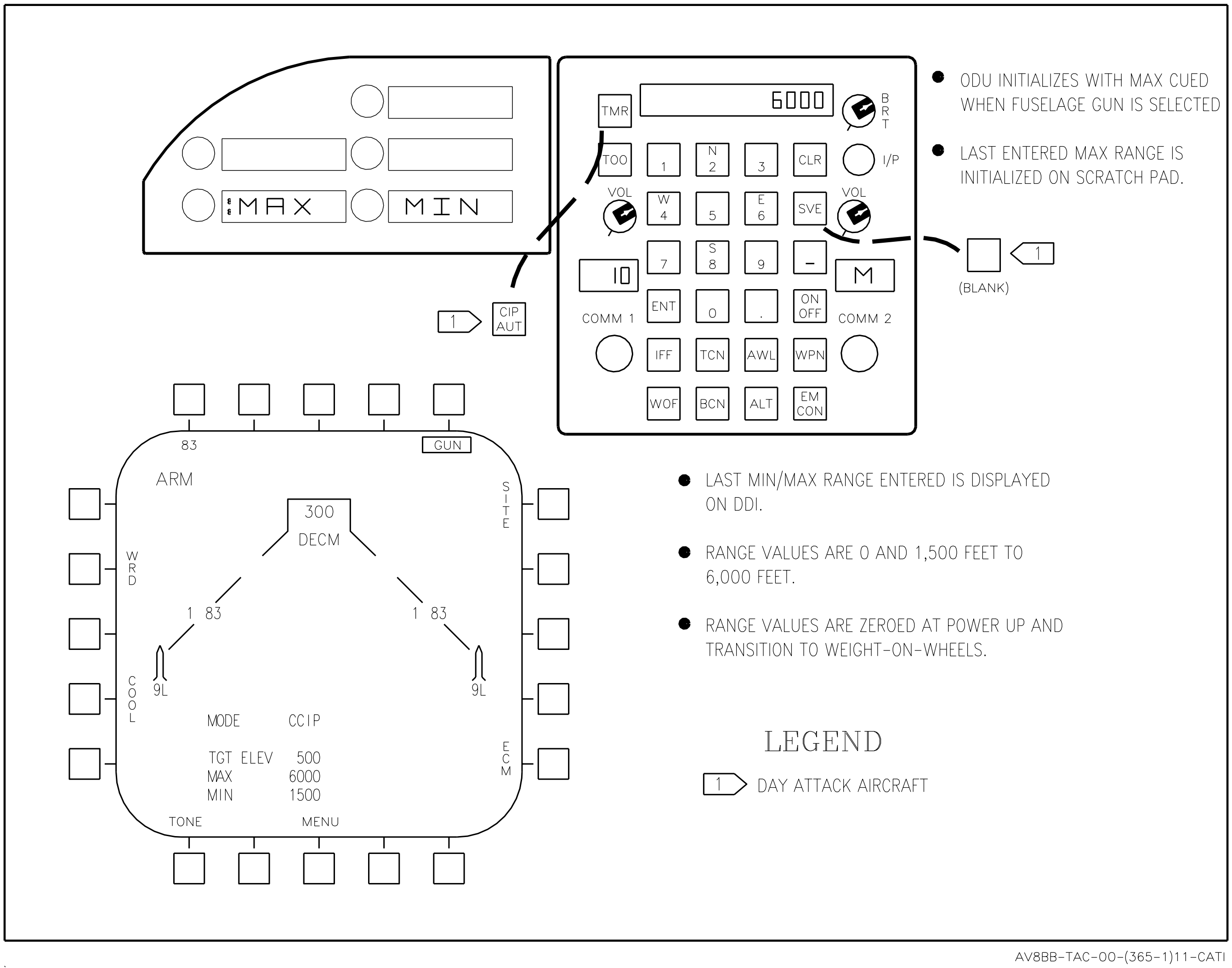


Figure 1-208. A/G Gun Reticle Range Cue Programming

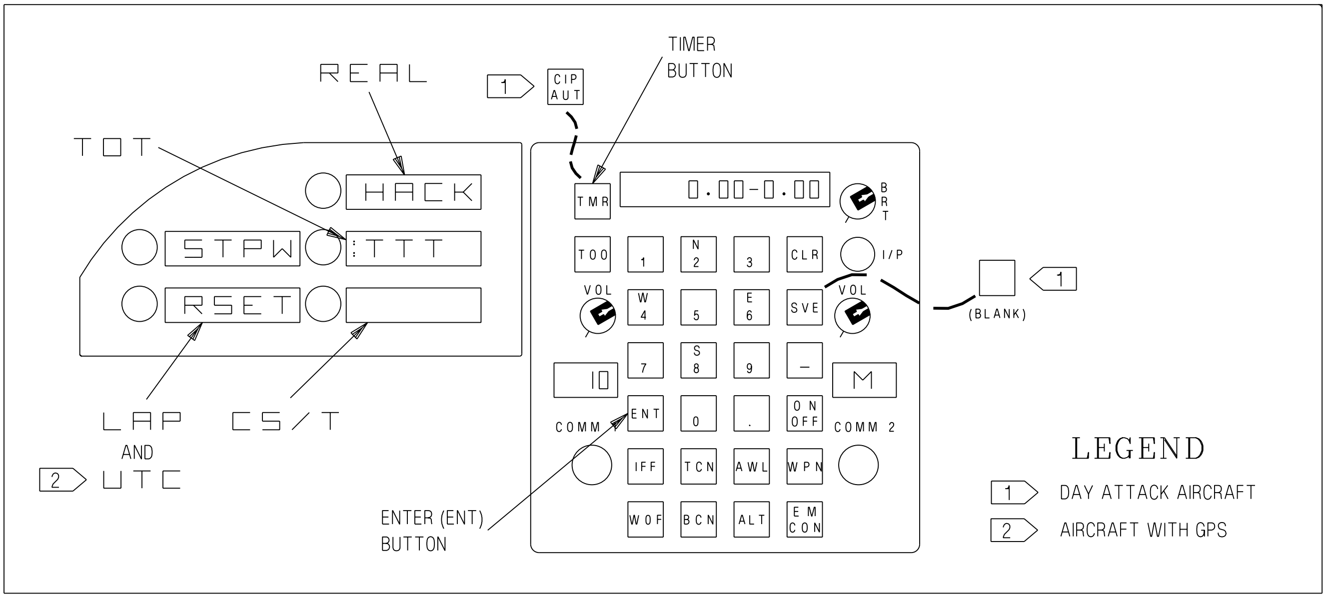


Figure 1-209. Time Data Programming Controls

1.15 TIME DATA PROGRAMMING

The time data function is provided to aid the pilot in overflying a designated point (target, waypoint, mark, or waypoint/mark offset) at a precise time during a coordinated strike. It may also be employed during routine navigation. Time data functions can be programmed for any point for which steering can be selected (waypoints, marks, waypoint/mark offsets, or tacan); however, the designated point (if any) has priority.

The time data function provides a way for the pilot to program and select the following:

1. Time-of-Day (REAL or UTC)
2. Time-to-Target (TTT)
3. Time-on-Target (TOT)
4. Command Speed and Time (CS/T)
5. Stopwatch (STPW)
6. Elapsed time (LAP) function
7. Time hack (HACK)
8. Reset (RSET)

See Figure 1-209. The time data function is enabled by pressing the timer button (CIP AUT or TMR) on the UFC. Timer options are displayed on the ODU until the timer function is deselected, TTT or TOT option times out, another ODU function is selected, or the ODU times out (approximately 30 seconds). The timer data does not time out on the scratch pad. Timer data returns to the scratch pad when the timer function is reselected or another selected function times out (30 seconds) or is deselected.

1.15.1 Time Data Options. The options displayed are dependent upon the status of the aircraft transition from weight-on-wheels to weight-off-wheels and vice versa. If weight is on the wheels and power up, the system initializes with HACK, TTT, STPW, and RSET displayed on the ODU. The TTT option is cued, the UFC keyboard is enabled for data entry, and the scratch pad displays zeros. All time functions are initialized to zero at transition to weight-on-wheels. If weight is off wheels when the timer button is pressed, the last selected options are displayed; else, the initial options are displayed.

1.15.1.1 Option Window 1. The HACK or REAL option is displayed in option window 1. The time hack option provides a reference for the calculation of TTT for data entered prior to or after the selection of HACK. The REAL option is displayed when TOT is entered and flashes until the current military time (24 hour clock) is entered.

1.15.1.2 Option Window 2. The TTT or TOT option is displayed in option window 2. These options scroll between TTT and TOT when the option button is pressed. When either option is selected, the keyboard is enabled for data entry. Selecting TTT displays the value entered for TTT and the current TTT counting down (if any) in the scratch pad. If HACK has been selected and no TTT is entered, the current TTT counts up from 0.00. Selecting TOT displays the current TOT (if any) in the scratch pad.

1.15.1.3 Option Window 3. The CS/T option is displayed in option window 3. This option is available when a TTT (with HACK) or TOT is entered and a tacan, waypoint, waypoint/offset, or target designate steering point is selected. When selected, this option provides display of the command speed and time to the target on the scratch pad.

1.15.1.4 Option Window 4. The STPW option is displayed in option window 4. This option is independent of and can work simultaneously with the TOT and TTT options. When selected, the STPW option is cued, the LAP option is displayed in option window 5, and the count is displayed in the UFC scratch pad.

1.15.1.5 Option Window 5. The RSET, LAP, or UTC option is displayed in option window 5. The RSET option provides a way to zero out the TOT and TTT data entries or stopwatch stop value. This option is displayed when the stopwatch is not selected or is stopped; also, on GPS equipped aircraft when the REAL option is not selected. The LAP option, when selected, freezes the time when the stopwatch is counting. This option is displayed when the stopwatch is selected. On GPS equipped aircraft, the UTC option provides a way for aircraft REAL time to be synchronized to GPS UTC time. The UTC option is displayed when the REAL option is selected and GPS UTC time is valid.

1.15.1.6 Interrelated Options. The TOT option, TTT option, and CS/T option are interrelated because they are only applicable to a designation or a point for which waypoint, mark, waypoint/mark offset, or tacan steering is selected. Entering a new TTT changes the TOT and CS/T displays. Overflying the designation times out and deselects the TOT, TTT, and CS/T functions. However, if STPW was previously selected, the TOT function is not deselected when the internal timer decrements to zero.

1.15.2 Time-of-Day Entry. To enter current time, cue the REAL option on the ODU by pressing the REAL option button. See Figure 1-210. If the REAL option is not displayed, select the TOT option by scrolling option 2 from TTT to TOT. The REAL option is now displayed.

Selecting REAL enables the UFC for data entry with the last entered (and running) time (00.00.00 if nothing entered) displayed. Real time is entered as military time in hours, minutes, and seconds. Enter real time by sequentially entering values from 00 00 01 to 23 59 59 in increments of 1 second. Entry of trailing zeroes is required. For example, a time of 01:05:43 can be entered by sequentially pressing 1, 0, 5, 4, 3 and ENT key. The clock starts when ENT is pressed. Real time is independent of TTT, TOT, and STPW, and can only be updated by entering a different real time or by synchronization with UTC time.

1.15.2.1 Universal Time Coordinated (UTC). On GPS equipped aircraft, UTC - also referred to as Zulu and Greenwich Mean Time - is provided, by way of the GPS, to allow the aircraft REAL time to be synchronized to UTC time. The UTC option is available and displayed in option window 5 when GPS UTC time is valid and the REAL option is displayed.

To synchronize REAL time to GPS UTC time select the UTC option. See Figure 1-211. The REAL option is deselected and the time displayed on the scratch pad is preceded by a ″G″ to indicate REAL time is now extrapolated GPS

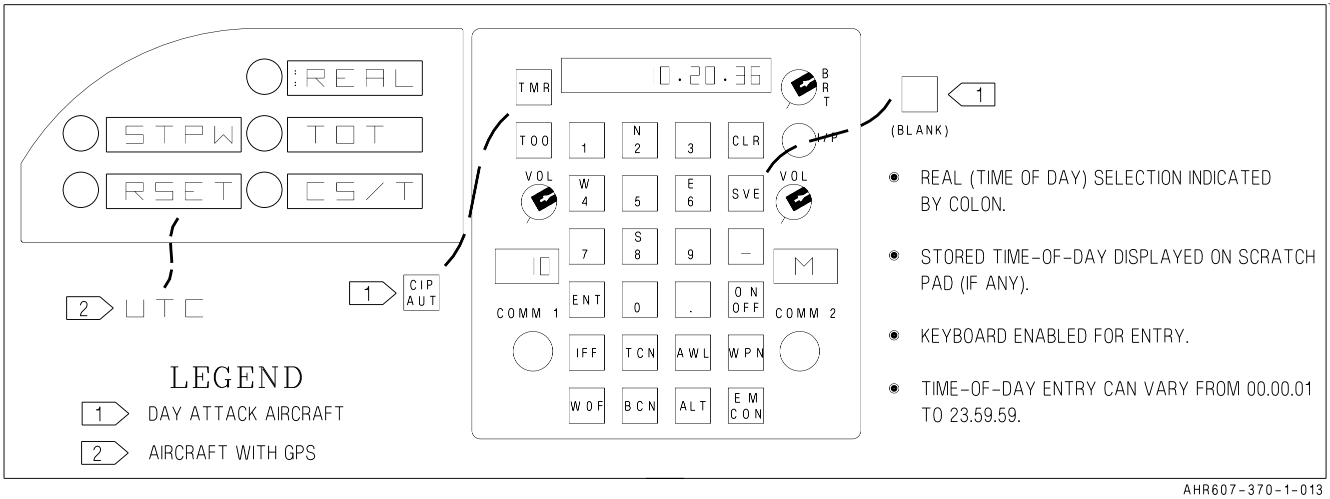


Figure 1-210. Time-of-Day (REAL Selected)

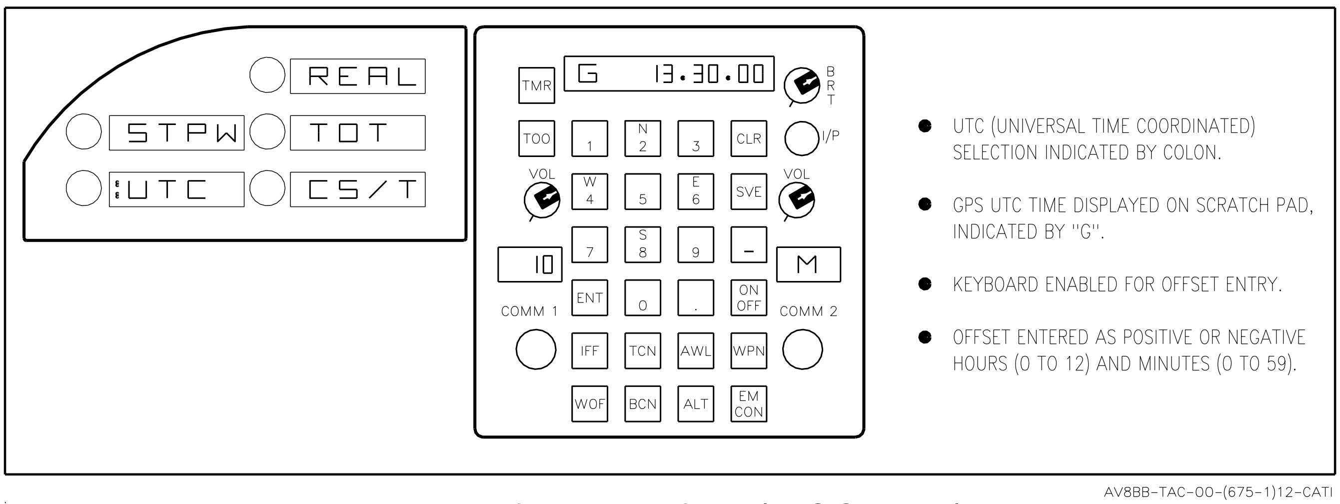


Figure 1-211. Time-of-Day (UTC Selected)

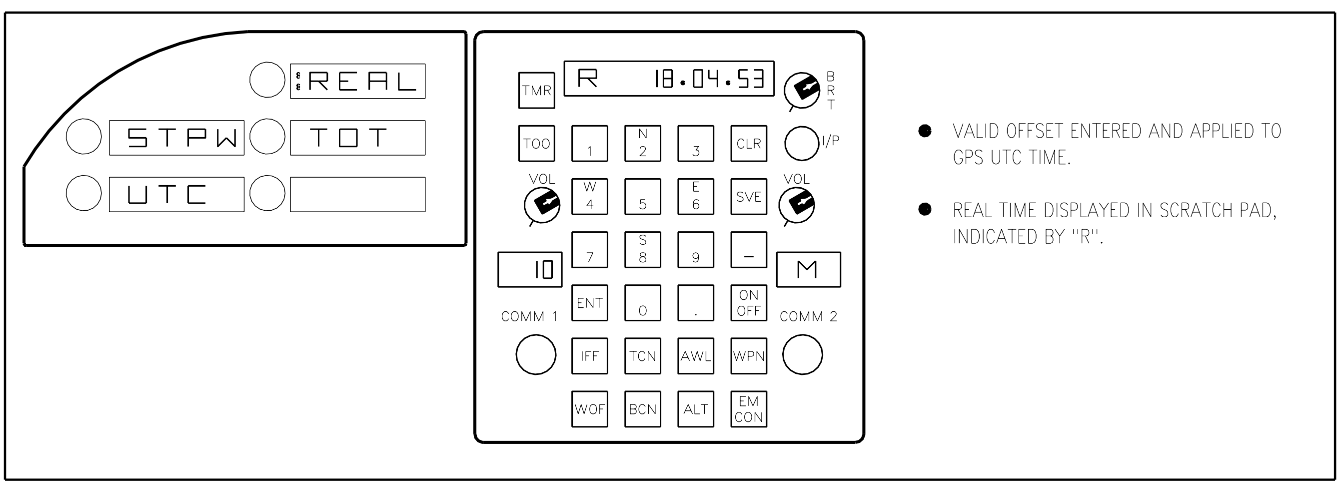


Figure 1-212. Time-of-Day (Offset Entered)

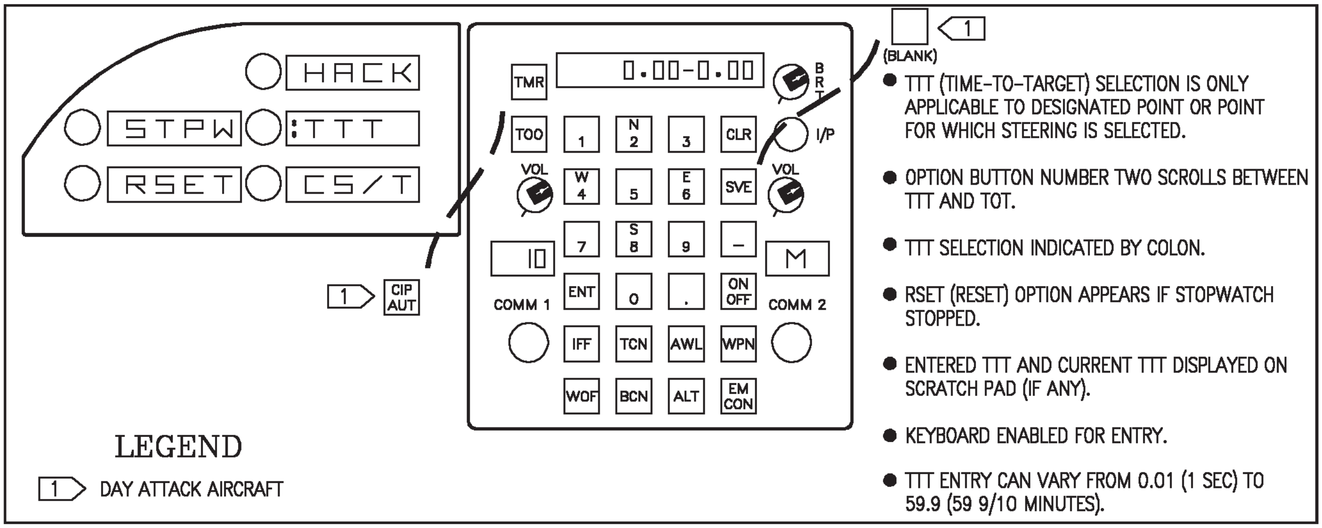


Figure 1-213. Time-to-Target (TTT Selected)

UTC time. While the UTC option is selected an offset can be entered to convert extrapolated GPS UTC time to local time. The offset is entered as either a positive or negative, hours (0 to 12) and minutes (0 to 59). If a valid offset is entered, the offset is applied to the extrapolated GPS UTC time, the UTC option is deselected, the REAL option is selected, the "G" in the scratch pad is replaced by an "R" to indicate REAL time (local time). See Figure 1-214.

NOTE

- To return to GPS UTC time the UTC option can be selected to re-synchronize REAL time to GPS UTC time.
- Aircraft REAL time will default to a synchronized GPS UTC time if no previous REAL time was entered since aircraft power-up.

1.15.3 Time-to-Target Entry. To enter time-to-target, cue the TTT legend on the ODU by pressing the TTT option button. See Figure 1-213. If the TOT legend is displayed, press the TOT option button to scroll to the TTT option. Selecting TTT enables the UFC for entry with the last entered and counting TTT displayed (0.00 - 0.00 if nothing entered or counting). TTT is entered in minutes and seconds. If less than 10 minutes, enter TTT by sequentially entering values from 0.01 to 9.59 in increments of 1 second. Entry of the decimal point and trailing zeros is required. For example a time of 8:32 can be entered by sequentially pressing 8, ., 3, 2 and ENT keys. See Figure 1-214. If 10 minutes or greater, enter TTT by sequentially entering values from 00.1 to 59.9 in increments of minutes and tenths of a minute. For example a time of 12:36 can be entered by sequentially pressing 1, 2, ., 3, 6 and ENT keys. The timer function starts when ENT is pressed. If HACK not previously selected, the timer starts counting upward from 0.00. If HACK selected prior to TTT entry, TTT starts counting downward from the time HACK was selected. When both HACK selected and TTT entered, TOT and CS/T are calculated. If a target is designated, a caret and lubber line will appear on the HUD (refer to paragraph 1.15.5). TOT and CS/T are not displayed on the scratch pad until cued.

1.15.4 Time-on-Target Entry. To enter time-on-target, cue the TOT legend on the ODU by pressing the TOT option button. See Figure 1-215. If the TTT legend is displayed, press the TTT option button to scroll to the TOT option. Selecting TOT enables the UFC for data entry with the last entered (if any) TOT (00.00.00 if nothing entered) displayed. TOT is entered in hours, minutes, and seconds. Enter TOT by sequentially entering values from 00 00 01 to 23 59 59 in increments of 1 second. Entry of trailing

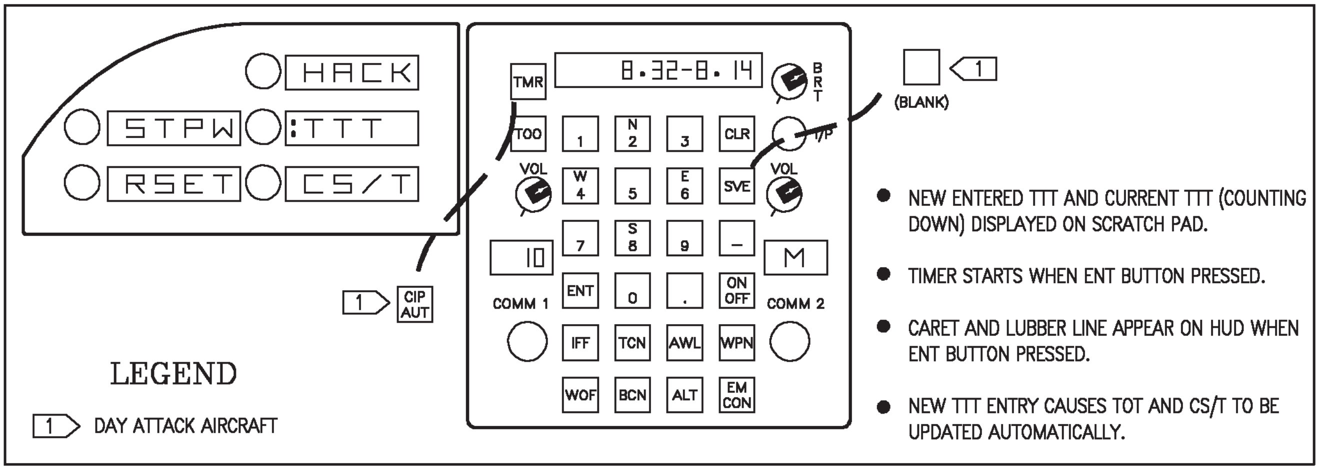


Figure 1-214. Time-to-Target (New Entry)

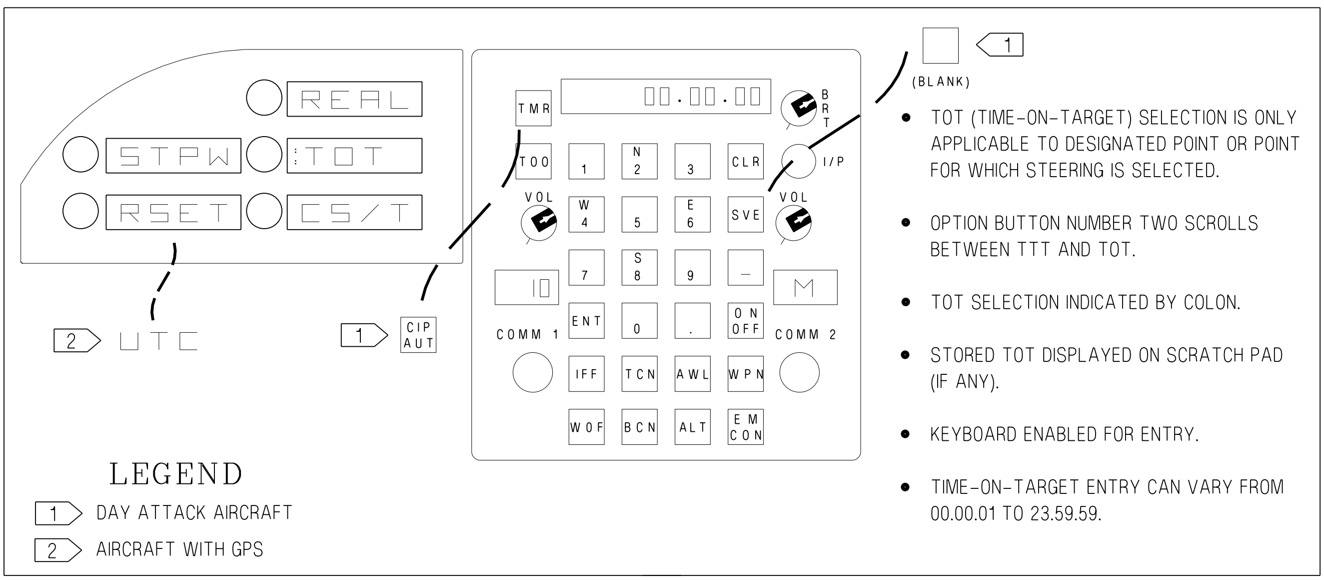


Figure 1-215. Time-on-Target (TOT Selected)

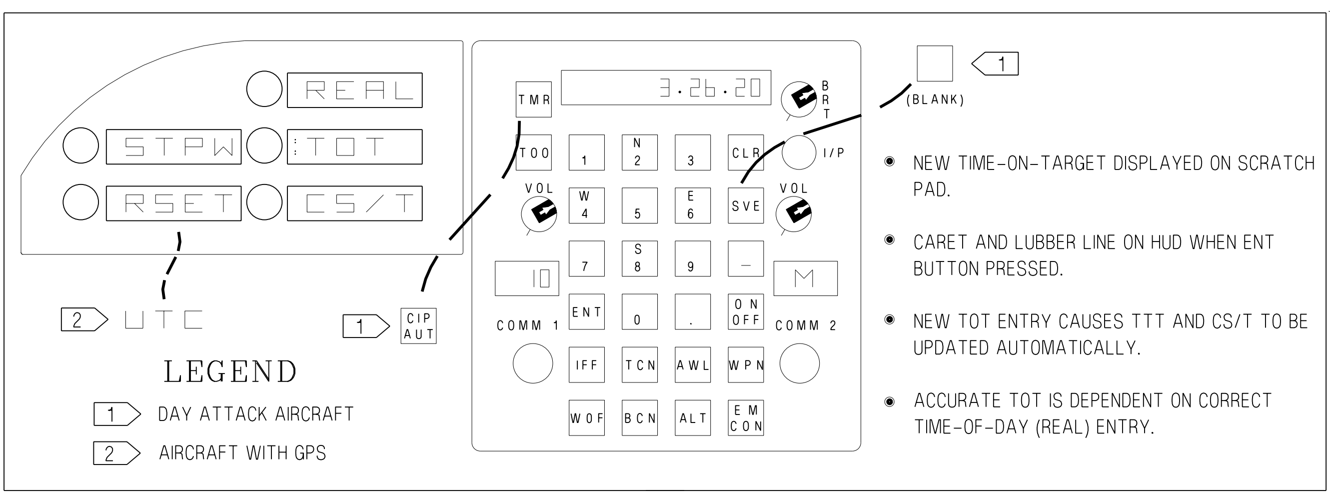


Figure 1-216. Time-on-Target (New Entry)

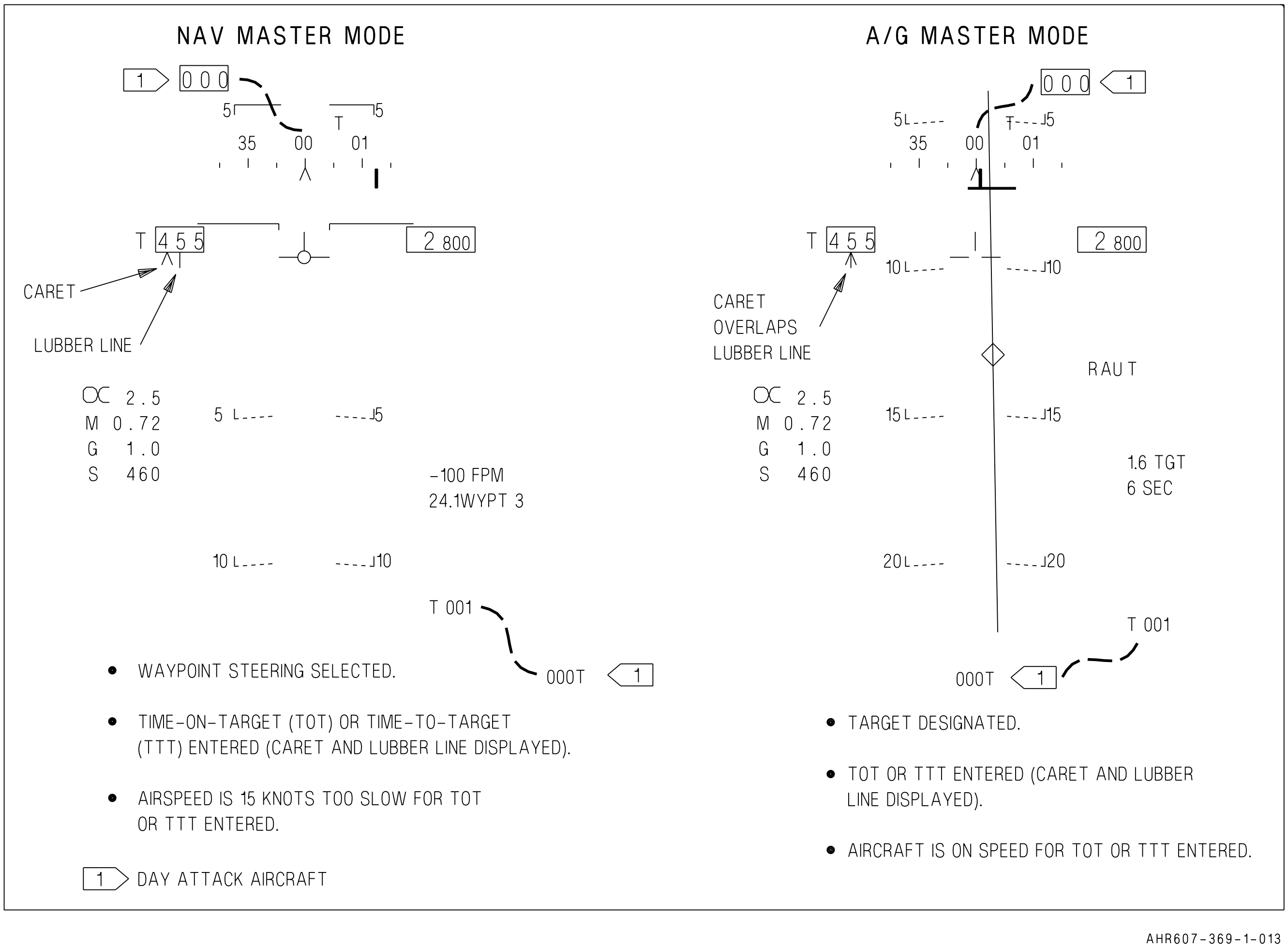


Figure 1-217. HUD Time Data Symbology

zeroes is required. For example, a time of 03:26:20 can be entered by sequentially pressing 3, 2, 6, 2, 0 and ENT keys. See Figure 1-216. The TOT is accepted, TTT and CS/T are calculated, and the caret and lubber line appear on the HUD when ENT is pressed. TTT and CS/T are not displayed until cued.

1.15.5 Caret and Lubber Line. A caret and lubber line appear on the HUD under the airspeed box. See Figure 1-217. The bottom left corner of the airspeed box indicates a maximum of 30 knots below the on speed condition and the bottom right corner indicates 30 knots above the required airspeed for the TOT or TTT entered. The lubber line indicates the airspeed required to be maintained to overfly the designation or other NAV steering destination at the time selected. The caret indicates the current airspeed relative to the required airspeed. The aircraft is on speed when the caret overlays the lubber line. Overflying the designation (internal timer decrements to zero) or selecting RSET on the ODU zeroes out TOT and TTT and removes the lubber line and caret from the HUD.

1.15.6 Command Speed and Time . The command speed and time option provides the pilot command symbology for the airspeed required to arrive at a specific point at a certain time. The option may be selected after entering a TOT or TTT to the selected steering or designated point. Once CS/T is cued, the TOT or TTT option is deselected and the command speed and time remaining is displayed on the scratch pad. See Figure 1-218.

The scratch pad displays command speed from zero to 999 knots and time remaining from

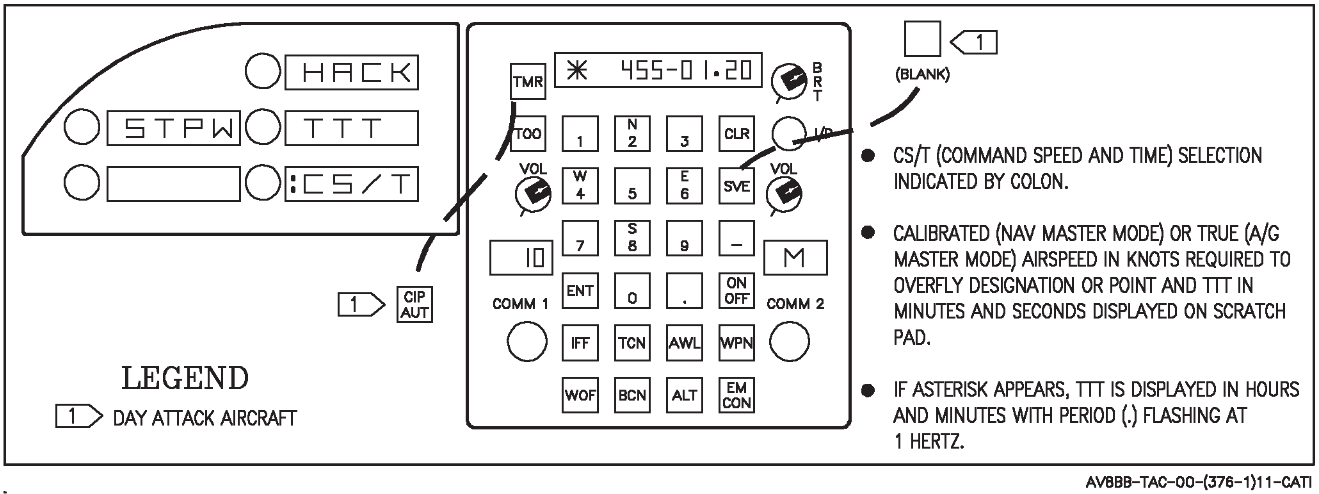


Figure 1-218. Command Speed and Time (CS/T Selected)

zero to 59 minutes and 59 seconds. If a TOT is entered that results in a time remaining greater than 59 minutes 59 seconds, the scratch pad displays an asterisk, command speed and time remaining in hours and minutes with a period (.) between hours and minutes flashing at 1 Hz.

The command speed display is dependent on the master mode selected. If NAV or VSTOL master mode is selected command speed is displayed in KCAS. If A/G or A/A master mode is selected command speed is displayed in KTAS. The speed is derived form the distance from aircraft present position to the steering or designated point and time remaining.

1.15.6.1 Calculations. Three methods of calculating CS/T are available:

1. Direct routing to a selected point (i.e., designation, waypoint, waypoint offset, tacan, tacan offset).

2. Sequential routing through intermediate waypoints and their offsets to a terminal waypoint or offset.

3. Non-sequential routing through intermediate waypoints and their offsets to a terminal waypoint or offset.

1.15.6.1.1 Direct Routing. With an offset present for a selected waypoint (as would be for most CAS missions), the distance to the target is dependent upon system designation. Three examples are presented:

With waypoint steering selected, an offset present for the selected waypoint, and *nothing designated*, the system assumes the target to be the offset and routing to be through the waypoint. The distance to the target is based upon the distance from the aircraft to the waypoint to the waypoint offset. Once through the waypoint, the waypoint offset must be selected. This can be done manually or by use of the WOF function. If this is not accomplished at the waypoint, timing is based upon aircraft's position, back to the waypoint and then to the offset.

With waypoint steering selected, an offset present for the selected waypoint, and the *waypoint designated*, the system assumes the target to be the waypoint. Distance to the target is based upon the distance from the aircraft to the designated waypoint. This causes the pilot to be late if the intended target is the offset.

NOTE

If the bomb pickle button has been used as would be the case for multiple CAS missions, the system automatically designates the last target. If the designation is not deselected prior to running a new attack, timing is to the designated waypoint.

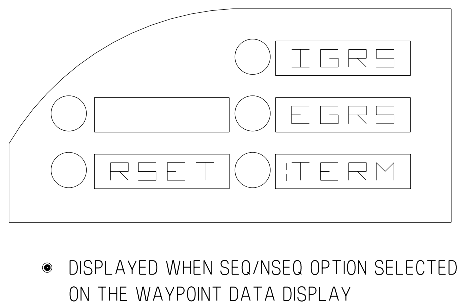


Figure 1-219. SEQ and NSEQ Options

With an offset present for the selected waypoint and the offset boxed, the system assumes the target to be the waypoint offset. This is true whether it is designated or not. Distance to the target is based upon the distance from the aircraft direct to the offset. Routing is not through the selected waypoint.

1.15.6.1.2 Sequential Routing. Command speed and time is provided through a sequential string of waypoints and waypoint offsets to a terminal waypoint if a terminal waypoint is identified. To identify a terminal waypoint do the following:

1. On Night Attack/Radar aircraft select NSEQ on the waypoint data display (MENU-EHSD-DATA-NSEQ).

NOTE

NSEQ is also displayed on the top level EHSI display and is used to turn on/off the NSEQ function. Waypoint programming is not availible from this option button.

2. On Day Attack aircraft select SEQ on the waypoint data display (MENU-EHSI-DATA -SEQ).

Either action enables display of the TERM option on the ODU. See Figure 1-219. Cuing the TERM option enables the UFC for data entry. When the TERM waypoint is entered, a sequential string is defined from waypoint zero to the terminal waypoint offset (waypoint if no offset) via all intermediate waypoints and their offsets. The TERM option is automatically deselected when the timing function (TOT, TTT) times out. When TERM is not selected, CS/T provides command speed and time remaining to the selected designation, waypoint, waypoint offset, tacan, or tacan offset as described in paragraph 1.15.6.1.1.

If TERM is cued and the RSET option is pressed, the terminal waypoint is set equal to zero. If NSEQ is boxed on the EHSI display, command speed and time remaining is calculated to waypoint zero's offset or to waypoint zero if no offset exists.

1.15.6.1.3 Non-sequential Routing. Command speed and time is provided through a non-sequential string of waypoints and waypoint offsets to the target waypoint or offset if a preprogrammed ingress string is stored in the system. Waypoint string programming is enabled by selecting NSEQ on the data display (MENU-EHSI/EHSD-DATA-NSEQ). The IGRS (ingress) and EGRS (egress) options are displayed on the ODU as shown in Figure 1-219. Cuing the IGRS option enables the UFC for ingress string data entry. Up to 20 waypoints for both the ingress and egress string combined may be entered. Refer to A1-AV8BB-NFM-000, see NSEQ waypoint programming.

When waypoint steering is selected, the IGRS or EGRS option is cued, and NSEQ is boxed on the EHSI display the command speed and time remaining are computed from the current aircraft present position to the target waypoint (if no offset is entered) via the selected waypoint, its offset and all other intermediate waypoints and their offsets in the NSEQ Ingress string.

When waypoint offset steering is selected, the commanded airspeed calculations are computed from the current aircraft position via the selected waypoint offset and all other intermediate waypoints and their offsets to the target waypoint (if no offset entered) in the NSEQ Ingress string. Timing is not provided through the egress string. Once past the target waypoint or offset, timing through the egress string reverts to the direct routing method discussed in paragraph 1.15.6.1.1.

1.15.7 Adjustments

If it is determined the indicated command speed to be slower than that required, the pilot can increase command speed by several options. Flying slower than the indicated command speed in the scratch pad allows the required command speed to increase. This technique may work for small timing corrections. For larger corrections the pilot could increase distance to be flown by changing routing (not flying directly to selected waypoint) if deviations and fuel allowed. Also loitering, as in CAS holding, would be another option available to the pilot.

If it is determined that indicated command speed to be faster than that required, the pilot can decrease command speed by flying faster than the command speed indicated in the scratch pad. Again this works for smaller corrections but increases fuel consumption and is limited by the maximum airspeed of the airframe. For larger corrections the pilot must change routing to decrease the distance flown (i.e., direct to the target).

1.15.7.1 Time Hack Option. The time hack option provides a reference for the calculation of TTT for data entered prior to or after the selection of HACK. The time hack option is selected by cuing the HACK legend on the ODU by pressing the HACK option button. See Figure 1-220. The HACK legend is displayed when the TTT legend is displayed.

If HACK is selected prior to entering a TTT, the scratch pad displays time counting up in seconds in the current TTT display. See Figure 1-220. When a TTT is entered, it is displayed in the scratch pad with the current TTT displayed, based on the time elapsed since the selection of HACK. See Figure 1-221.

If a TTT was previously entered and it has not timed out, then selecting the HACK option causes the current TTT to restart from the initially entered value. See Figure 1-222. Reselecting HACK again also causes the current TTT to restart from the initially entered value. If the TTT is re-entered, the current TTT is recomputed based on the new TTT and the elapsed time since the last HACK.

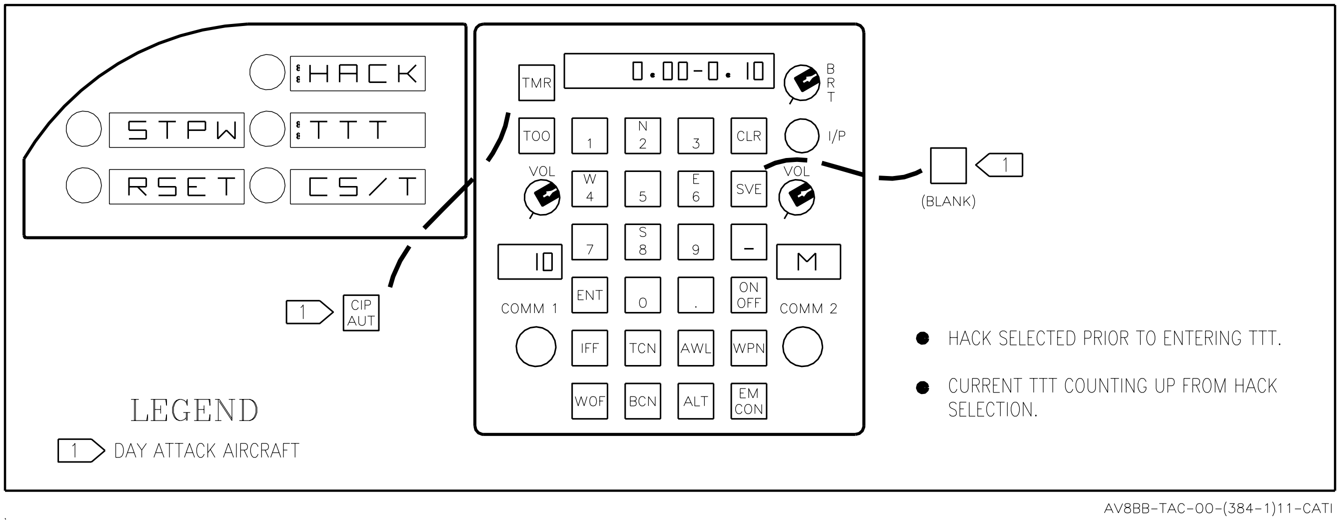


Figure 1-220. HACK Selected (Prior to Entering TTT)

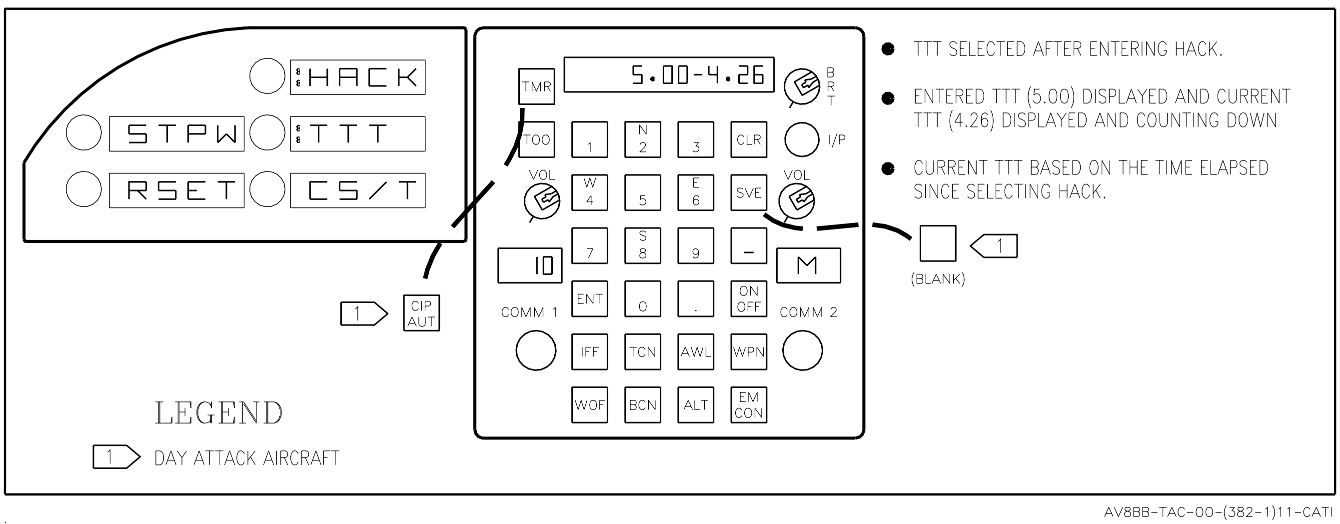


Figure 1-221. TTT Entered (After Selecting HACK)

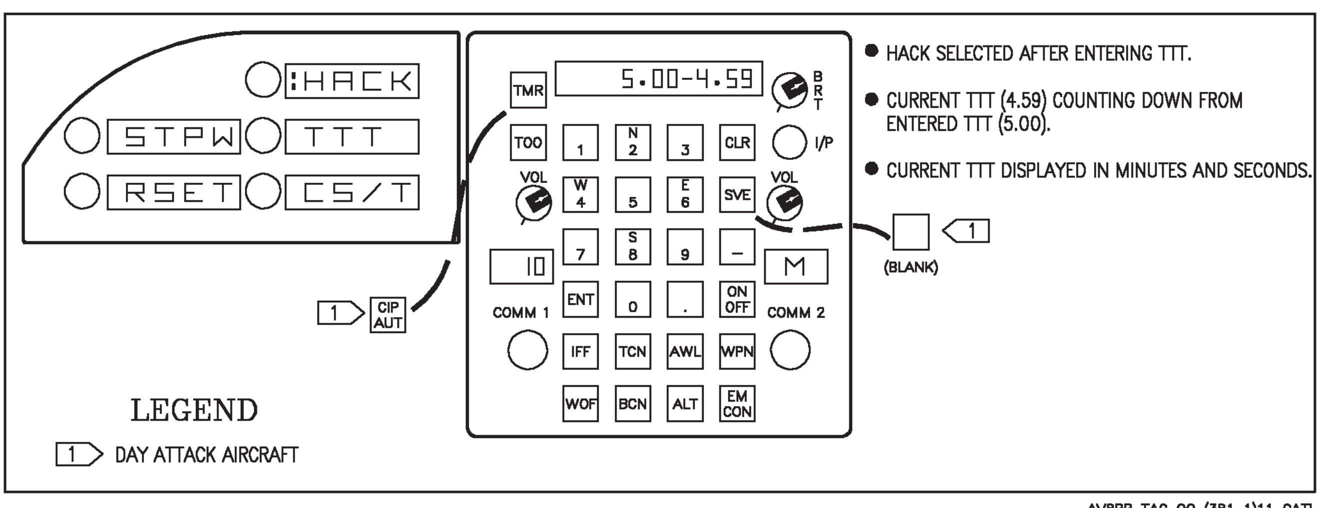


Figure 1-222. HACK Selected (After Entering TTT)

1.15.7.2 Stopwatch Option. The stopwatch option is independent of the TTT or TOT functions. The stopwatch option is selected by cuing the STPW legend on the ODU by pressing the STPW option button. See Figure 1-223. This action starts the counter, displays the running time on the scratch pad, and enables the LAP option on the ODU. Pressing the STPW option button adjacent to the STPW legend a second time stops the clock and freezes the count of the timer on the scratch pad. See Figure 1-224. A subsequent actuation of the stopwatch button starts the timer at the last displayed time. When the stopwatch is stopped the RSET legend is displayed instead of LAP whether or not LAP is cued. Selecting RSET zeroes the stopwatch and displays 00.00.00 on the scratch pad. Reselecting stopwatch starts the cycle.

1.15.7.3 Lap Option. If STPW is cued, LAP is displayed when stopwatch is running. The lap option is selected by cueing the LAP legend on the ODU by pressing the LAP option button. See Figure 1-225. Selecting LAP freezes the elapsed time displayed on the scratch pad, however, the timer continues to count. A subsequent actuation of the LAP option button unfreezes the stopwatch display and displays the current elapsed time on the scratch pad. LAP remains displayed and uncued on the ODU until the stopwatch is stopped.

1.15.7.4 Timer Display on HUD. On Day and Night Attack aircraft, whenever timer options are displayed on the ODU, pressing the ON/OFF button on the UFC enables the time of the selected timer function (TTT, real time if TOT selected, and STPW etc.) to be displayed on the HUD. See Figure 1-226. The timer display can be removed from the HUD by pressing the ON/OFF button a second time whenever the timer ODU options are displayed. The time displayed on the HUD is automatically removed when the timer function times out or RESET is selected. On Night Attack aircraft, the timer function is displayed in raster when video is enabled and in stroke when video is not enabled. A ″G″ preceding the timer display indicates the source of time is the GPS. An ″R″ represents real time.

1.15.8 Selecting WOF. If WOF is selected any time during the operation of the timer function (time data option selected), the timer displays are blanked from the ODU, UFC, and HUD and the standard WOF displays appear. If the WOF is accepted, newly calculated command speed is displayed when the CS/T option is selected.

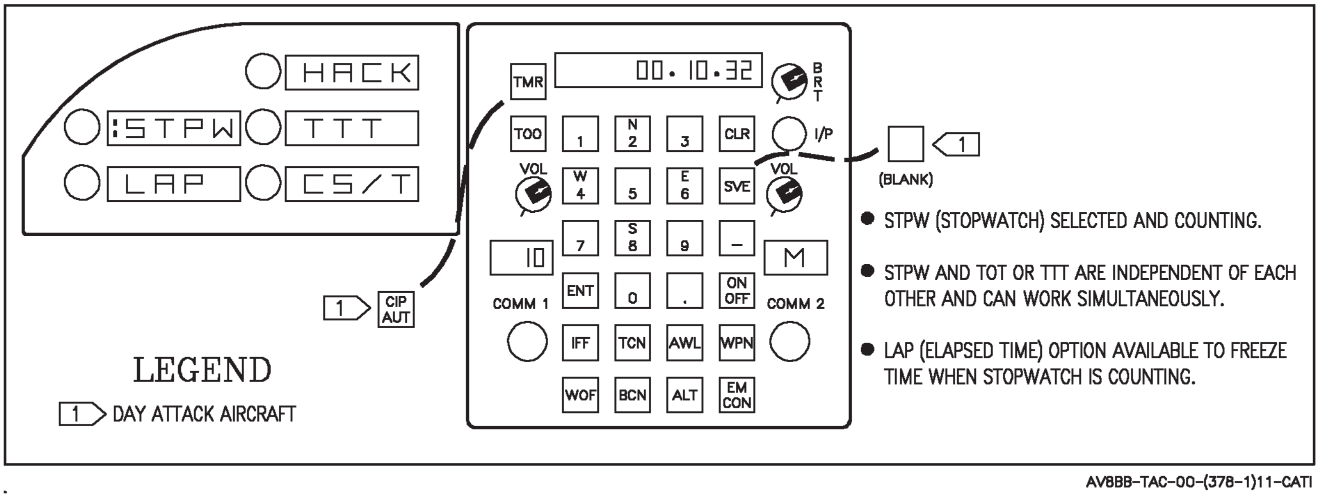


Figure 1-223. Stopwatch Running (STPW Selected)

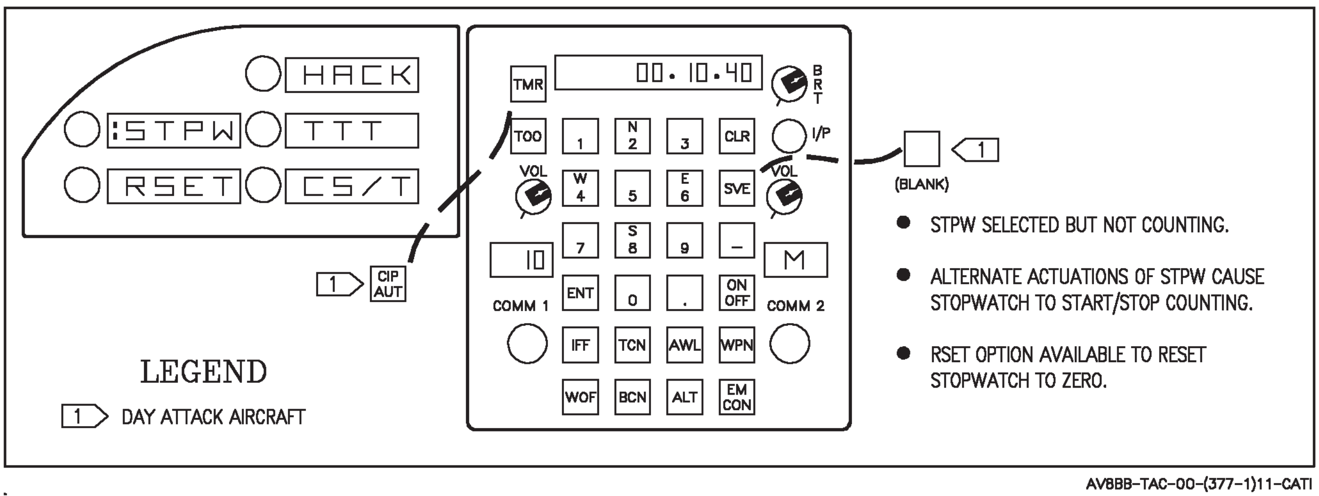


Figure 1-224. Stopwatch Stopped (STPW Selected)

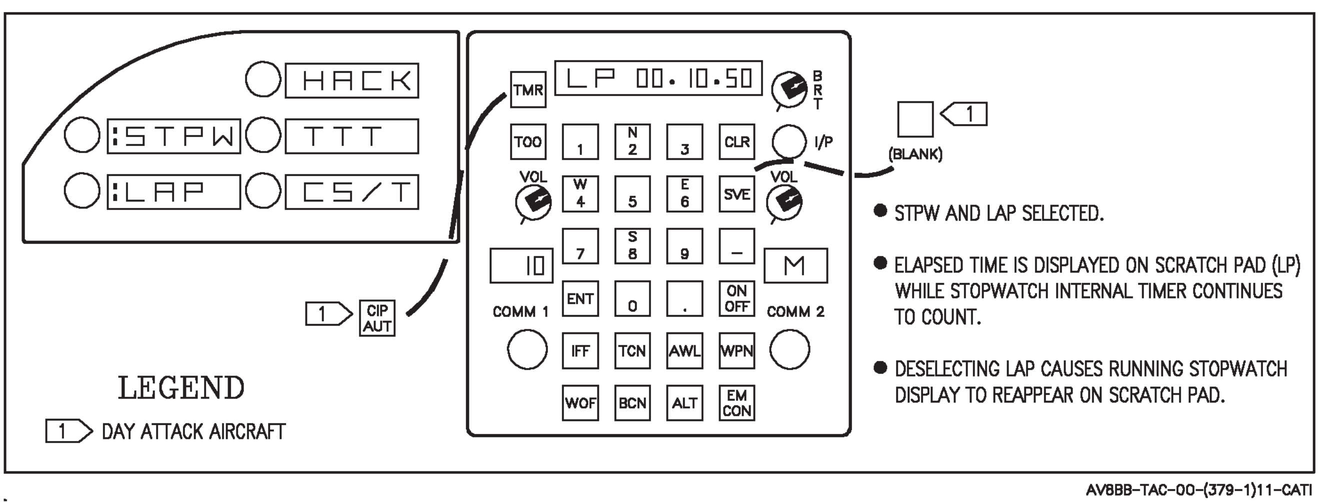


Figure 1-225. Lap (LAP Selected)

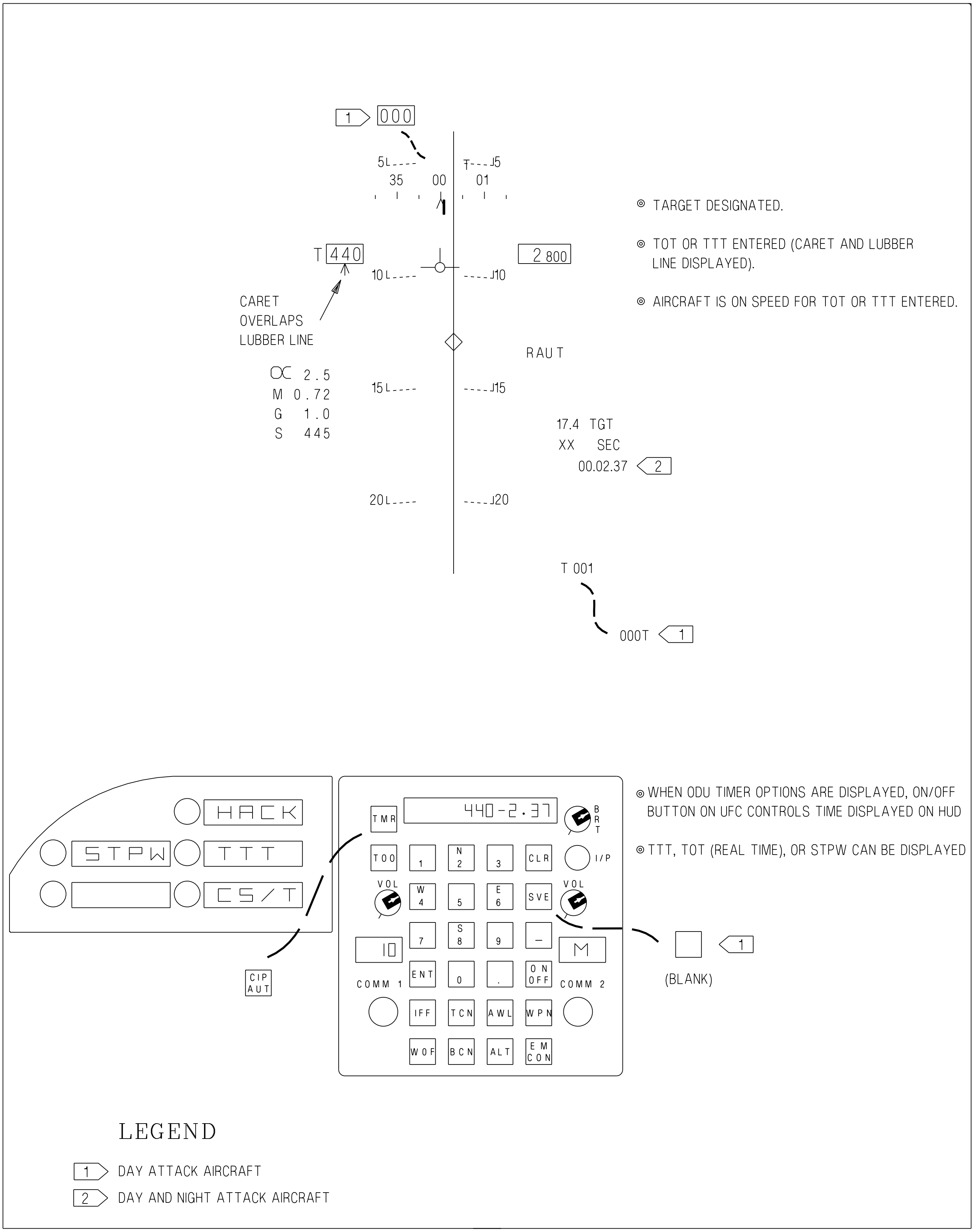


Figure 1-226. Time Function (HUD Display)

1.16 APN-202 Radar Beacon Preflight Programming.

The APN-202 radar beacon set is used to identify aircraft position to specially equipped ground or ship based radars by the use of coded signals. A single pulse code or one of five double pulse codes may be selected by the pilot for encoding or decoding beacon signals. The encoding and decoding codes are determined during mission briefing or by direct radio contact with the radar site. Encode/decode options provide flexibility in selecting ground stations and identifying aircraft.

1.16.1 Beacon Controls and Displays. Pilot control of beacon operation is via the UFC and the ODU. See Figure 1-227. The UFC is used to select and apply power to the radar beacon set. Radar beacon mode selection (NORM, STBY) and pulse codes are selected on the ODU.

1.16.2 Radar Beacon Programming. Pressing the BCN pushbutton on the UFC brings up the radar beacon options on the ODU. See Figure 1-228. The upper two windows display the radar beacon operating options: standby (STBY) and normal (NORM). The last entered pulse code is displayed in the bottom option window.

Once the system is turned ON, an approximate 30-second warmup time is required for system operation. In the STBY mode transponder outputs are inhibited. In NORM, the transponder is capable of responding when interrogated. The STBY mode provides the capability to warmup the system to permit immediate operation when NORM is selected. NORM and STBY are mutually exclusive such that selecting one automatically deselects the other.

The power ON/OFF switch on the UFC applies power to the radar beacon set. See Figure 1-229.

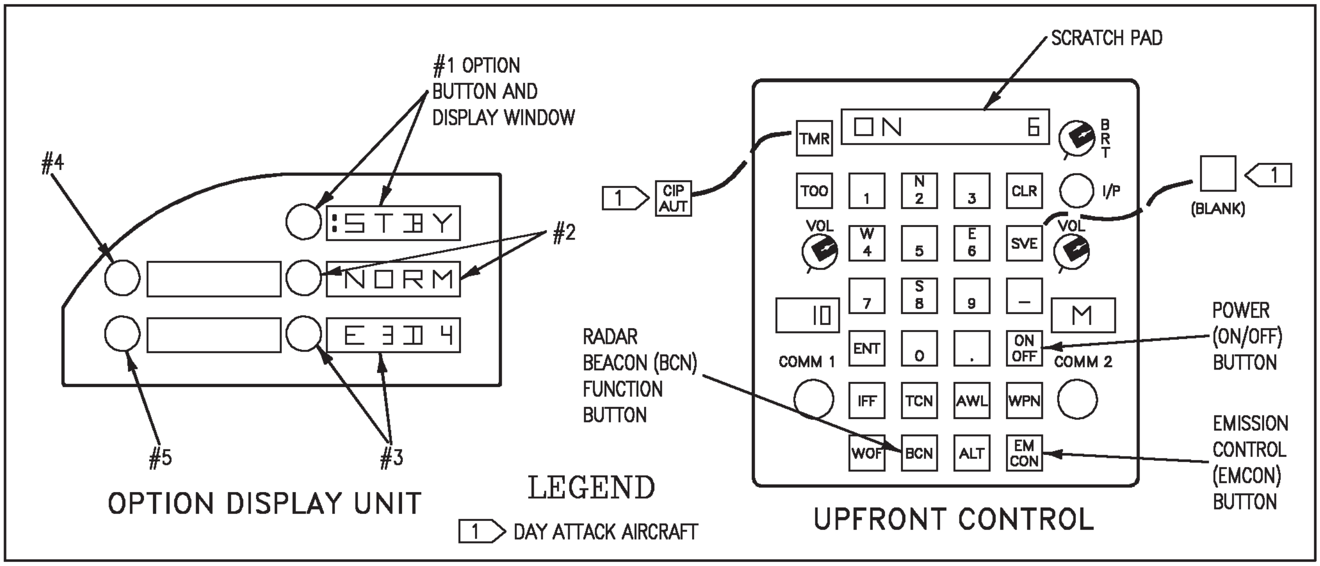
Selecting BCN with EMCON selected displays the STBY and pulse code options on the ODU. NORM is not displayed since it is not selectable during EMCON operation. See Figure 1-230. Selecting EMCON automatically switches the beacon to standby. Selecting EMCON with BCN selected displays the EMCN legend in place of STBY in the number one ODU window to denote emission control operation. A colon is also displayed next to the EMCN legend. All other ODU legends and the scratch pad blank upon EMCON selection. Deselecting EMCON will return the beacon to its previous operating state.

Pulse code selection, either single or double pulse code, is initiated by pressing the third option button on the ODU. This brings up four pulse code options on the ODU: encode single pulse (ESGL), encode double pulse (EDBL), decode single pulse (DSGL) and decode double pulse (DDBL). See Figure 1-231.

Pressing either the single pulse encode (ESGL) or decode (DSGL) options restores the beacon options on the ODU and updates the respective pulse mode legend shown in the third window to correspond to the selected encode or decode single pulse. For example, if the ESGL option is selected, the ODU would be updated to show ES as the first two digits in the third option display window. See Figure 1-232.

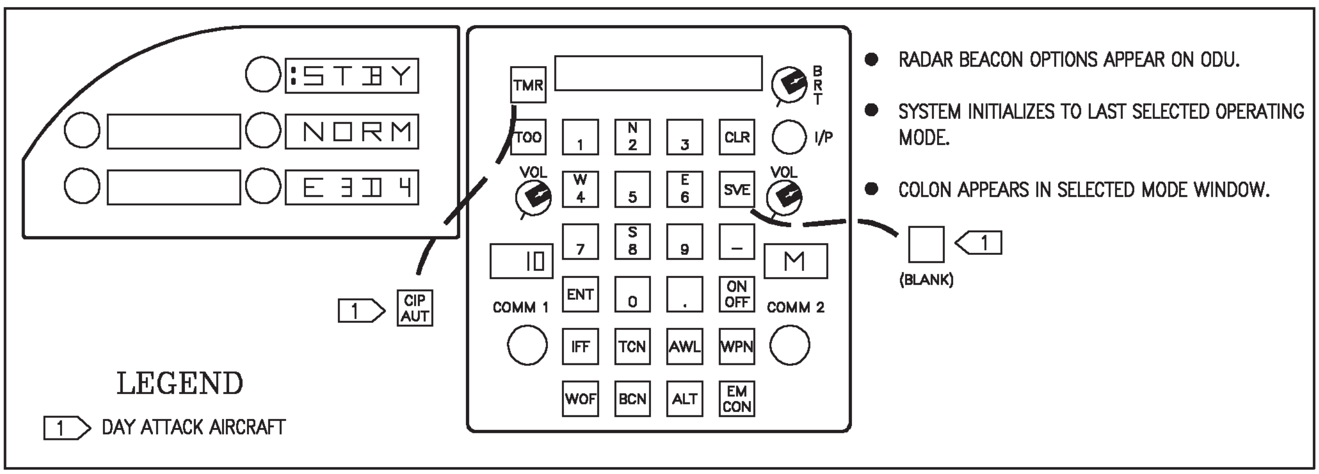
Selecting either the encode double pulse (EDBL) or decode double pulse (DDBL) option will display the double pulse options on the ODU. See Figure 1-233. Five option codes (1 through 5) are available.

Pressing one of these codes will cause the ODU to revert to the beacon options and update the pulse mode legend shown in the third window for whichever (encode or decode) function was selected. Double pulse code selection is indicated by the selected numeral (1 through 5) appearing after the encode (E) or decode (D) legend in the third window: For example, if option 5 double pulse is pressed for encode and option 3 double pulse is pressed for decode, the ODU display will be as shown in Figure 1-234.



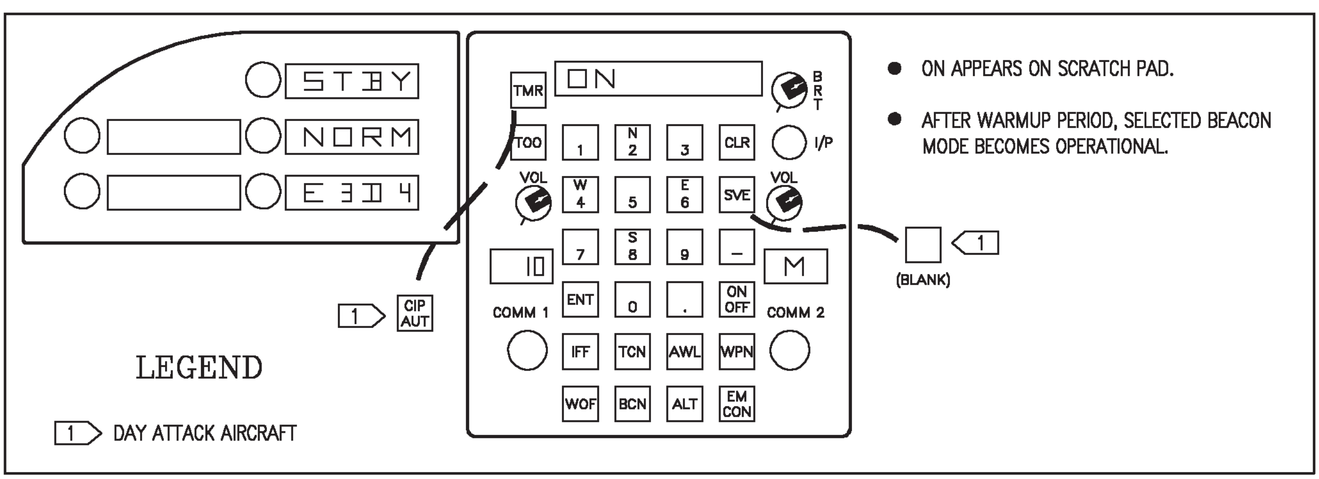
AV8BB–TAC–00–(23–1)11–CATI

Figure 1-227. Radar Beacon Control



AV8BB–TAC–00–(160–1)11–CATI

Figure 1-228. Beacon Options (BCN Selected)



AV8BB–TAC–00–(118–1)11–CATI

Figure 1-229. Beacon ON

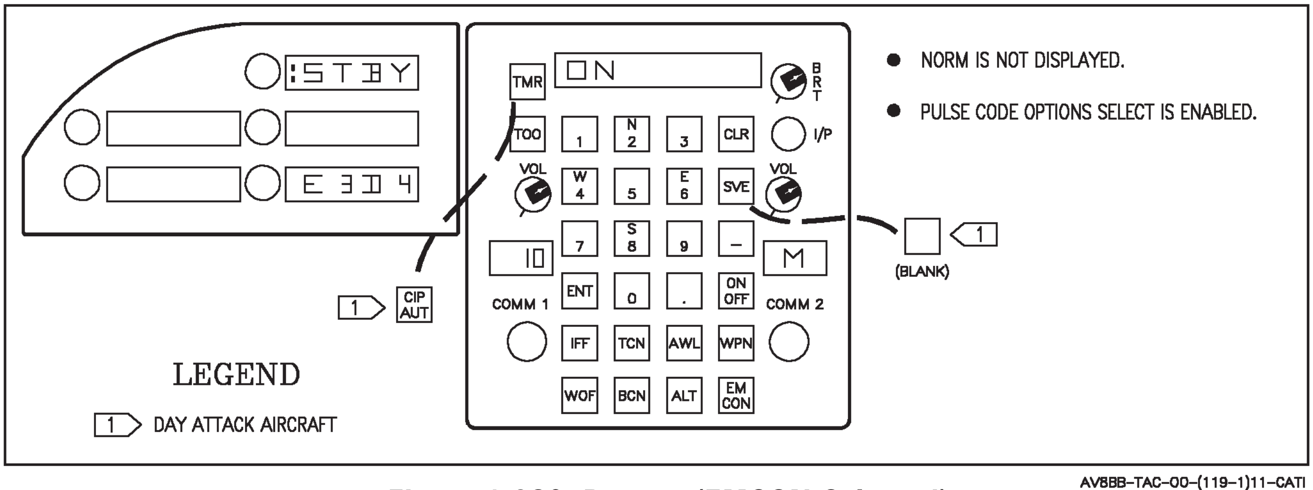


Figure 1-230. Beacon (EMCON Selected)

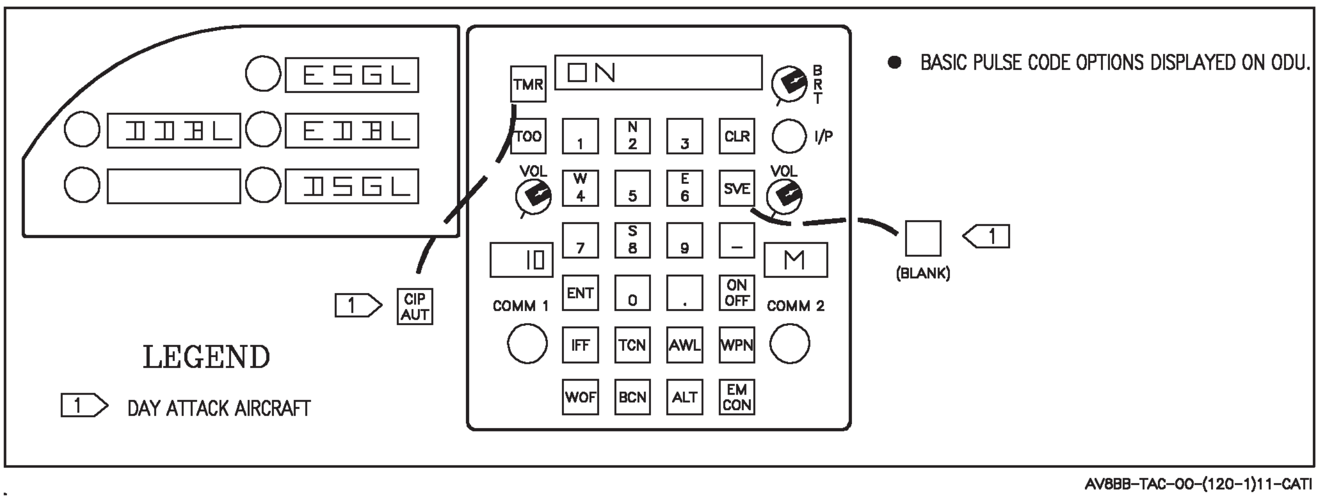


Figure 1-231. Pulse Code Selection

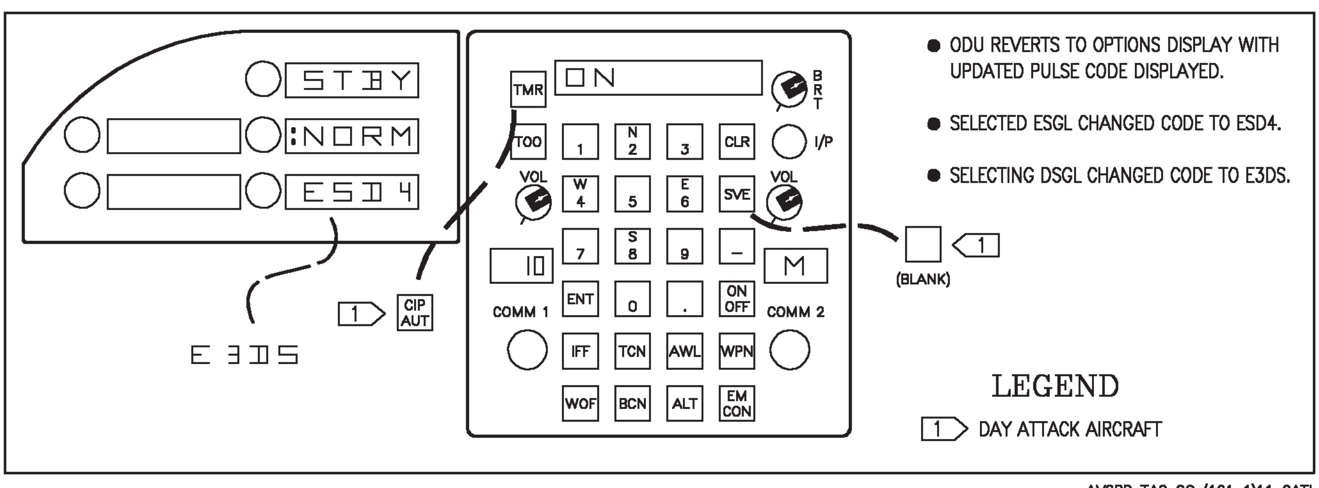


Figure 1-232. ESGL/DSGL Code Selection

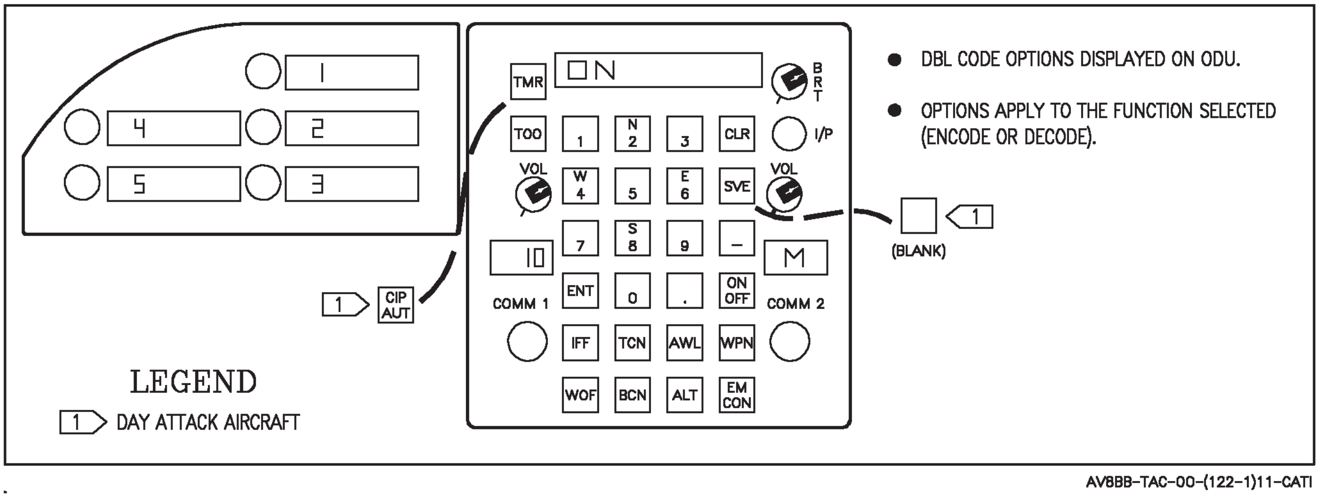


Figure 1-233. EDBL/DDBL Options

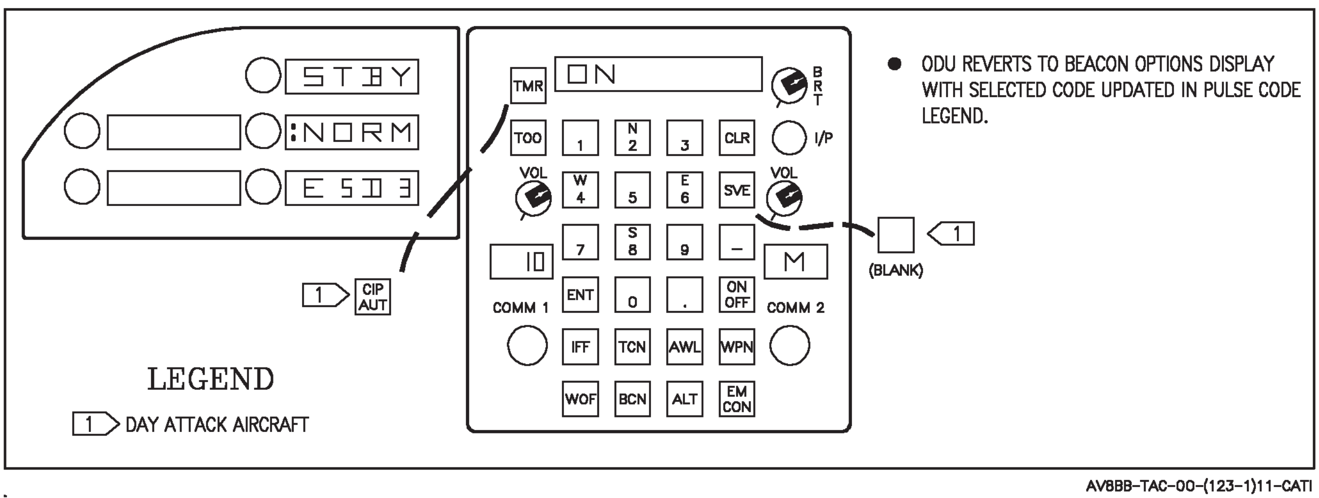


Figure 1-234. Double Pulse Code Selection

1.17 AUTOMATIC TARGET HANDOFF SYSTEM (ATHS)

1.17.1 Description. The automatic target handoff system provides a digital communication link between the forward air controller (FAC), airborne observer (AO), or shipboard system and the AV-8B with a high degree of security, efficiency and speed. The system allows for transmitting and receiving CAS briefs, AAW briefs, free text, on station reports, clearance and abort messages. The system is capable of communicating with both Army and USAF FACs and AOs as well as USMC FACs. Received data is displayed in USMC format. The ATHS provides the following advantages over conventional methods:

- Reduces time in a hostile zone while entering mission data into the navigation target logic.
- Reduces voice transmissions which may give opposing forces location information.
- Increases target data accuracy caused by poor voice transmissions or interference.
- Allows the pilot to communicate with the Army and the Air Force.

1.17.1.1 Component Description. The ATHS integrated system is comprised of aircraft and ground components. See Figure 1-235.

1.17.1.1.1 Aircraft Components. The aircraft components of the ATHS are the Processor-Interface Unit (serves as modem), the mission computer (controls avionics), the control and display subsystem (display computer, HUD, UFCS, MPCD) and the communication system (ARC-182 or ARC-210 radios and KY-58 encryption equipment).

1.17.1.1.2 Ground Components. The ground counter-parts for the ATHS II can vary. The USMC has fielded several FO/FAC systems that communicate via MTS (Marine Tactical Systems) protocol. The fielded DCT (Digital Communication Terminals) do not support the airborne message necessary for a CAS mission, however a specific software load was developed for the DCT to test the airborne ATHS but has not been fielded. The Army has fielded ATHS I that only communicates via TACFIRE protocol and the ATHS II is compatible with TACFIRE protocol. The USAF uses AFAPD protocol with the IDM that the ATHS II is also compatible with.

1.17.1.2 CONTROLS AND INDICATORS. See Figure 1-236. The controls and indicators for the aircraft segment of the ATHS include the UFC, ODU, MPCD and HUD.

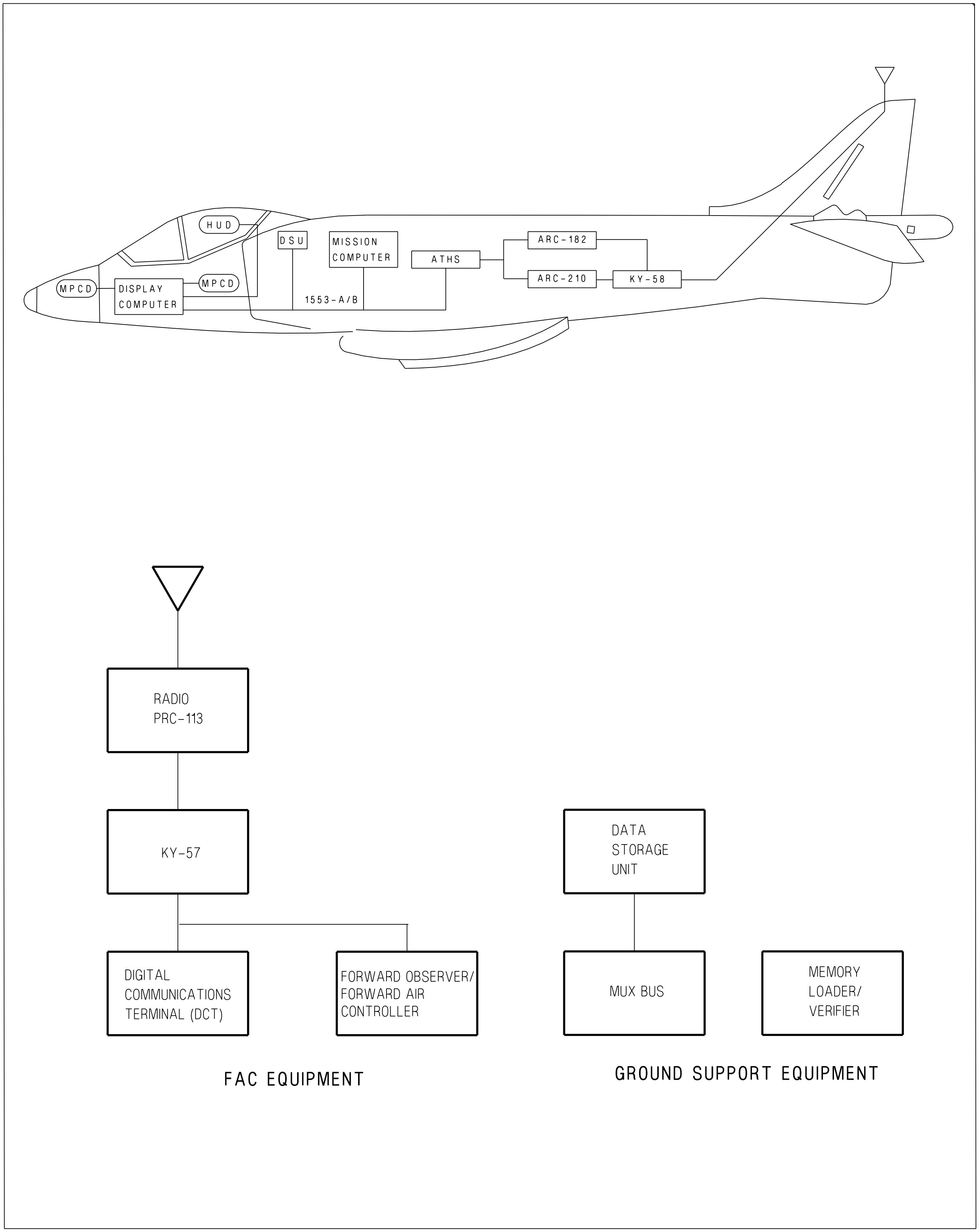
1.17.1.2.1 Upfront Control. This control is used for entering numerical data when editing a CAS brief, network page or a free text message. The keyed entry is displayed on the scratchpad prior to entry.

1.17.1.2.2 Option Display Unit. This control/indicator provides a way of displaying and selecting various options available for ATHS operation. Options are available for editing CAS briefs, free text messages and network parameters. Options are also available for accepting or rejecting a received CAS brief, AAW brief or free text message.

1.17.1.2.3 Multipurpose Color Display. The CAS brief, free text message, network parameters, and recall displays are presented on this control/indicator. The 20 pushbutton switches surrounding the CRT provide display selection and control.

1.17.1.2.4 Head-Up Display. This indicator displays primary flight and attack data, a flashing legend alerts the pilot that a CAS brief, free text, or OSR message was received from the FAC and is waiting to be displayed. A flashing AAW indicates Anti-Aircraft Warfare (AAW) mission data was received from the FAC. A flashing HOT message indicates mission clearance from the FAC and a flashing ABORT legend is a mission abort message from the FAC. The flashing HOT message may include a “Move Impact Direction and Distance Command” displayed beneath the HOT legend. See Figure 1-237.

1.17.2 Operation. The AV-8B aircraft are usually pre-briefed with the address and the frequency of their FAC/AO contact. Each mission may be comprised of a lead aircraft and 0, 1, 2 or



AHR607-699-1-013

Figure 1-235. ATHS Integrated System Block Diagram.

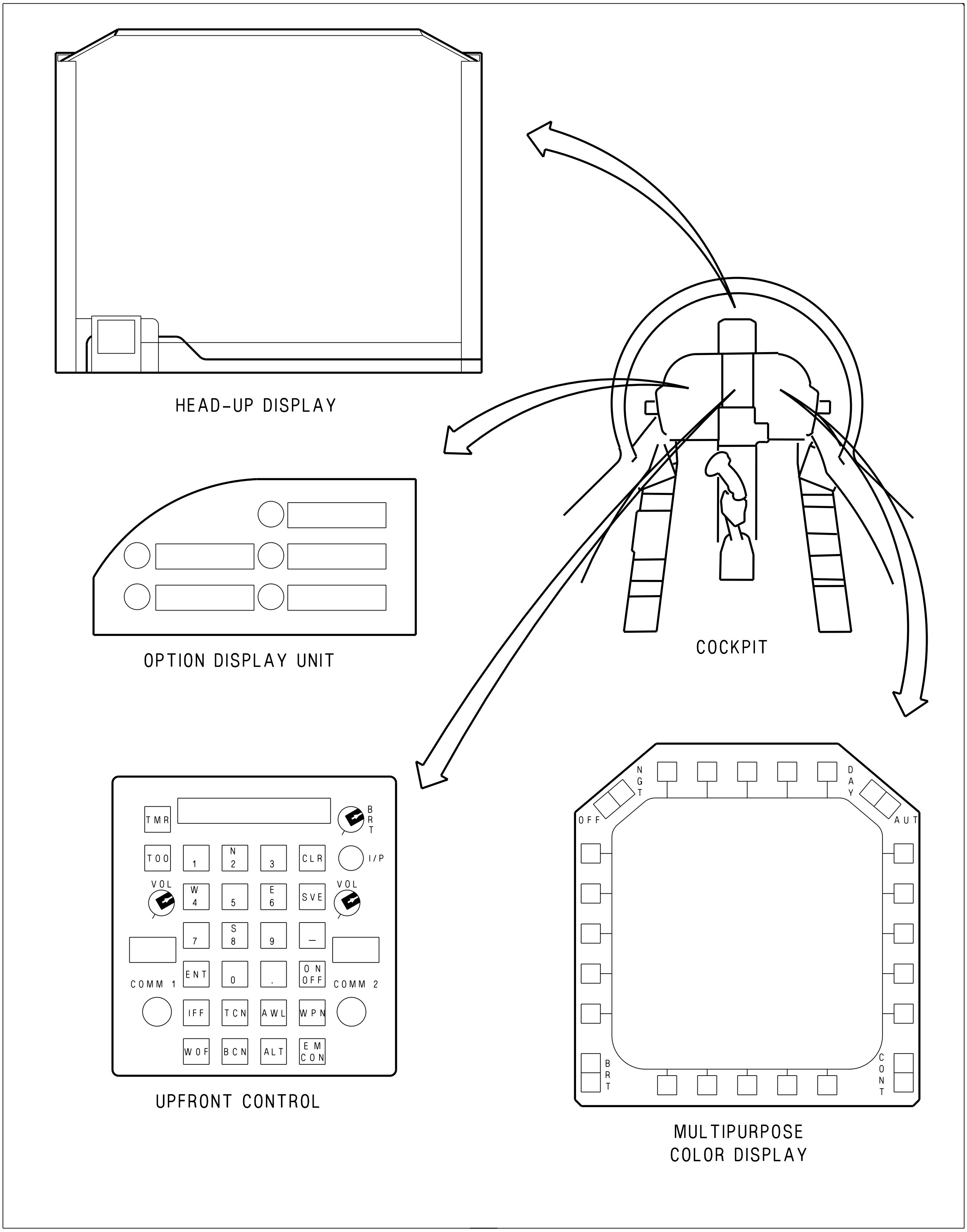


Figure 1-236. ATHS Controls and Indicators

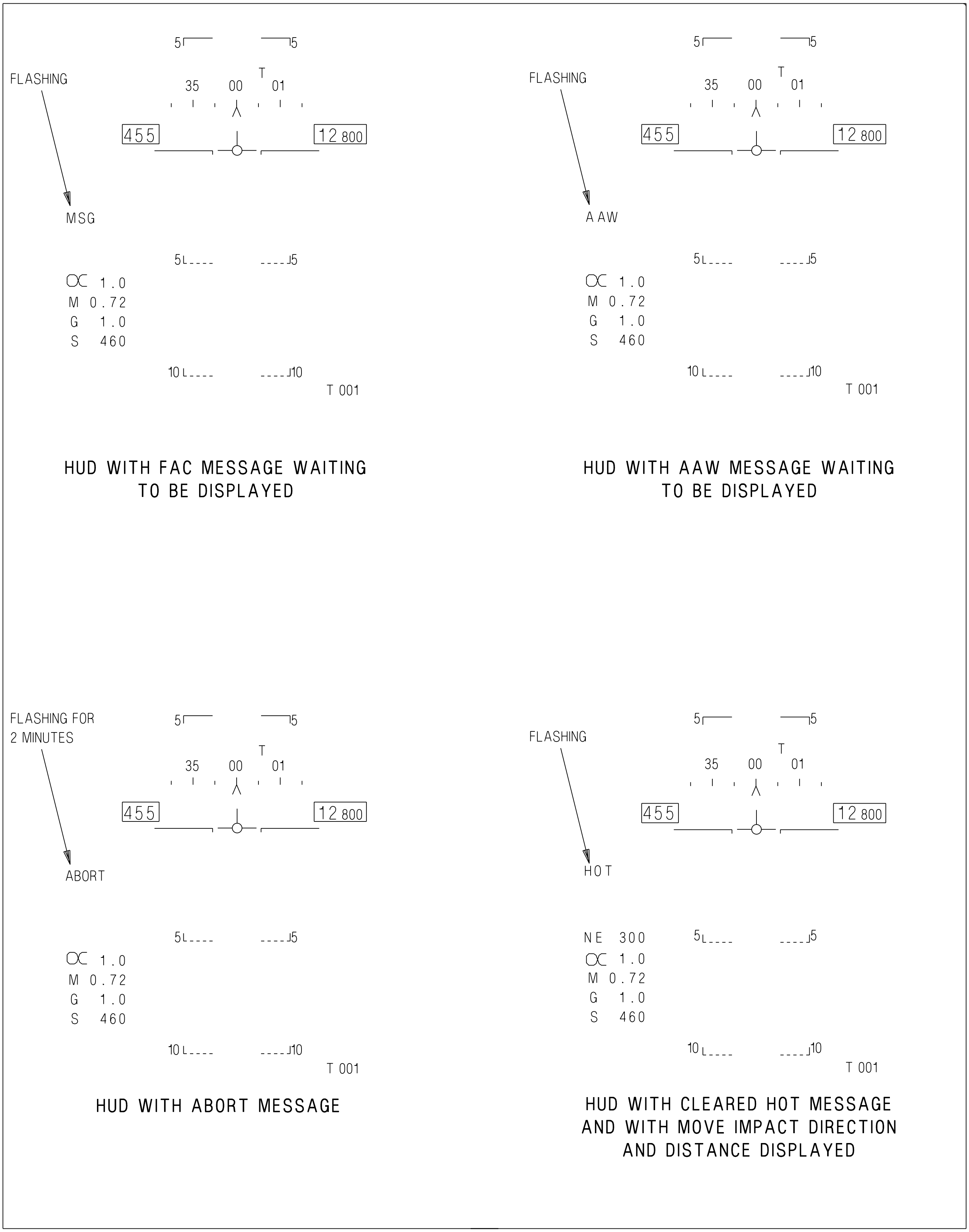


Figure 1-237. HUD ATHS Displays

3 wingmen with the capability of changing the lead or swapping aircraft data as needed. Voice radio is used as the primary communication mode until the aircraft arrives at the control point (CP). Voice radio is also the backup for the ATHS.

1.17.2.1 Marine Corps Scenario. When the pilot of the lead aircraft arrives at the CP, he will send the FAC an on station report (OSR) containing the necessary aircraft and ordnance data and the FAC will acknowledge it. The FAC will then send a nine line CAS brief to the lead aircraft and wingmen. The lead pilot may accept or reject the brief, or exchange edited versions of the brief with the FAC until they are in agreement. Only the lead pilot can accept or reject a brief, wingmen receive information copies. Free text or voice communication messages may also be exchanged to clarify data or instructions in the brief. Each edited version of the brief and any free text message is also sent as information copies to the wingmen. After agreement is reached, the lead pilot will press the departing initial point (DPIP) button to alert the FAC that the aircraft is inbound to the target from the initial point (IP) and the FAC will issue a mission clearance to each pilot (flashing HOT legend on HUD). The FAC may at any time issue an individual or general abort mission command (flashing ABORT legend on HUD).

1.17.2.2 Air Force Scenario. The Air Force does not use time-on-target data or exchange edited versions of briefs. Changes to briefs are transmitted via voice radio. When the pilot of the lead aircraft arrives at the CP, he will send the FAC an OSR containing the necessary aircraft and ordnance data and the FAC will acknowledge it. The FAC will then send a CAS brief to the lead aircraft and information copies to the wing aircraft. Only the lead pilot can accept or reject the brief. The FAC and the lead pilot will discuss changes to the brief, via voice radio, until they are in agreement. Each wingmen will be listening to the verbal exchange regarding changes to the brief and update his own CAS brief page. After agreement is reached, the FAC will issue a verbal mission clearance to each pilot or a general cleared hot and each pilot in turn will press the DPIP button to alert the FAC that his aircraft is inbound to the target from the IP. The FAC may at any time issue an individual or a general verbal abort mission command.

1.17.2.3 Army Scenario. The Army has three significant differences in their communication format. First, the Army uses an AO instead of a FAC. Second, the Army has a limit of 48 characters per message requiring two or more messages to be sent, in order to transmit the needed data. Third, the Army recognizes only the lead aircraft address, so the lead and all wing aircraft must use the same address to receive messages from the Army. When the pilot of the lead aircraft arrives at the CP, he will send the AO an OSR, via two or more messages, containing the necessary aircraft and ordnance data, and the AO will acknowledge it. The AO will then send a CAS brief, also via two or more messages, to the common address of all aircraft in the mission. Only the lead pilot can accept or reject the brief. The AO and the lead pilot may exchange edited versions of the brief until they are in agreement. Free text messages may also be exchanged to clarify data or instructions in the brief. Each pilot edited version of the brief and any free text messages will be sent as information copies to the wingmen. Since the aircraft have a common address for Army format, the wingmen will automatically receive copies of each AO edited brief or message. After agreement is reached, the AO will issue a single mission clearance to the common address and each pilot will press the DPIP button to alert the AO that his aircraft is inbound to the target from the CP. The AO may at any time issue an abort mission command.

1.17.2.4 Anti-Air Warfare Scenario. The controller transmits an Anti-Air Warfare (AAW) message to the AV-8B aircraft using the Marine Tactical System (MTS) protocol. This message provides a location, altitude, intercept course and other data to enable the AV-8B to engage the threat aircraft. When the AAW message is received by the aircraft, AAW flashes on the HUD. After the lead pilot accepts the AAW task, the data to the aircraft can be updated in a 5 to 20 second window, after each transmission. The location of the threat aircraft is given in latitude/longitude and is referenced to the AV-8B aircraft. The 20 second counter starts upon the receipt of the controller's automatic response of the lead pilot's acceptance of the AAW mission. If the lead pilot and the controller agree that an automatic response (AR) is not required after the lead pilot accepts the AAW mission, the lead pilot can turn his AR to OFF and this reduces the minimum time for an update rate to two seconds. The wingmen will automatically set AR to OFF.

1.17.2.5 Anti-Ship Warfare Scenario (ASW). The ASW function is supported by using the existing CAS brief. The target elevation for ASW is zero.

1.17.3 The CAS Display. The CAS display (Figure 1-238) is enabled by pressing the CAS pushbutton on the MPCD menu display. The last selected CAS brief is displayed. The displayed brief is enabled for editing.

1.17.3.1 Received CAS Brief. The flashing MSG legend on the HUD cues the pilot that a message was received. Selecting the RECV pushbutton on the CAS display enables the received message on the display. It stays boxed until ACPT or REJ selected of ODU. The received message may be a CAS brief or a free text message (TXT would be flashing). If a CAS brief was received (Figure 1-239) the pilot of the lead aircraft must accept, reject, or save the brief. The ACPT and REJ options are displayed on the ODU for the lead aircraft only.

1.17.3.1.1 Accepting the Brief. If the pilot chooses to accept the brief, the ATHS transmits a WILCO (Will Comply) to the FAC and displays OK for the pilot status when an auto response is received from the FAC; otherwise it displays a '?'. The FAIL legend is displayed for the FAC status if an auto response is not received from the FAC. ACPT/REJ will still be displayed and the message can be retrieved by selecting ACPT again.

1.17.3.1.2 Rejecting the Brief. If the lead aircraft rejects the brief, then he must edit the brief and transmit it to the FAC for review (USMC/ARMY formats). Changes to the brief for USAF are discussed verbally and the pilots must update their displays manually. The FAC will either accept or reject the edited version of the brief. Messages between the lead aircraft and the FAC are transmitted to the wing aircraft as information copies and displayed on their MPCDs once received (pressing RECV on their respective CAS pages).

1.17.3.1.3 Saving the Brief. The pilots can choose to save the CAS brief if the brief is for future use or to transmit to another FAC. This is accomplished by selecting the SAVE pushbutton on the CAS display.

1.17.3.1.4 Editing the CAS Brief. The edit function is enabled when: (1) CAS display is initially selected, (2) a stored CAS brief is recalled, (3) a received CAS brief is accepted or rejected. The edit display initializes with line 14 TOT enabled for editing, as indicated by the asterisk unless the IP name sent was not found in the aircraft system and a manual IP must be entered. See Figure 1-240 for a typical edit display. To select other lines for editing move the asterisk, using the up and down arrows, to the line to be edited. The line selected can be edited by using the UP and DOWN pushbuttons, the RECALL menu and the UFC. The following is a description of the line by line edit process:

1. Line 1. The IP is edited by entering a waypoint number between 0 and 24 on the UFC.

2. Line 2. The IP offset bearing (bearing to the target) is edited using the UFC. The options available are BNG, R (right), L (left) and NONE. Selecting BNG enables the scratch pad for entering the desired bearing. If a valid UTM was entered for the selected IP waypoint then the UTM bearing (UTMB) is automatically calculated and displayed. Conversly if a lattitude/longitude is entered POS B is automatically calculated and displayed. The R and L options are for selecting a right or left offset approach to the target. Selecting NONE erases the R or L offset.

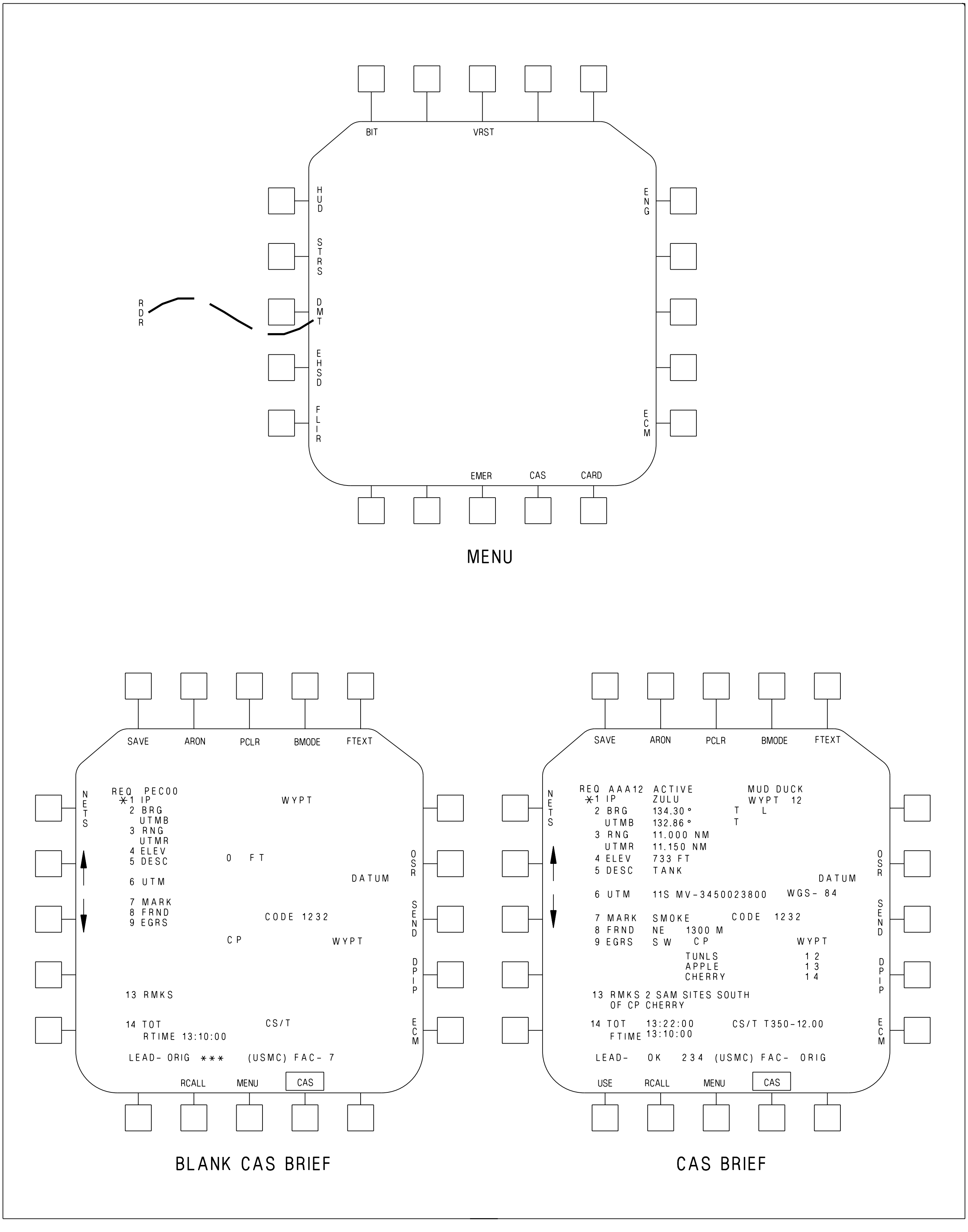


Figure 1-238. The CAS Display

3. Line 3. Range to the target is edited using the UFC. Range can be entered in nautical miles or meters. Range entries equal to or less then 100 are considered to be nautical miles. Nautical mile entries can be to hundredths of a nautical mile if a decimal is entered. Meters are entered in whole numbers only. If a valid UTM was entered for the selected IP waypoint then the UTM range (UTMR) is automatically calculated and displayed.

4. Line 4. Target elevation is edited using the UFC. Valid entries are −2000 to 25,000 feet.

5. Line 5. Target description is edited using the UP and DOWN pushbuttons. These pushbuttons are displayed when the asterisk is placed on line 5. The UP and DOWN pushbuttons allow the pilot to step through the following target descriptions to select the appropriate choice:

UNKN	EQPMT
PERSNL	BLDG
WPN	TERR
MORTAR	ASSEMB
ARTIL	AAA
ARMOR	BRIDGE
VEHCL	RKTLAU
RKTS	SHIP
S DUMP	DAM
CCC	FORTIF

6. Line 6. Target position is defined by UTM coordinates, latitude and longitude, or both. UTM is the default if both UTM and latitude and longitude are present in the CAS brief. If UTM is displayed on line 6 the ODU initializes with the UTM option selected and the applicable two-letter alpha identifiers displayed in options 2 thru 5. UTM coordinates are entered in the same manner as presented in A1-AV8BB-NFM-000, chapter 23. If latitude and longitude are displayed on the CAS brief the ODU is initialized with the LAT and LONG options displayed. Selecting the desired option enables editing via the UFC.

7. Line 7. Two ODU options are displayed for target marking, MARK and CODE. The options are displayed when line 7 is selected for editing and initialize with the MARK option selected. Target marking is edited using the UP and DOWN pushbuttons. These pushbuttons are displayed when the asterisk is placed on line 7 and MARK is selected on the ODU. The UP and DOWN pushbuttons allow the pilot to step through the following mark descriptions to select the appropriate choice:

SMOKE	LASER
FLARES	STROBE
MIRROR	VEHLT (vehicle)
GAIL	CSMOKE
LIGHT	WP
PANELS	IR
FIRE	NONE

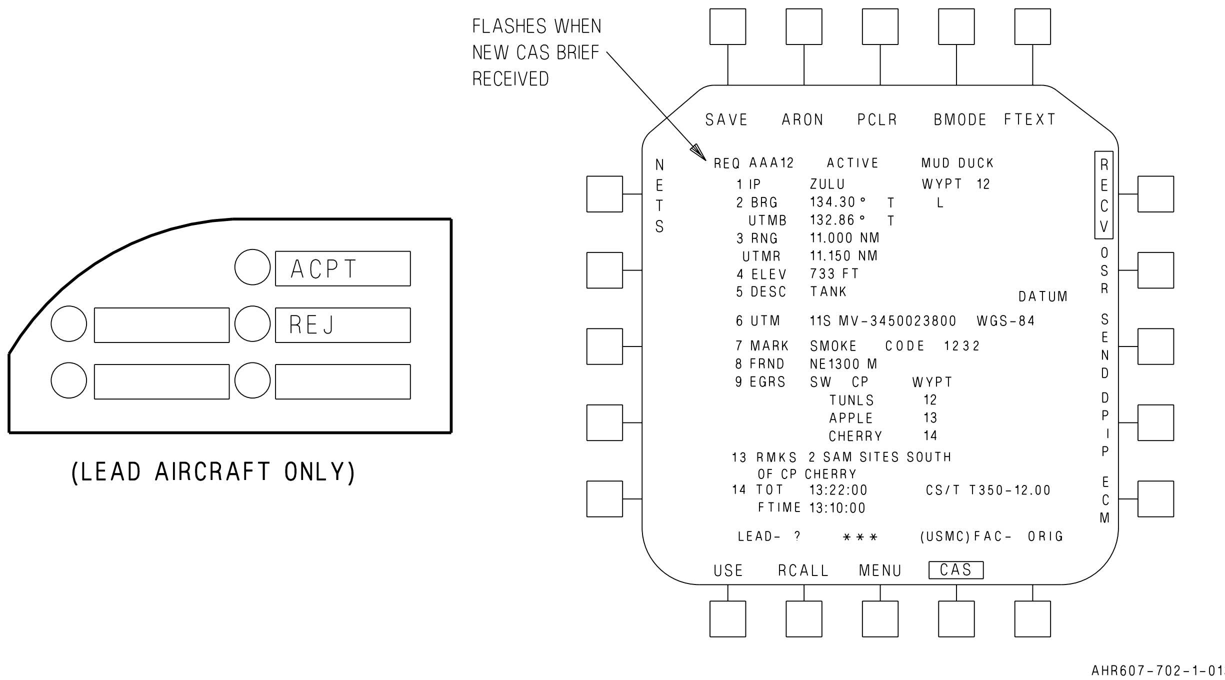
The laser code entry is enabled by selecting the CODE option on the ODU. When selected the UFC is enabled for code entry.

8. Line 8. Two ODU options are displayed for entering the position of friendly forces, DIR (direction) and DIST (distance). These options are available when line 8 is selected for editing and initialize with the DIR option selected. Direction is edited using the UP and DOWN pushbuttons. These pushbuttons allow the pilot to select one of eight cardinal directions (N, NE, E, SE, S, SW, W, NW). Distance to friendly forces is entered by selecting the DIST option on the ODU and entering the distance, 0 to 10,000 meters, on the UFC.

9. Line 9. Five ODU options are displayed for entering egress CPs and direction; these options are CP1, CP2, CP3, DIR and CLR. The options are available when line 9 is selected for editing and initialize with the CP1 option selected. The UFC is used to enter a waypoint number between 0 and 25. Selecting the DIR option enables the egress direction to be edited using one of eight possible egress directions (N, NE, E, SE, S, SW, W, NW) as selected on the UFC (1 thru 9, excluding 5). The CLR option is used to clear the entry for the currently selected CP. This option is only available when a CP option is selected (cued).

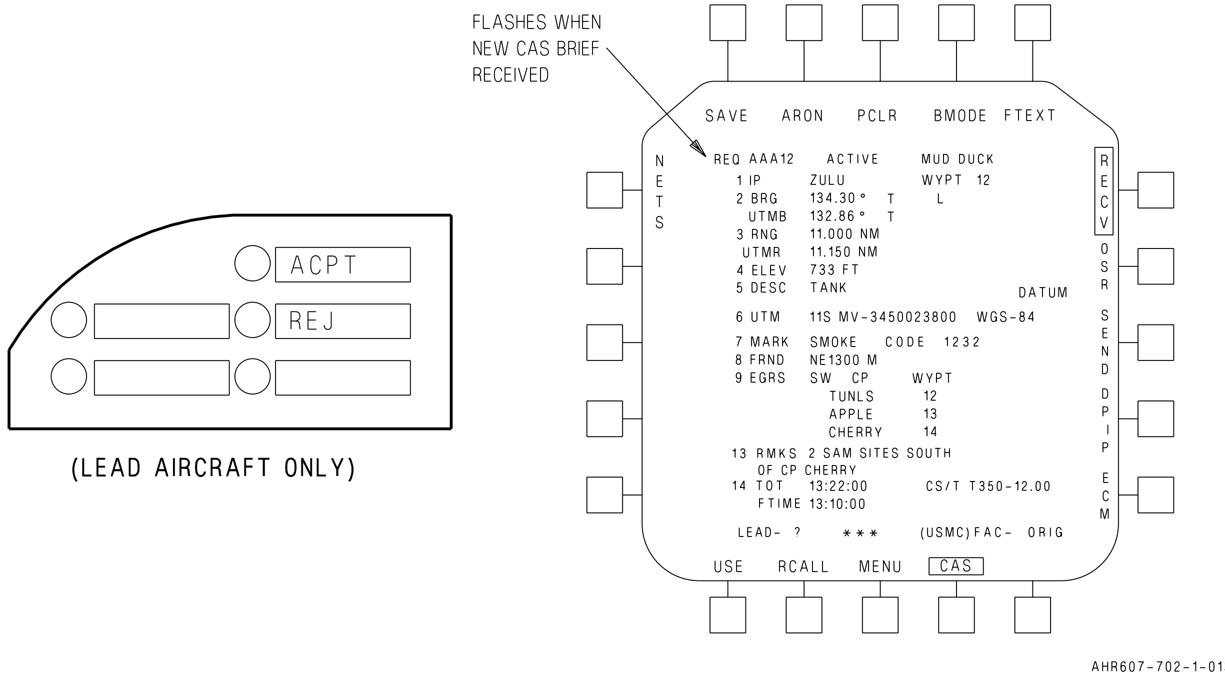
10. Line 13. The pilot must use the HOTAS ALPHA function to edit remarks.

11. Line 14. Time-on-target (TOT), command speed/time (CS/T), and FAC time (FTIME), GPS time (GTIME), or real time (RTIME) is displayed. The mission computer calculates and displays CS/T based on the difference in time between the TOT and FTIME, GTIME, or RTIME. The route is **always** aircraft to IP to CAS offset. This should be used to evaluate if the brief should be accepted or a new TOT should be negotiated with the FAC. The pilot can edit TOT using the UFC. The mission computer recalculates CS/T when a new TOT is entered.



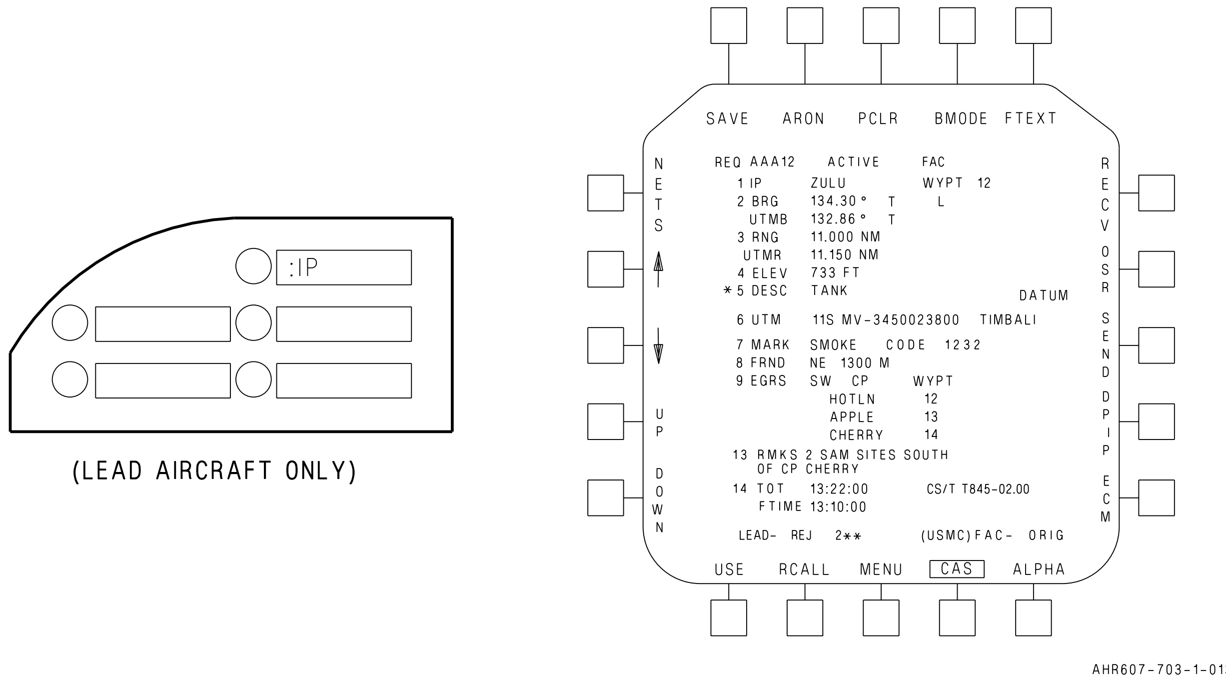
PUSHBUTTON	FUNCTION
SAVE	Stores CAS brief, maximum of 18 CAS briefs may be stored. If memory locations are full, overwrites oldest brief.
ARON/AROFF	Enables/disables the auto response function. Scrolls between ARON and AROFF.
PCLR	When pressed, the page is cleared of all data. The displayed CAS brief is deleted and if a CAS brief was in temporary storage it will be displayed.
BMODE	When pressed, broadcast mode is enabled. Each time SEND is pressed, the message goes to all receivers for the selected NET. Response messages (ACPT/REJ) are not requested and, if sent, not processed.
FTEXT	When pressed, boxes legend and selects the free text display, Figure 1-245.
RECV	When pressed, boxes legend and displays received message. This action is cued by flashing ‘MSG’, ‘TXT’, ‘OSR’, ‘AAW’, legend on the HUD. Received message may be a CAS brief, free text, on station report or AAW message.
OSR	Selects OSR display, Figure 1-243.
SEND	When pressed, transmits displayed CAS brief to FAC for acceptance or rejection, and transmits an information copy to the wingman. Legend remains boxed until automatic response is received.

Figure 1-239. Received CAS Brief (Sheet 1 of 2)



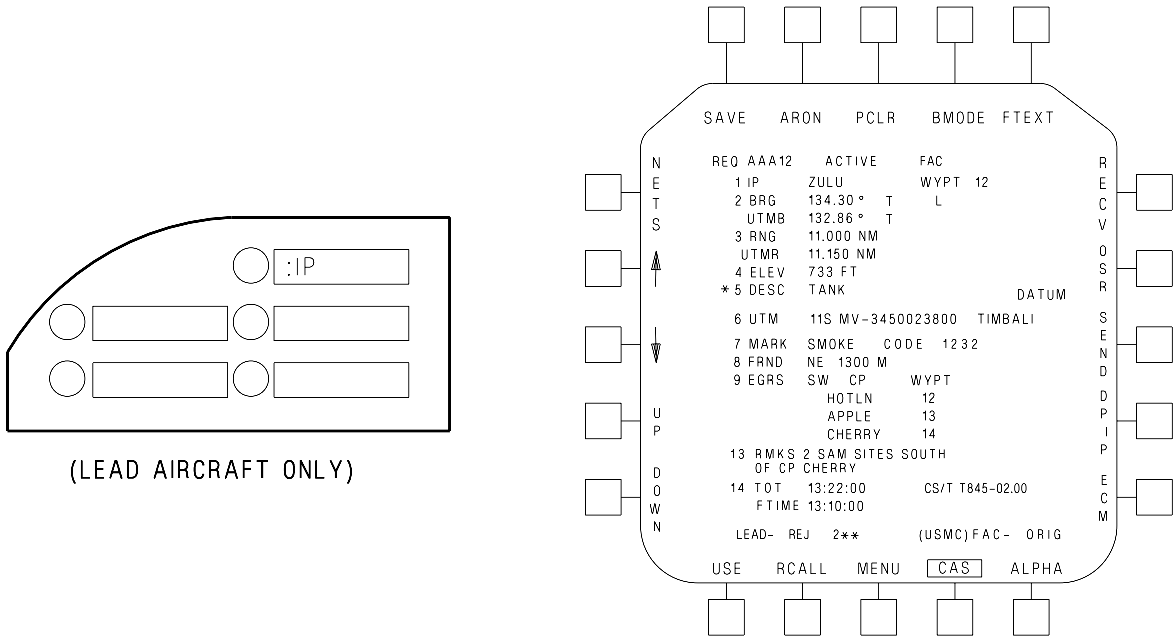
PUSHBUTTON	FUNCTION
DPIP	Departing initial point, when pressed, alerts FAC that the aircraft is inbound to the target from the initial point. Legend remains boxed until automatic response is received.
ECM	Selects RWR display, legend boxed when selected, returns to this display when deselected.
CAS	Enable/disables UFCS for data entry.
MENU	When pressed, deselects this display and enables menu display.
RCALL	When pressed, legend is boxed and recall CAS brief is displayed. See Figure 1-241.
USE	When selected, loads CAS brief parameters into the mission computer navigation and targeting logic, includes laser code if applicable.
NETS	Selects NETS display, Figure 1-252.
ACPT	Displayed for lead aircraft only. When selected, transmits a WILCO to the FAC.
REJ	Displayed for lead aircraft only. When selected, rejects received CAS brief, transmits a CANTCO (cannot comply) to the FAC and enables the CAS brief edit mode, Figure 1-240.

Figure 1-239. Received CAS Brief (Sheet 2 of 2)



PUSHBUTTON	FUNCTION
SAVE	Stores CAS brief, maximum of 18 CAS briefs may be stored. If memory locations are full, overwrites oldest brief.
ARON/AROFF	Enables/disables the auto response function. Scrolls between ARON and AROFF.
PCLR	When pressed, the page is cleared of all data. The displayed CAS brief is deleted and if a CAS brief was in temporary storage it is displayed.
BMODE	When pressed, broadcast mode is enabled. Each time SEND is pressed, the message goes to all receivers for the selected NET.
FTEXT	When pressed, boxes legend and selects the free text display, Figure 1-245.
RECV	When pressed, boxes legend and displays received message. This action is cued by flashing 'MSG', 'TXT', 'OSR', 'AAW', legend on the HUD. Received message may be a CAS brief, free text, on station report or AAW message.
OSR	Selects OSR display, Figure 1-243.
SEND	When pressed, transmits displayed CAS brief to FAC for acceptance or rejection, and transmits an information copy to the wingman. Legend remains boxed until automatic response is received.
DPIP	Departing initial point, when pressed, alerts FAC that the aircraft is inbound to the target from the initial point.

Figure 1-240. Editing a CAS Brief (Sheet 1 of 2)



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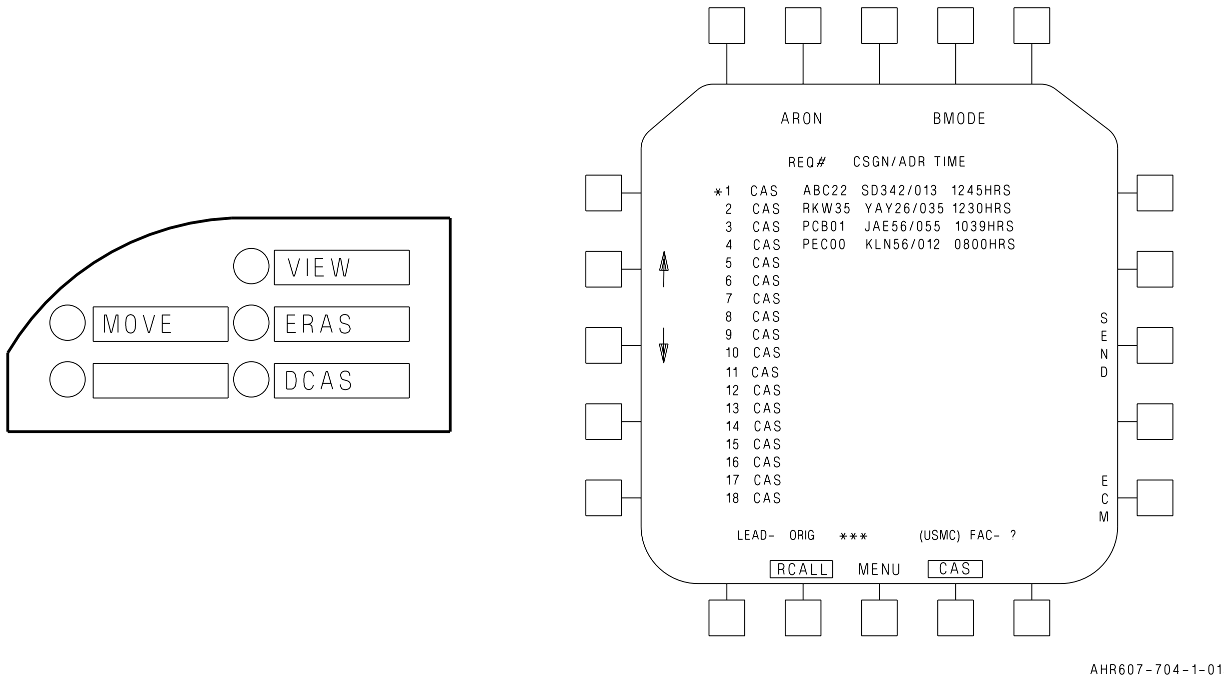
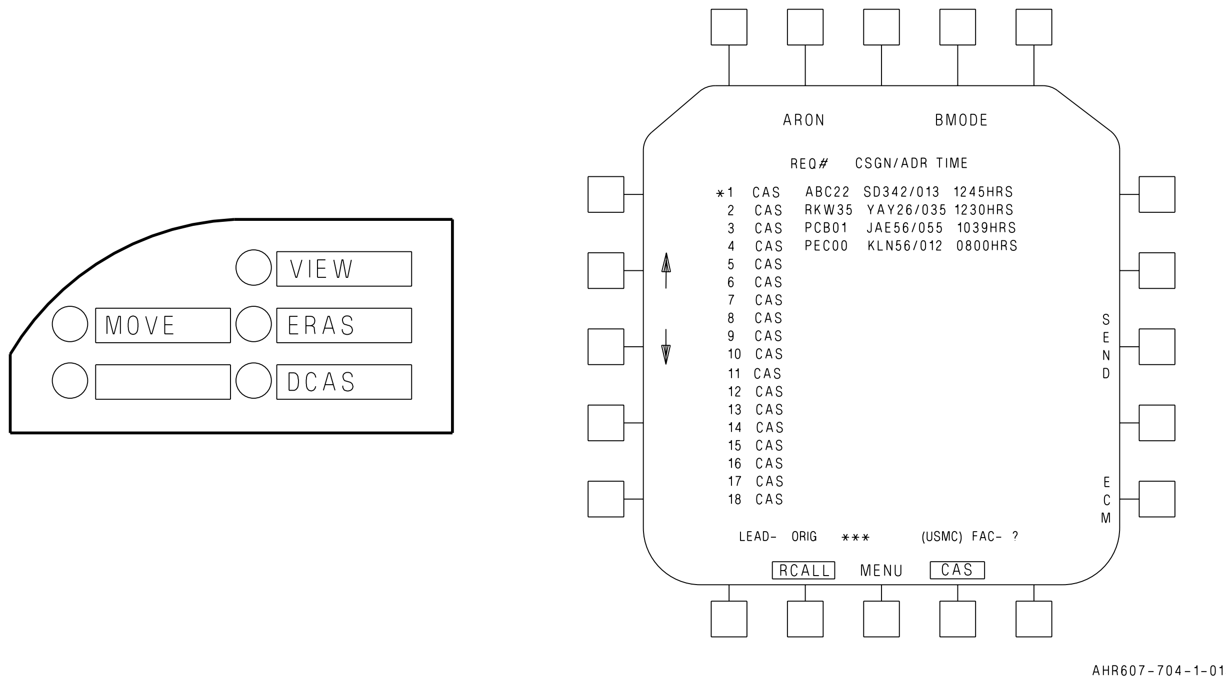
PUSHBUTTON	FUNCTION
ECM	Selects RWR display, legend boxed when selected, returns to this display when deselected.
ALPHA	Selects ALPHA menu, Figure 1-250.
CAS	Enable/disables UFCS for data entry.
MENU	When pressed, deselects this display and enables menu display.
RCALL	Selecting this pushbutton displays the recall CAS brief page, Figure 1-241.
USE	When selected, loads CAS brief parameters into the mission computer navigation and targeting logic, includes laser code if applicable.
UP/DOWN	Displayed only when the line to be edited is associated with a set of preprogrammed choices for the selected parameter (DESC and MARK only). The UP/DOWN pushbuttons allow the pilot to step through the available choices.
up/down arrow	Used to select the line to be edited by moving the asterisk to the desired line.
NETS	Selects NETS display, Figure 1-252.

Figure 1-240. Editing a CAS Brief (Sheet 2 of 2)



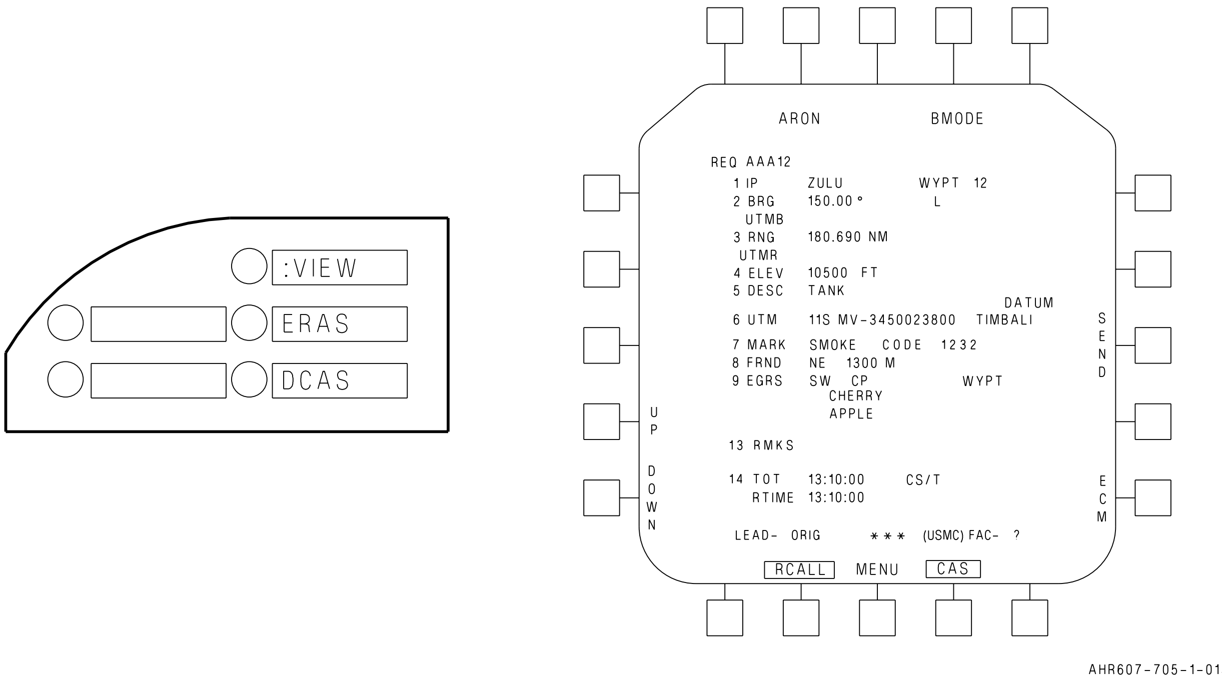
PUSHBUTTON	FUNCTION
ARON	Enables/disables the auto response function. Scrolls between ARON and AROFF.
BMODE	When pressed, broadcast mode is enabled. Each time SEND is pressed, the message goes to all receivers for the selected NET.
SEND	When pressed, transmits displayed CAS brief to the current FAC for acceptance or rejection, and transmits an information copy to the wingman. Legend remains boxed until automatic response is received.
ECM	Selects ECM display, legend boxed when selected, returns to this display when deselected.
CAS	Deselecting CAS returns to previous display.
MENU	When pressed, deselects this display and enables menu display.
RCALL	Deselecting RCALL returns to the CAS page with no action on the selected CAS message.
up/down arrows	Used to select the CAS brief by moving the asterisk to the desired line.
VIEW	Enables the view mode and displays the selected CAS brief on the view CAS page. See Figure 1-242.
ERAS	Erases selected CAS brief from memory.

Figure 1-241. Recall CAS Brief (Sheet 1 of 2)



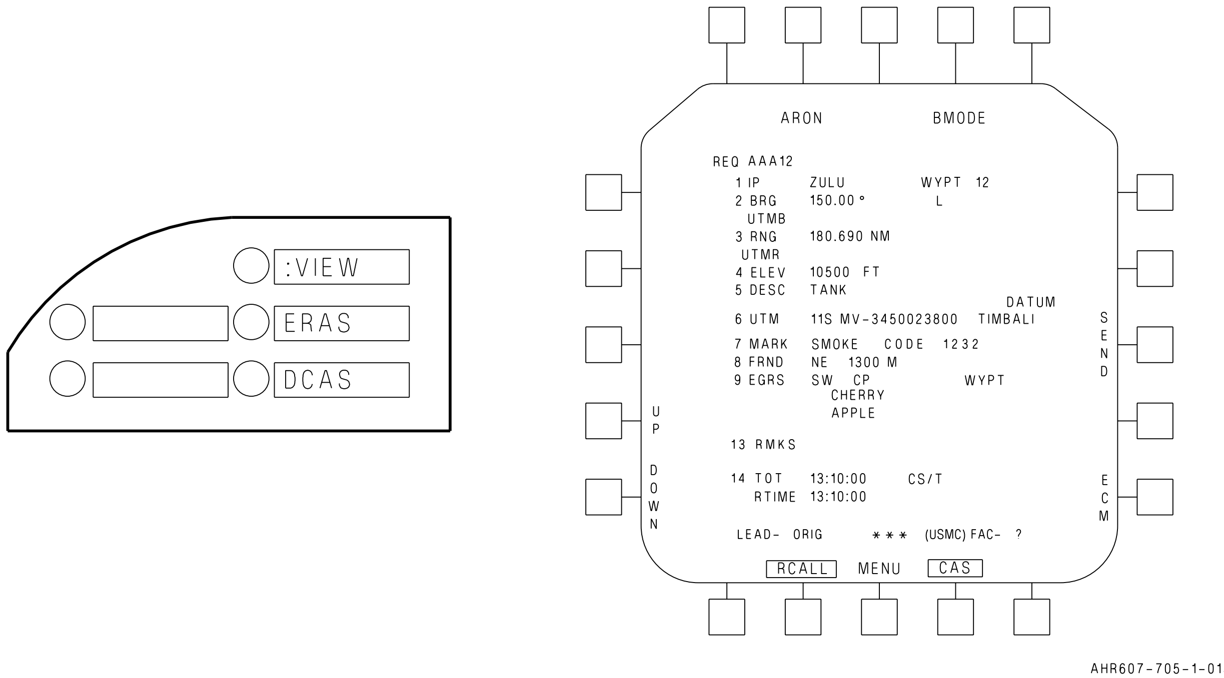
PUSHBUTTON	FUNCTION
DCAS	Displays selected brief on CAS page and updates network parameters to the parameters that were used when the CAS brief was saved. The FAC call sign is updated to the originators address and call sign.

Figure 1-241. Recall CAS Brief (Sheet 2 of 2)



PUSHBUTTON	FUNCTION
ARON/AROFF	Enables/disables the auto response function. Scrolls between ARON and AROFF.
BMODE	When pressed broadcast mode is enabled. Each time SEND is pressed, the message goes to all receivers for the selected NET.
SEND	When pressed, transmits displayed CAS brief to FAC for acceptance or rejection, and transmits an information copy to the wingman. Legend remains boxed until automatic response is received.
ECM	Selects ECM display, legend boxed when selected, returns to this display when deselected.
MENU	When pressed, deselects this display and enables menu display.
RCALL	Deselecting RCALL returns to the CAS page with no action on the selected CAS message.
UP/DOWN	The UP/DOWN pushbuttons allow the pilot to step through the stored CAS briefs.
VIEW	Uncueing VIEW returns to the recall CAS page, Figure 1-241, with the asterisk next to the last viewed CAS brief.
ERAS	Erases selected CAS brief from memory and returns to the recall CAS page, Figure 1-241.

Figure 1-242. View CAS Brief (Sheet 1 of 2)



PUSHBUTTON	FUNCTION
DCAS	Displays selected brief on CAS page and updates network parameters to the parameters that were used to transmit the CAS brief. The FAC call sign is updated to the originators address and call sign.

Figure 1-242. View CAS Brief (Sheet 2 of 2)

1.17.4 On Station Report (OSR). Upon arriving at the CP, the lead pilot can transmit the OSR to a Marine Corps FAC and an INFO copy to the wing aircraft. Pressing OSR on the CAS page accesses the OSR page, Figure 1-243.

1.17.5 Free Text Message. Free text messages can be sent by anyone who has the address of the aircraft on the same comm frequency. As with the CAS brief, a flashing TXT legend on the HUD cues the pilot that a message was received. To display the message the pilot must select the RECV pushbutton on the CAS display. If the received message is a free text message the free text page is displayed (Figure 1-244), otherwise the received CAS brief page is displayed. If a display other than the CAS display is present when the TXT legend is flashed, the pilot must respond to that display before selecting the CAS display. For example, if a free text display is present, the pilot must save, erase, or reply to the displayed free text message before returning to the CAS display. When a free text message is received the pilot has several choices:

1. Erase the message,
2. Save the message,
3. Send the message to the addresses specified on the NETS page,
4. Reply to the message.

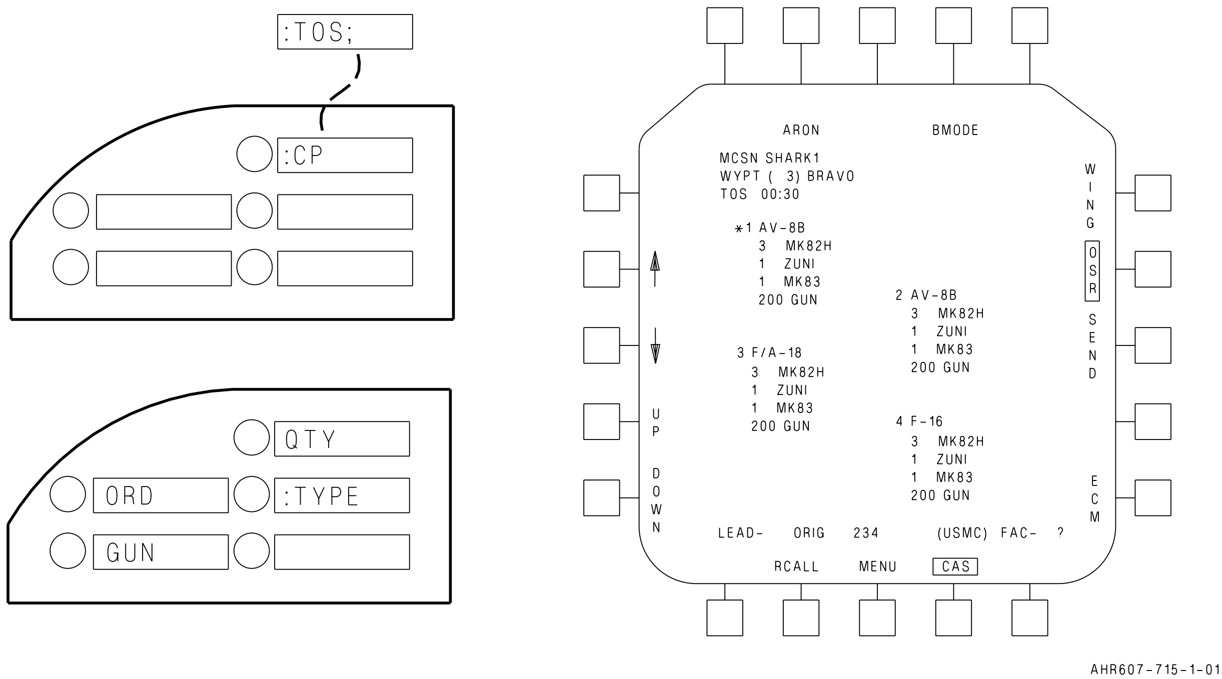
1.17.5.1 Erase. Unboxing FTEXT erases the message and returns the display to the CAS page and the NETS are returned to before the RECV.

1.17.5.2 Save. Selecting RCALL allows the pilot to recall the stored free text messages and erase messages of choice from storage. The pilot can then return to the free text page and save the displayed message.

1.17.5.3 Send. If the SEND pushbutton is pressed, the legend is boxed and the displayed message is sent to the addresses specified on the NETS page. Upon completion of the send the legend is unboxed and the message remains displayed.

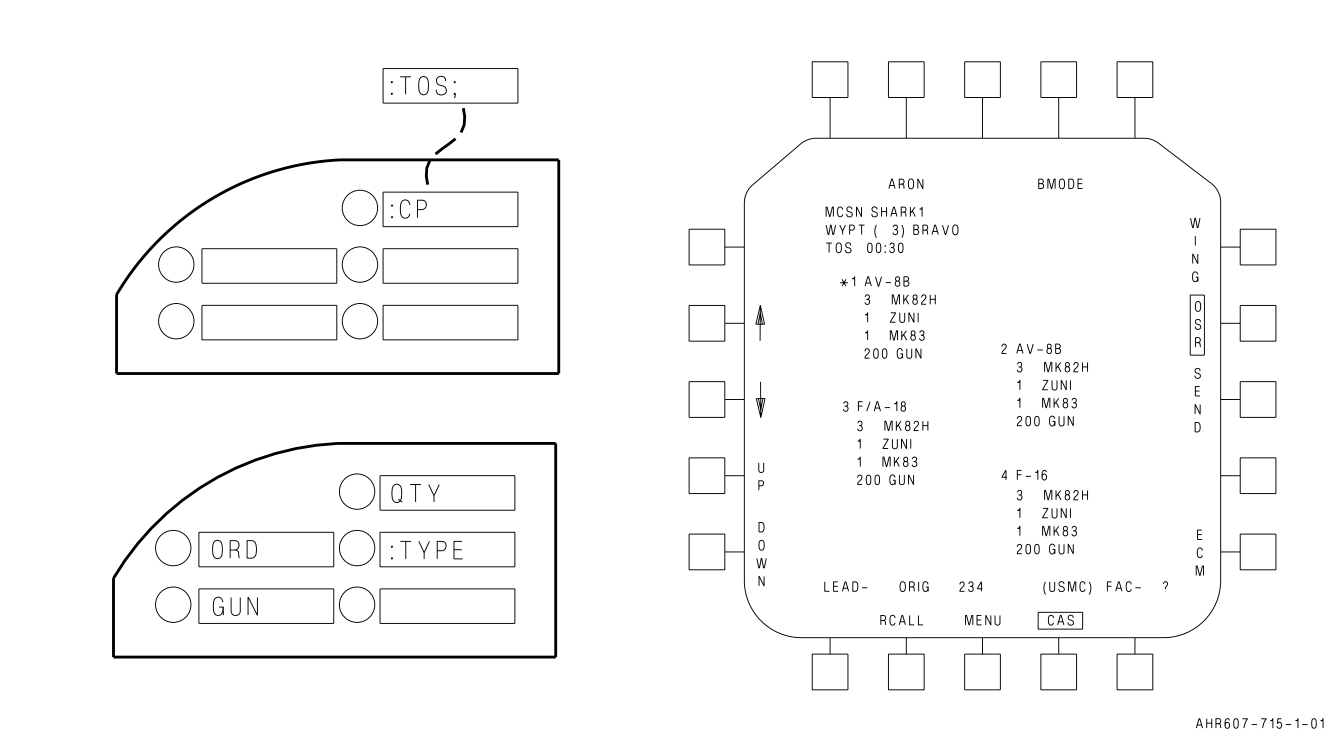
1.17.5.4 Reply. Selecting RPLY boxes the legend and enables the reply page, Figure 1-248. Selecting RCALL on the reply page displays the list of stored free text messages for selection. Selecting a message and pressing the DRPL option on the ODU displays the selected message on the reply page. The message can then be sent to the originator of the free text message by selecting XMIT.

1.17.6 ALPHA Menu. The ALPHA menu is available on the FTEXT and RPLY pages. The CAS and NETS pages have an ALPHA pushbutton that, when selected, displays the alphabetic page. When the pilot selects ALPHA, the menu is displayed with the cursor at the first character location. The pilot uses the TDC to move the box to the desired character and then depresses the TDC to select that character, Figure 1-250.



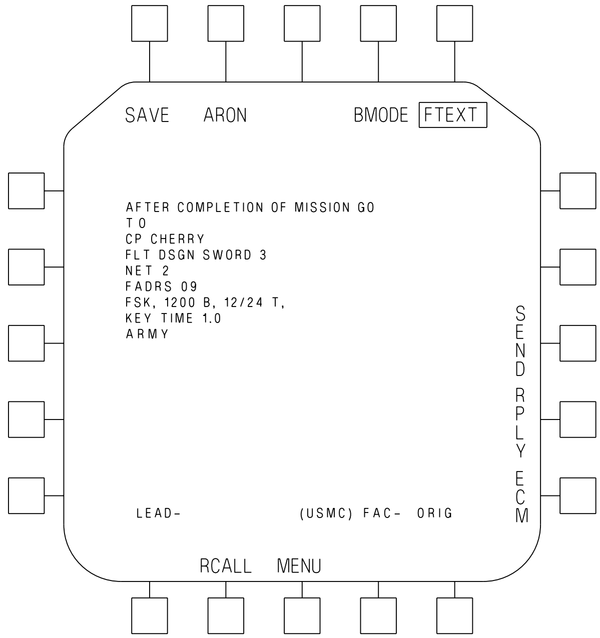
PUSHBUTTON	FUNCTION
ARON/AROFF	Enables/disables the auto response function. Scrolls between ARON and AROFF.
BMODE	When pressed, broadcast mode is enabled. Each time SEND is pressed, the message goes to all receivers for the selected NET.
WING	Displayed for lead aircraft only. When pressed, updates the wing aircraft status and ordnance.
OSR	Unboxing OSR returns the display to CAS display.
SEND	When pressed, transmits displayed OSR to addresses specified on the NETS page. Legend remains boxed until automatic response is received.
ECM	Selects RWR display, legend boxed when selected, returns to this display when deselected.
MENU	When pressed, deselects this display and enables menu display.
RCALL	When pressed, legend is boxed and recall free text message list is displayed. See Figure 1-246.
UP/DOWN	Displayed only when the line to be edited is associated with a set of preprogrammed choices for the selected parameter. The UP/DOWN pushbuttons allow the pilot to step through the available choices.

Figure 1-243. On Station Report (Sheet 1 of 2)



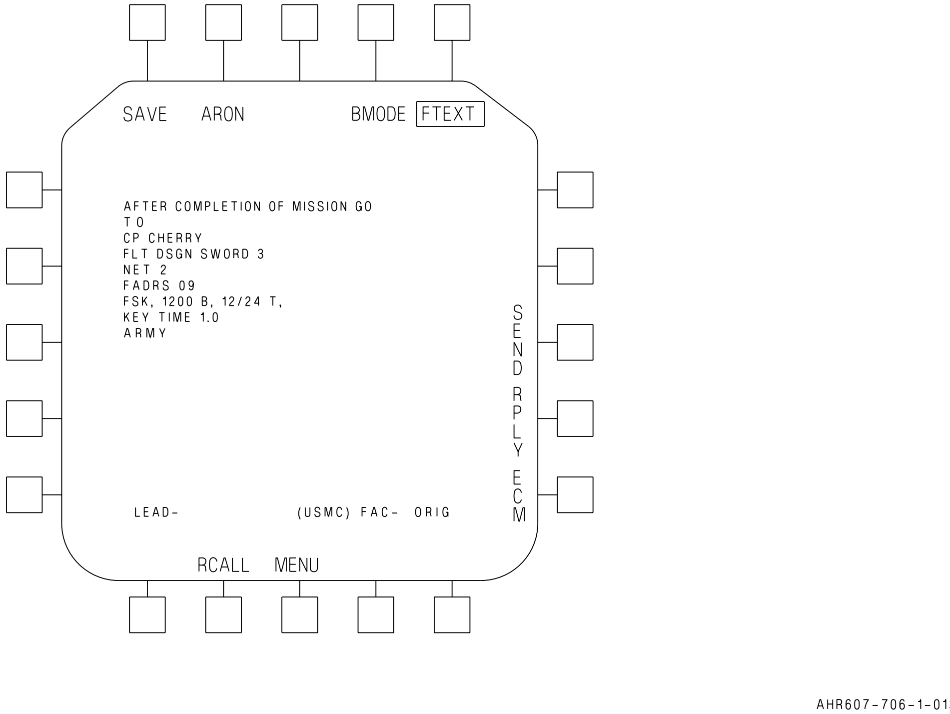
PUSHBUTTON	FUNCTION
up/down arrow	Used to select the line to be edited by moving the asterisk to the desired line.

Figure 1-243. On Station Report (Sheet 2 of 2)



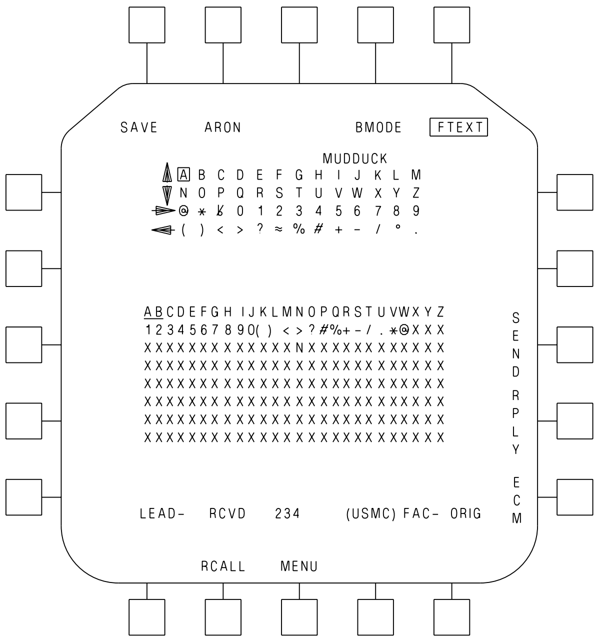
PUSHBUTTON	FUNCTION
SAVE	Stores free text message and returns to previous display. If memory full, a save overwrites oldest free text message. Also saves the corresponding network parameters with the displayed message.
ARON/AROFF	Enables/disables the auto response function. Scrolls between ARON and AROFF.
BMODE	When pressed, broadcast mode is enabled. Each time SEND is pressed, the message goes to all receivers for the selected NET.
FTEXT	Unboxing FTEXT erases the displayed free text message and returns to the previous display.
SEND	Transmits displayed free text message to FAC and transmits an information copy to wingmen. Legend remains boxed until automatic response is received.
RPLY	When pressed, selects reply page. See Figure 1-248.
ECM	Selects RWR display, legend boxed when selected, returns to this display when deselected.
MENU	When pressed, deselects this display and enables menu display.

Figure 1-244. Received Free Text Message (Sheet 1 of 2)



PUSHBUTTON	FUNCTION
RCALL	When pressed, legend is boxed and recall free text message list is displayed. See Figure 1-246.

Figure 1-244. Received Free Text Message (Sheet 2 of 2)



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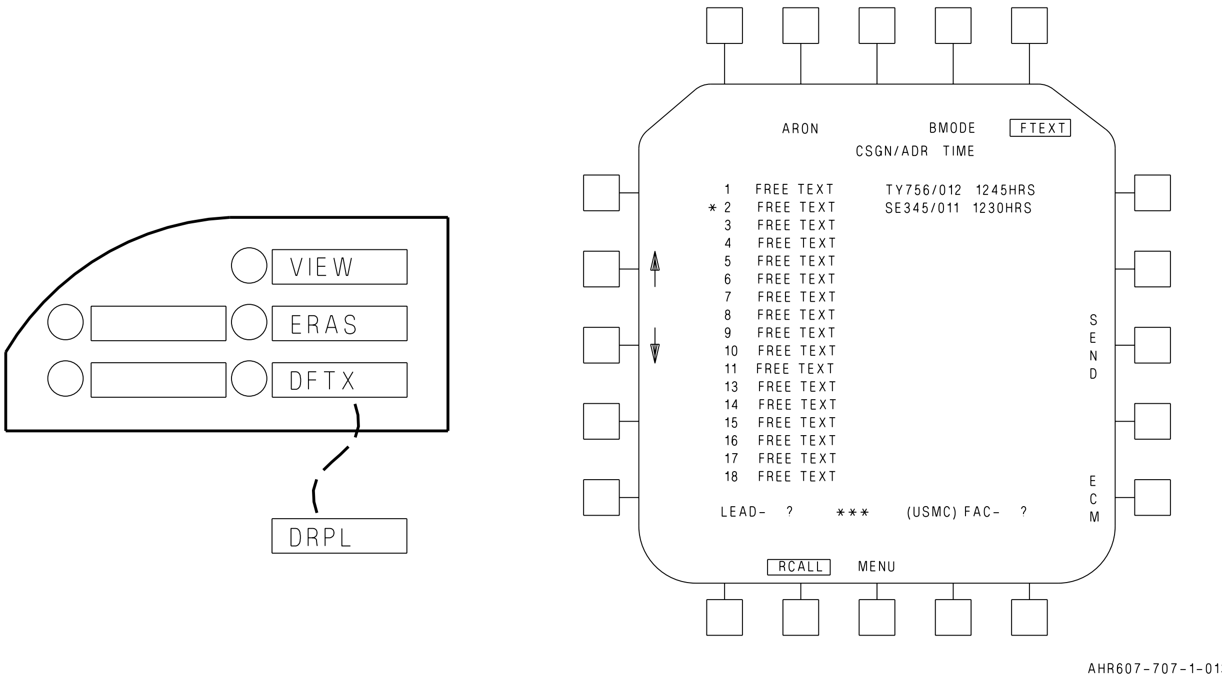
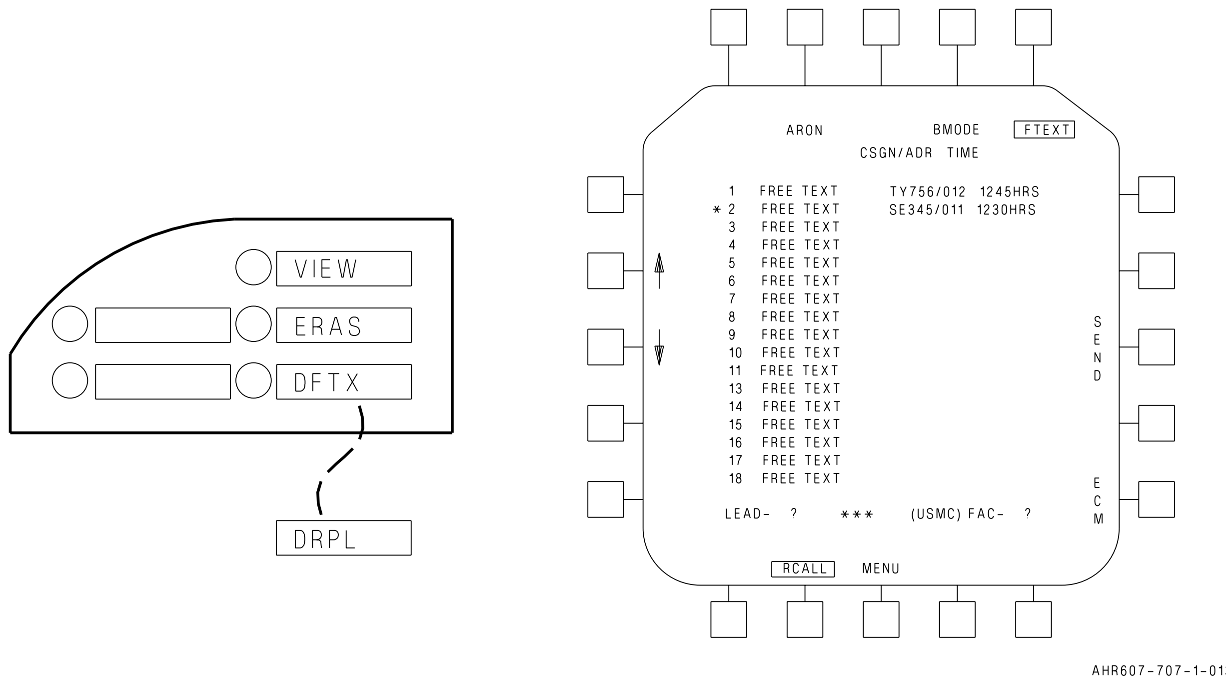
PUSHBUTTON	FUNCTION
SAVE	Stores free text message and returns to previous display. If memory full, a save over-writes oldest free text message. Also saves the corresponding network parameters with the displayed message.
ARON/AROFF	Enables/disables the auto response function. Scrolls between ARON and AROFF.
BMODE	When pressed, broadcast mode is enabled. Each time SEND is pressed, the message goes to all receivers for the selected NET.
FTEXT	Boxed legend indicates free text function enabled. Unboxing FTEXT returns to the CAS display.
SEND	Transmits displayed free text message to FAC for acceptance or rejection, and trans-mits an information copy to wingmen. Legend remains boxed until automatic response is received.
ECM	Selects RWR display, legend boxed when selected, returns to this display when dese-lected.
MENU	When pressed, deselects this display and enables the menu display.
RCALL	Displays recall free text message list, Figure 1-246.
RPLY	When pressed, selects reply page. See Figure 1-248.

Figure 1-245. Free Text Page After Selecting FTEXT From CAS Page



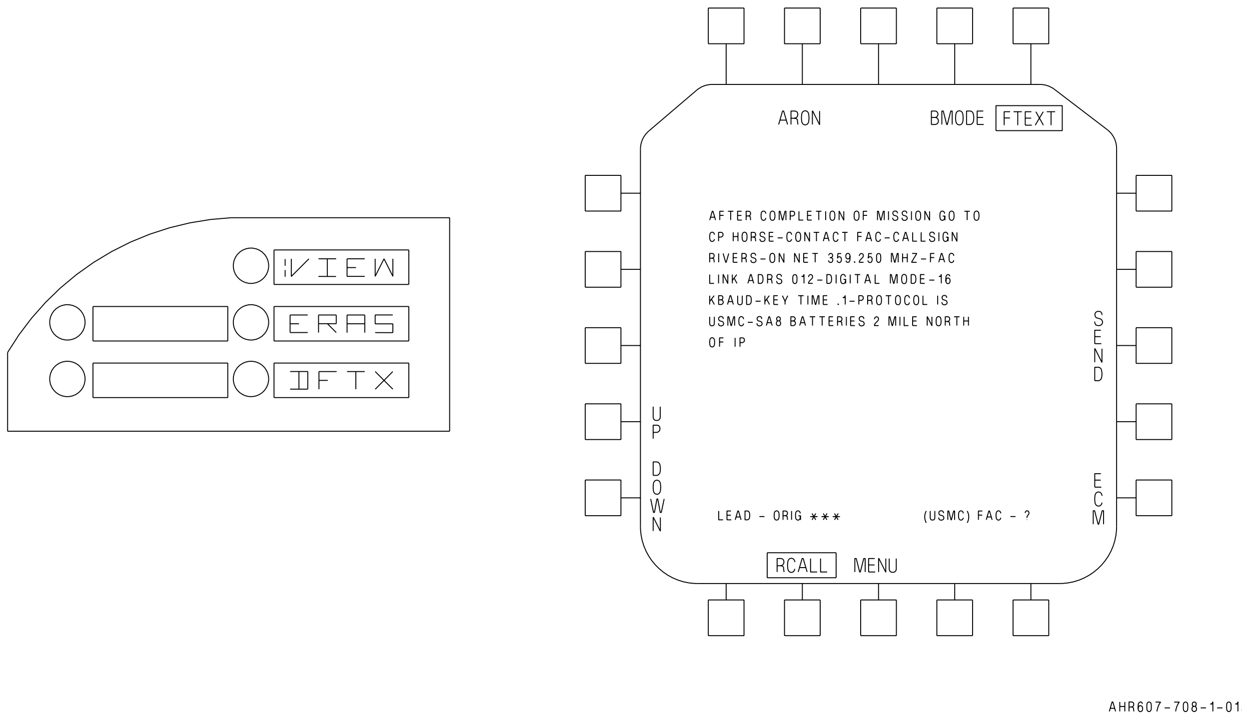
PUSHBUTTON	FUNCTION
ARON/AROFF	Enables/disables the auto response function. Scrolls between ARON and AROFF. Used to enable/disable the auto response function without going to the NETS page.
BMODE	When pressed, broadcast mode is enabled. Each time SEND is pressed, the message goes to all receivers for the selected NET.
FTEXT	Unboxing FTEXT deselects free text and returns to the CAS display.
SEND	Transmits displayed free text message to FAC for acceptance or rejection, and transmits an information copy to wingmen. Legend remains boxed until automatic response is received.
ECM	Selects RWR display, legend boxed when selected, returns to this display when deselected.
MENU	When pressed, deselects this display and enables the menu display.
RCALL	Deselecting RCALL returns to the previous display with no action taken.
up/down arrow	Used to select the line to be edited by moving the asterisk to the desired line.
VIEW	Enables the view mode and displays the selected message, as applicable, on the view free text page (Figure 1-247) or view reply page (Figure 1-249).

Figure 1-246. Recall Free Text Message (Sheet 1 of 2)



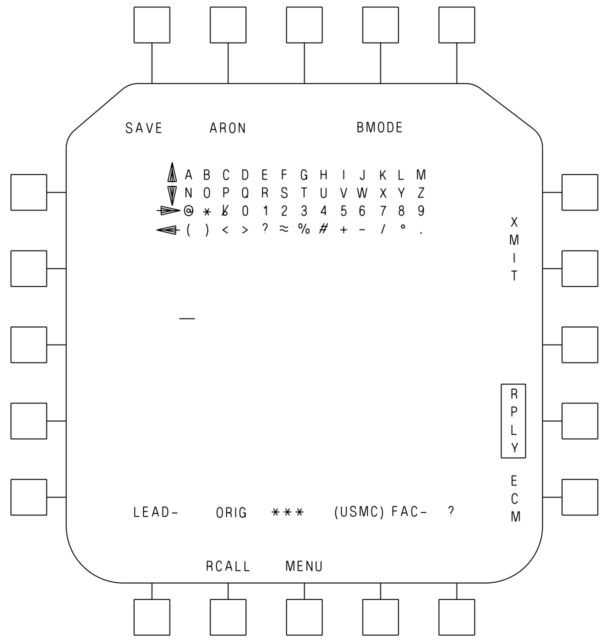
PUSHBUTTON	FUNCTION
ERAS	Erases selected free text message from memory.
DFTX	Displays selected message on free text page and updates network parameters to the parameters that were used to transmit the free text message. The FAC call sign will be updated to the free text message originators address and call sign.
DRPL	Displays selected message on reply page, Figure 1-248.

Figure 1-246. Recall Free Text Message (Sheet 2 of 2)



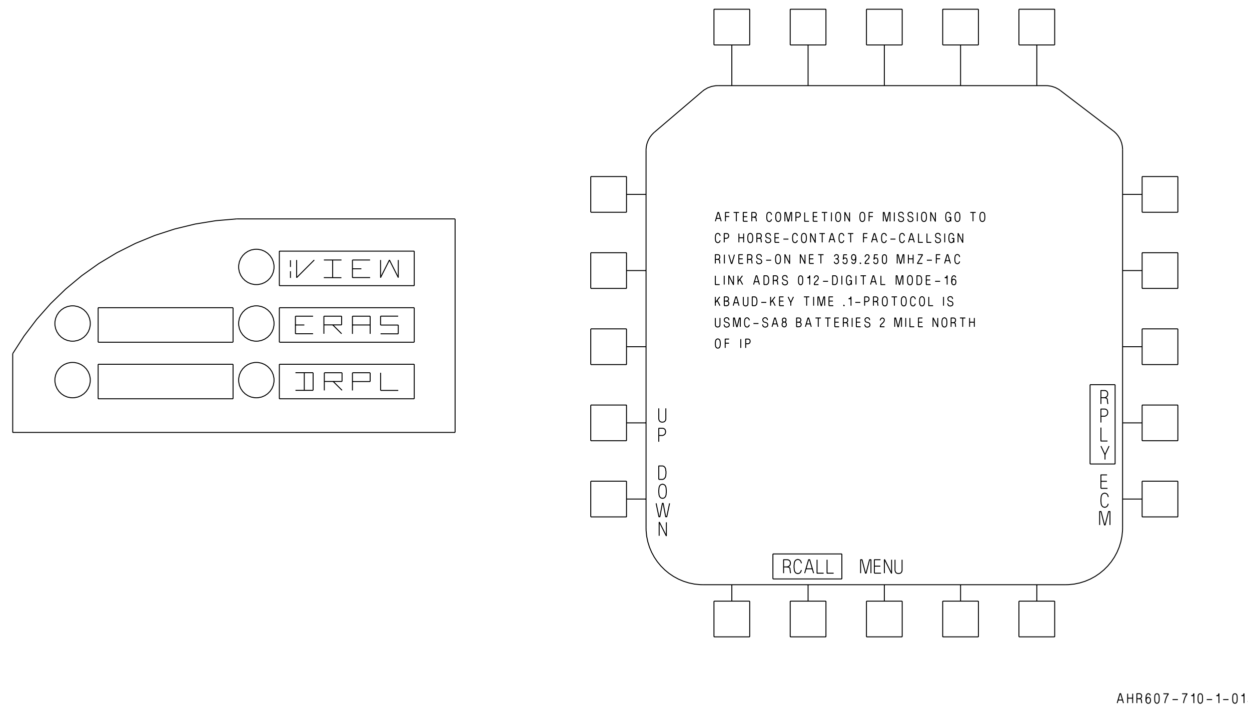
PUSHBUTTON	FUNCTION
ARON/AROFF	Enables/disables the auto response function. Scrolls between ARON and AROFF. Used to enable/disable the auto response function without going to the NETS page.
BMODE	When pressed broadcast mode is enabled. Each time SEND is pressed, the message goes to all receivers for the selected NET.
FTEXT	Unboxing FTEXT deselects free text and returns to the CAS display.
ECM	Selects RWR display, legend boxed when selected, returns to this display when deselected.
MENU	When pressed deselects this display and enables the menu display.
RCALL	Boxed legend indicates recall function enabled. Deselecting RCALL returns to the free text page with no action on the selected free text message.
UP/DOWN	The UP/DOWN pushbuttons allow the pilot to step through the stored free text messages.
VIEW	Uncueing VIEW will return to the recall free text message page, Figure 1-246, with the asterisk next to the last viewed free text message.
ERASE	Erases displayed free text message from memory.
DFTX	Recalls the displayed free text message to the free text page, Figure 1-244.

Figure 1-247. View Free Text Message



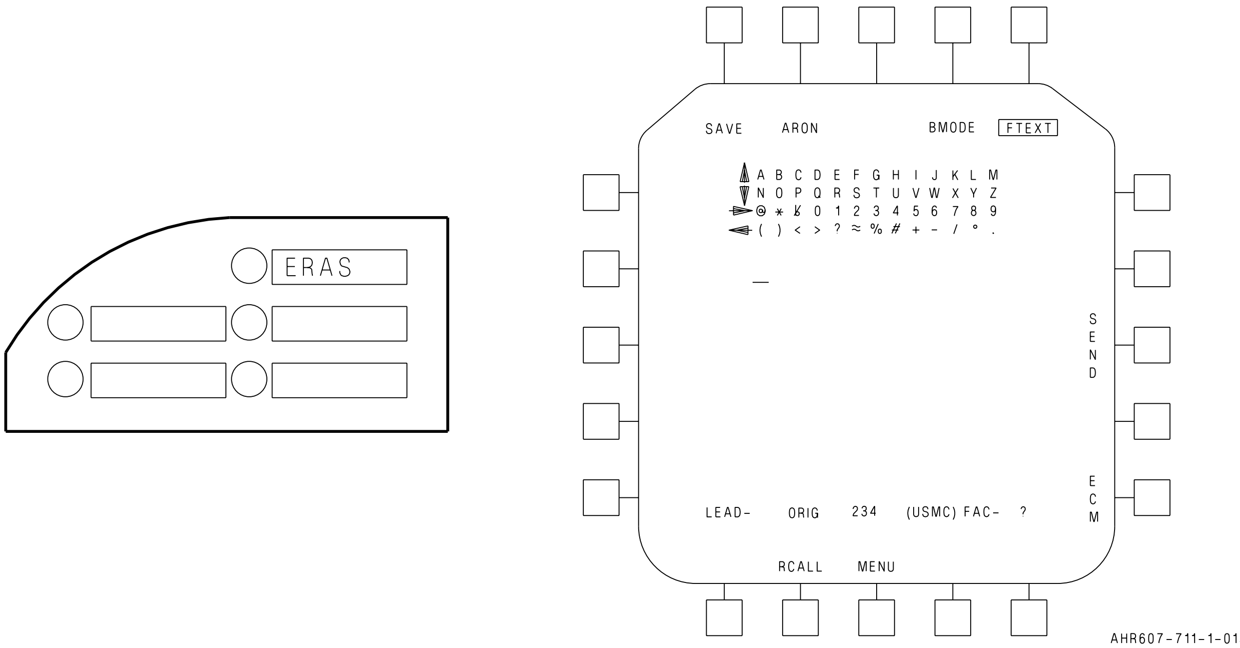
PUSHBUTTON	FUNCTION
SAVE	Stores free text response, maximum of eight free text messages may be stored. If memory is full, overwrites oldest message.
ARON/AROFF	Enables/disables the auto response function. Scrolls between ARON and AROFF.
BMODE	When pressed, broadcast mode is enabled. Each time SEND is pressed, the message goes to all receivers for the selected NET.
XMIT	Transmits reply to originator of free text message displayed on free text page. The XMIT legend is boxed until auto response is received.
RPLY	When pressed, unboxes legend and returns to free text page, Figure 1-244. The reply is not saved unless the SAVE pushbutton is pressed.
ECM	Selects RWR display, legend boxed when selected, returns to this display when deselected.
MENU	When pressed, deselects this display and enables the menu display.
RCALL	When pressed, legend is boxed and recall free text message list is displayed. See Figure 1-246.

Figure 1-248. Reply Page



PUSHBUTTON	FUNCTION
RPLY	When pressed, unboxes legend and returns to free text page, Figure 1-244. The reply is not saved unless the SAVE pushbutton is pressed.
ECM	Selects RWR display, legend boxed when selected, returns to this display when deselected.
MENU	When pressed, deselects this display and enables the menu display.
RCALL	Boxed legend indicates free text recall page enabled. Deselecting RCALL returns to the free text page with no action on the selected free text message.
UP/DOWN	The UP/DOWN pushbuttons allow the pilot to step through the stored Free Text messages.
VIEW	Uncueing VIEW returns to the recall free text message page, Figure 1-246, with the asterisk next to the last viewed free text message.
ERASE	Erases displayed free text message from memory.
DRPL	Recalls the displayed free text message to the reply page, Figure 1-248.

Figure 1-249. View Reply Page



PUSHBUTTON	FUNCTION
SAVE	Stores free text response, maximum of eight free text messages may be stored. If memory is full, overwrites oldest message.
ARON	Enables/disables the auto response function. Scrolls between ARON and AROFF. Used to enable/disable the auto response function without going to the NETS page.
BMODE	When pressed, broadcast mode is enabled. Each time SEND is pressed, the message goes to all receivers for the selected NET.
FTEXT	Unboxing FTEXT deselects free text and returns to the CAS display.
SEND	Transmits displayed free text message to addresses specified on the NETS page. Legend remains boxed until automatic response is received.
ECM	Selects RWR display, legend boxed when selected, returns to this display when deselected.
MENU	When pressed, deselects this display and enables the menu display.
RCALL	Boxed legend indicates free text recall page enabled. Deselecting RCALL returns to the free text page with no action on the selected free text message.
ERASE	Erases displayed free text message from memory.

Figure 1-250. ALPHA Menu Page

1.17.7 Anti-Air Warfare Message. The controller transmits an AAW message to the AV-8B, providing an altitude, intercept course, heading, speed, position, and other data to enable the AV-8B to engage the threat aircraft, Figure 1-251. When an AAW message is received by the aircraft, a flashing AAW appears on the HUD. This gives the pilot the option of saving the data on the CAS page before pressing RECV. When RECV is pressed the AAW data overwrites everything on the CAS page. AAW messages cannot be saved. When an Anti-Air Warfare message is received the pilot has two choices:

1. Accept the message,

2. Reject the message,

1.17.7.1 ACCEPT. When ACPT is pressed, WILCO is transmitted to the controller and to the wingmen. Also AAW data is automatically loaded into the navigation logic of the aircraft and displayed as a synthetic target track. The wing aircraft, after receipt of lead pilot's acceptance, automatically loads the AAW data into the navigation logic and sets AR to OFF. The status line is removed once the automatic responce is received from the ACPT. If the controller sends another AAW message with a different Request Number, AAW flashes on the HUD and if RECV is pressed the new AAW message overwrites the displayed AAW message. If an update message is not received within 20 seconds, STALE is displayed. If an update message is received after 20 seconds, the data is updated and STALE removed.

1.17.7.2 REJECT. If the AAW message is rejected, the AAW message disappears from the MPCD, leaving a blank CAS page.

1.17.8 The NETS Page. The ATHS has variable parameters that define its operation on each of its two networks, see Figure 1-253. The pilot can edit these parameters by selecting the NETS display on the MPCD. The NETS display, Figure 1-251, is selected by pressing the NETS pushbutton on the CAS display. When selected the NETS pushbutton legend is boxed and the active network parameters are displayed. The active network for the radio selected is indicated by the boxed NET1 or NET2 pushbutton legend at the top of the display. Selecting this pushbutton selects the other NET display, the pushbutton scrolls between NET1 and NET2 displays. Pressing the boxed NETS pushbutton returns to the CAS display.

1.17.8.1 Editing The NETS Page. The edit function is enabled when the display is selected. As with the CAS brief, the line to be edited is indicated by the asterisk and the up and down arrows are used to move the asterisk to the desired line. The UP and DOWN pushbuttons are only displayed when the line to be edited is associated with a preprogrammed list of options, available choices. The UP and DOWN pushbuttons allow the pilot to step through the available choices. The NETS page is edited as follows:

1. RADIO. With the asterisk on the radio option, the UP and DOWN pusbuttons are enabled for selecting either radio 1 or radio 2 for the selected network. The system does not allow selection of the same radio for both networks.

2. MSN TYPE. No editing allowed. CAS is the only defined mission type for the ATHS system.

3. MODE. The UP and DOWN pushbuttons are enabled for selecting mode. Choices are FSK (frequency shift keying), DIG BB (digital baseband), and DIG DP (digital diphase).

4. SPEED. The UP and DOWN pushbuttons are enabled for selecting the baud rate (transmission speed) of the selected network. Baud rates are: FSK-75, 150, 300, 600, 1200 and DIG-75, 150, 300, 600, 1200, 2.4K, 8K, 9.6K, 16K.

5. TONES. The UP and DOWN pushbuttons are enabled for selecting the FSK tone pairs for the selected network. The selections available are: 12/24, 13/17 and 13/21. This option is not applicable if the selected mode is digital.

6. RETRIES. The UP and DOWN pushbuttons are enabled for selecting the number of retries, 0, 1 or 2. If an automatic response is

not received from the FAC, the ATHS retransmits any message for the specified number of retries. If a not ready is received, the ATHS modem waits 30 seconds and starts the retry sequence again.

7. KEY TIME. This data is entered using the UFC. Valid entries range form 0.1 to 5.6 seconds in increments of 0.1 seconds.

8. FEC/TDC. The UP and DOWN pushbuttons are enabled for selecting forward error coding/time dispersal ON or OFF.

9. PRTCOL. The UP and DOWN pushbuttons are enabled for selecting protocol. Choices are USMC, USAF and ARMY.

10. AO/ADRS/ARMY. The UP and DOWN pushbuttons are enabled for entering Army observer link address. Choices are 0 thru 9 or A thru Z.

11. AC/ADRS/ARMY. The UP and DOWN pushbuttons are enabled for entering the aircraft link address. Choices are 0 thru 9 or A thru Z.

12. DCT ADRS. The ADRS and FCSN options are available on the ODU for entering the digital communication terminal link address for USMC or USAF protocol and the FAC call sign. Address entries are 0 and 2 thru 126. The FAC call sign is limited to 12 characters. Data is entered using the UFC and ALPHA menu.

13. DCT CSGN. The DSCN option is available on the ODU for entering the DCT call sign (only used in USMC protocol). Valid entries are five alphanumerics. Data is entered using the UFC and ALPHA menu.

14. AC 1 thru AC 4. Five ODU options are available for entering aircraft data: ADRS, ACSN, MYAC, MCSN, and SWAP.

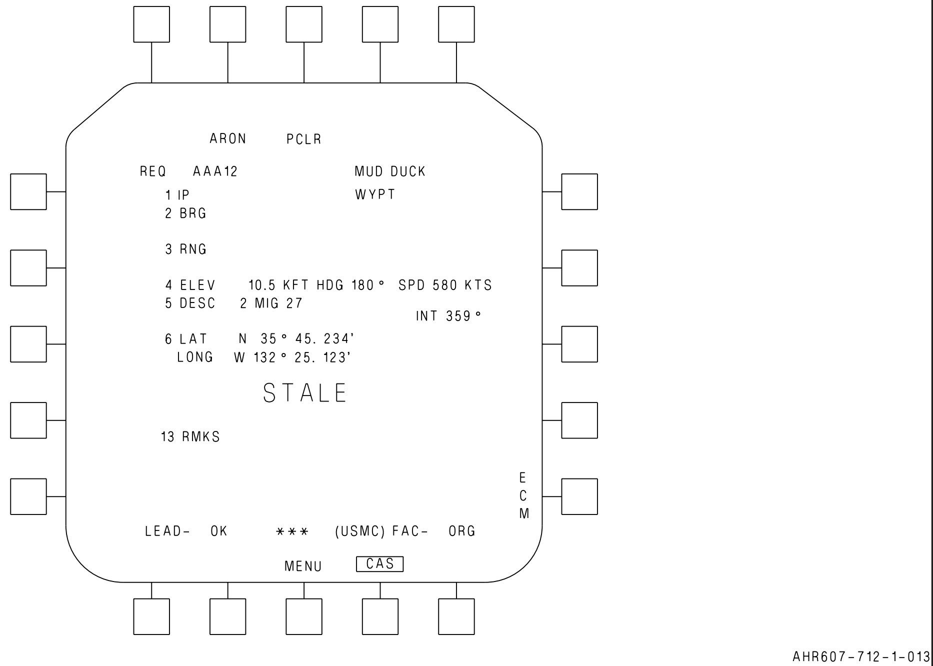
(a) The ADRS options allows for editing the aircraft link address.

(b) The ACSN option allows for entering the aircraft call sign. The aircraft call sign is limited to 12 characters. Data is entered using the ALPHA menu.

(c) The MYAC option allows the pilot to identify his aircraft by positioning the asterisk to the appropriate line and selecting MYAC. The AC legend is boxed to indicate selection. If MYAC was previously AC 1 and changed to AC 3, the flight position is automatically changed from lead to wing.

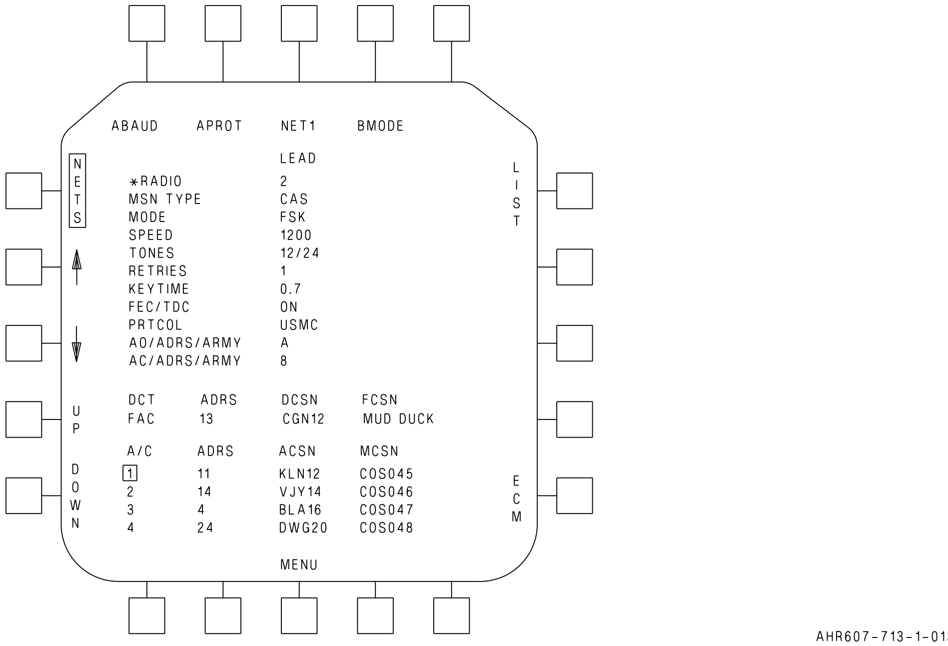
(d) The MCSN option allows the pilot to edit the mission call sign for each aircraft. The mission call sign is limited to 12 characters. Data is entered using the ALPHA menu.

(e) The SWAP option is used to change aircraft positions. This is accomplished by placing the asterisk on the line of one of the aircraft to be swapped and then entering the number of the other aircraft on the UFC. The pilot can load data for two reserve aircraft using the MPS. These aircraft are numbered 5 and 6. To SWAP with the reserve aircraft the pilot enters 5 or 6 and presses ENT.



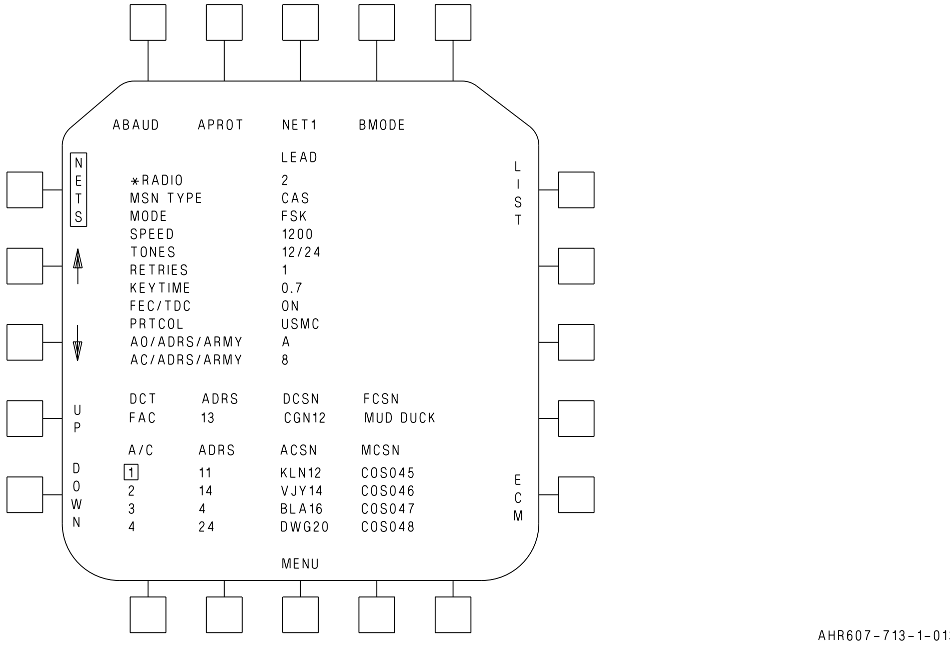
PUSHBUTTON	FUNCTION
ARON/AROFF	Enables/disables the auto response function. Scrolls between ARON and AROFF.
PCLR	When pressed, the page is cleared of all data. The displayed CAS brief is deleted and if a CAS brief was in temporary storage it is displayed.
ECM	Selects RWR display. Legend boxed when selected, returns to this display when deselected.
CAS	When pressed, deselects this display and returns to previous display.
MENU	When pressed, deselects NETS display and enables menu display.

Figure 1-251. Anti-Aircraft Warfare Display



PUSHBUTTON	FUNCTION
NETS	When selected (boxed) enables the network display NET1 or NET2. Initializes with the last selected NETS display. When deselected (unboxed) returns to the CAS display.
ABAUD	When pressed the pushbutton toggles Auto Baud on or off. Auto Baud allows the ATHS to automatically switch baud rate to match the incoming message; otherwise, the message will not be received if the baud rate does not match.
APROT	When pressed the pushbutton toggles Auto Protocol on or off. Each service has a different protocol for transmitting and receiving messages. With Auto Protocol off, the ATHS cannot receive an AFAPD message when it is initiated to USMC protocol.
NET1/NET2	Selects network 1 or network 2 for display. Scrolls between NET1 and NET2 display.
BMODE	When pressed broadcast mode is enabled. Each time SEND is pressed, the message goes to all receivers for the selected NET.
LIST	When pressed displays the list of authorized requesters and addresses for viewing or editing.
ECM	Selects RWR display. Legend boxed when selected, returns to this display when deselected.
MENU	When pressed deselects NETS display and enables menu display.

Figure 1-252. NETS Display (Sheet 1 of 2)



PUSHBUTTON	FUNCTION
UP/DOWN	Displayed only when the line to be edited is associated with a set of preprogrammed choices for the selected parameter. The UP/DOWN pushbuttons allow the pilot to step through the available choices.
up/down arrow	Used to select the line to be edited by moving the asterisk to the desired line.

Figure 1-252. NETS Display (Sheet 2 of 2)

VARIABLE NET PARAMETERS

Radio	1 or 2
Mission Type	CAS
Transmission mode	FSK, DIG BB or DIG DP
Speed	FSK Selected
	(75, 150, 300, 600, 1200 Hz)
	Digital Baseband Selected
	(75, 150, 300, 600, 1200, 2400, 8000, 9600, 16000 Hz)
	Digital Diphase Selected
	(75, 150, 300, 600, 1200, 2400, 8000 Hz)
Tone pairs (FSK Mode Only)	1200/2400 Hz
	1300/1700 Hz
	1300/2100 Hz
Retries	0, 1, 2
Key Time	0.1 to 5.6 sec
FEC/TDC	ON or OFF
Protocol	USMC, USAF, ARMY
ARMY Observer link ADRS	0 to 9 or A to Z (1 character)
ADRS (ARMY) for all AC	0 to 9 or A to Z (1 character)
DCT ADRS	Range 0, 2-126
DCT CSGN	Range (5 random alphanumeric)
FCSN for NET 1	FAC's personal call sign (12 characters)
FCSN for NET 2	FAC's personal call sign (12 characters)
A/C 1 MCSN	MCSN call sign (12 characters)
A/C 1 ACSN	Range (5 random alphanumeric)
A/C 1 ADRS	Range 0, 2-126 USMC/USAF Protocol
A/C 2 MCSN	MCSN call sign (12 characters)
A/C 2 ACSN	Range (5 random alphanumeric)
A/C 2 ADRS	Range 0, 2-126 USMC/USAF Protocol
A/C 3 MCSN	MCSN call sign (12 characters)
A/C 3 ACSN	Range (5 random alphanumeric)
A/C 3 ADRS	Range 0, 2-126 USMC/USAF Protocol
A/C 4 MCSN	MCSN call sign (12 characters)
A/C 4 ACSN	Range (5 random alphanumeric)
A/C 4 ADRS	Range 0, 2-126 USMC/USAF Protocol

Figure 1-253. Network Parameters (Sheet 1 of 2)

DEFAULT NET PARAMETERS

PARAMETER	NET 1	NET 2
Radio	1	2
Mission Type	CAS	CAS
Transmission mode	DIG BB	DIG BB
Speed	16K	16K
Tone pairs (FSK Mode Only)	—	—
Retries	2	2
Automatic Response	OFF	OFF
Key Time	0.7 sec	0.7 sec
FEC/TDC	ON	ON
Protocol	USMC	USMC
Flight Position	LEAD	WING
Auto Baud	ON	ON
Auto Protocol	ON	ON
ARMY Observer link ADRS	8	9
ADRS (ARMY) for all AC	4	5
DCT ADRS	10	20
DCT CSGN	123	123
FCSN for NET 1		
FCSN for NET 2		
A/C 1 MCSN	11	21
A/C 1 ACSN	11	21
A/C 1 ADRS	11	21
A/C 2 MCSN	12	22
A/C 2 ACSN	12	22
A/C 2 ADRS	12	22
A/C 3 MCSN	13	23
A/C 3 ACSN	13	23
A/C 3 ADRS	13	23
A/C 4 MCSN	14	24
A/C 4 ACSN	14	24
A/C 4 ADRS	14	24

Figure 1-253. Network Parameters (Sheet 2 of 2)

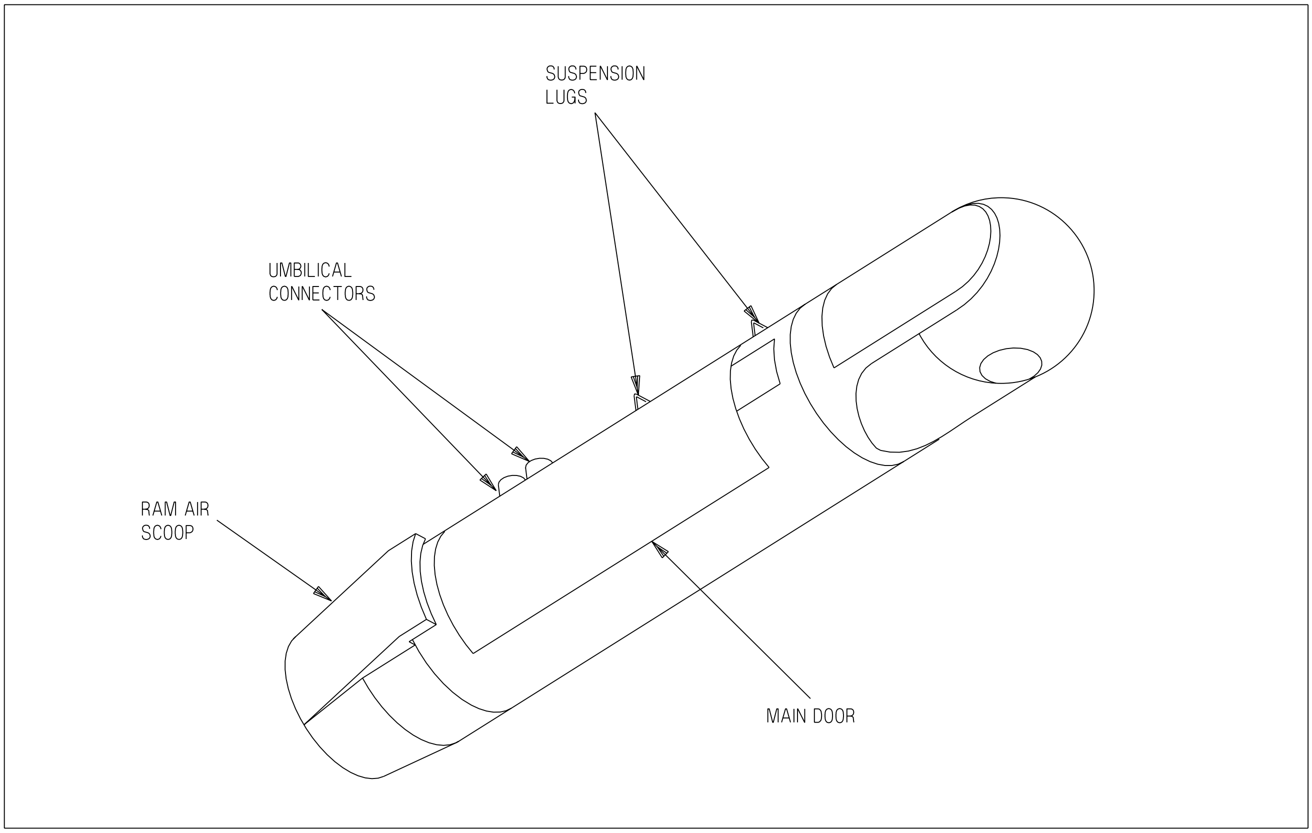


Figure 1-254. TPOD General Arrangement

1.18 AN/AAQ–28 LITENING II TARGETING POD

1.18.1 Description. The AN/AAQ–28 Litening II Targeting Pod (TPOD) is a multi–sensor targeting system developed to provide the AV–8B with precision strike capability against surface targets. The TPOD is equipped with a Charge Coupled Device (CCD) TV and FLIR thermal imager to generate video for display in the cockpit on either MPCD. Direct image recording is accomplished via a Video Cassette Recorder (VCR) contained within the pod. Target designation is achieved using a laser designator/range finder or an IR laser marker. The TPOD also includes a laser spot tracker capable of detecting and tracking laser energy.

The TPOD system is employed to assist the pilot in acquisition, recognition, and designation of surface targets. The pod's laser designation can be used for both autonomous and buddy delivery of laser guided or general purpose air–to–ground weapons. The TPOD system supports air–to–ground weapons delivery by providing laser designation for laser–guided weapons, performing laser spot detection for targets illuminated by external designators, and computing target location from optical tracking by CCD, FLIR, or laser spot detector sensors that the pilot can enter into the UFCS to create a system designation. Additionally, the TPOD system contains a NVG compatible laser marker for ground illumination.

1.18.1.1 Installation. The TPOD mounts on, and interfaces with, AV–8B night attack, radar and remanufactured aircraft on station 5 using standard 14–inch bomb lugs. The pod is approximately 87 inches long and 16 inches in diameter, and weighs approximately 445 pounds. Mechanical boresight of the TPOD to the aircraft is not required as the TPOD sensor head is boresighted by the pod's internal IMU that aligns to the output from the aircraft INS.

1.18.1.2 Electrical Connection and Power Requirements. The electrical connection between pod and pylon is by way of a special two–cable umbilical that connects to the two connectors located on top of the aft end of the pod's rear section (see Figure 1–254). The TPOD receives power from the standard aircraft 115 VAC, 400Hz, four–wire, three–phase power supply at aircraft weapon station 5. The pod also receives aircraft 28V power to service interlocks and switching of the three–phase power supply within the equipment. Power is applied to the pod by engaging the power on–off toggle switch on the umbilical in the pylon after aircraft power has been applied.

WARNING

All personnel should maintain a safe distance separation from the forward section of the pod within 1 minute of start–up as it moves with extreme force that could cause personal injury.

Following TPOD power–up, pod cooling is provided by the pod's ground fan at the rear of the Environmental Control Unit (ECU) drawing outside air through the pod's ram air duct for cycling through the component sections of the pod. If the pod's internal temperature rises requiring additional cooling, a thermal switch turns on the ECU air conditioning unit. The maximum power draw with the air conditioning unit running should not exceed the station 5 2.4 KVA power supply.

NOTE

Power draw in excess of 2.4 KVA could result in overheating the electrical circuitry to where the weapon station 5 7.5A circuit breakers may trip open and cut power to the pod.

The equipment should not be damaged by interruption of the DC voltage or any combination of one or more phases of the three–phase AC supply. The pod should not experience any detrimental electrical or electronic effects (beyond that normally encountered during a routine operational power–up/power–down cycle) as a result of the 7.5 amp circuit breakers opening without warning. Protective devices are included, where required, in the equipment to prevent damage caused by loss or degradation of the power supply. If the 7.5 amp circuit breakers open during operations, the roll and ball brakes engage and prevent the sensor head from moving due to airstream forces. However, the sensor head windows could be susceptible to FOD from landing or ground operations, depending on orientation when the breaker opened.

1.18.1.3 Pilot–Vehicle–Interface (PVI). The PVI is controlled by an Operational Flight Program (OFP) including MC and DC OFPs that provide MPCD pushbutton and HOTAS control of TPOD operations.

1.18.1.4 TPOD Video Display. The TPOD video display page is entered from normal aircraft MPCD displays by pressing the MENU, BIT, and VIDEO pushbuttons, in sequence on either MPCD. Weapon station 5 is the aircraft default weapon video source. The DC routes weapon station 5 video (TPOD video) to the appropriate MPCD, displaying FLIR or CCD and related TPOD symbology and MPCD pushbutton legends. The selected MPCD is then used for the primary TPOD control and displays. The TPOD software provides three MPCD display screen levels: primary, data, and VCR display pages. These display pages provide the pilot with the following:

(a) Pod video image.

(b) Pod status indications and messages.

(c) Pod operation using MPCD pushbuttons.

(d) Pod VCR operation using MPCD pushbuttons.

(e) Indications of pod operation using HOTAS controls.

NOTE

Because TPOD video is provided as maverick emulation, maverick video is not available when TPOD video is selected.

1.18.1.5 TPOD Operation. The TPOD operates on MIL−STD−1760 and non−MIL−STD−1760 compliant aircraft throughout the AV−8B flight operating envelope (see operating limitation note below). Its operating envelope is 0−585 KCAS/1.0 mach, and -3.0 to +7.0gs.

NOTE

Although the pod will operate above 40,000 feet, the laser is unable to fire if sensor head pressurization cannot be maintained between 9 PSI and sea level.

There are no restrictions to maintenance or preflight operations of the pod. However, if a POD OVERHEAT or POD HOT warning is displayed on the MPCD the following actions should be taken:

(a) On The Ground: Unless able to get airborne immediately, secure power to the pod.

(b) Airborne: Decrease pod operating temperature by either increasing altitude or decreasing airspeed until indication clears.

CAUTION

Overheat conditions could cause heat damage to pod electronic components due to insufficient cooling if allowed to persist.

1.18.2 TPOD Configuration and Components. The TPOD has three main body sections, the forward section, the rear section, and the ECU. The forward section and the ECU are WRAs, and the rear section contains five WRAs. The TPOD WRAs and components are described in the following paragraphs and shown in Figures 1−254 and 1−255.

1.18.2.1 Forward Section. The forward section WRA houses all sensors in a stabilized sensor payload. The forward section also includes the servo control devices used to drive and control the inner (pitch/yaw) and outer (roll/shroud) gimbals, and the environmental control devices (heat exchanger, fans, and air compressor). The forward section sensors include three on−gimbal electro−optical sensors (FLIR thermal imaging system, dual CCD sensors, and laser spot detector), the laser designator, the laser marker, the inertial sensor unit, and the LOS control mechanism. The forward section environmental control function is done by the forward section compressing unit, which maintains the air pressure in the forward section between 9 PSI and sea level pressure.

1.18.2.1.1 FLIR Thermal Imaging System (TIS). The FLIR TIS detects mid−wave infrared energy in the 3−5 micrometer wavelength region of the electromagnetic spectrum. The FLIR has two optical FOVs in the A/G mode and a super−wide FOV in navigation mode. The FLIR has a manual gain control, an automatic focus capability, a focus reset to a factory set value, and an electronic zoom capability.

1.18.2.1.2 Dual CCD Sensors. The CCD sensors are components of a dual lens, high resolution CCD camera. The CCD has two optical FOVs. The CCD also includes automatic gain control and an electronic shutter, and provides a digital zoom.

1.18.2.1.3 Laser Spot Detector (LSD). The LSD is a sub−assembly inside the WFOV CCD sensor assembly incorporating a dichroic beam splitter to separate the laser returned energy, and a four−quadrant silicon detector. The LSD operates in the 1.064 micron waveband, and has a 2.3° circular FOV. The search time in the wide search pattern is 8 seconds, and 4 seconds in the narrow search pattern.

1.18.2.1.4 Laser Designator/Range Finder. The laser designator is a standard military airborne laser, which radiates in the near infrared region at 1.064 microns. The laser is boresighted to very closely match the target tracker LOS. The range finder accuracy is ±5 meters at up to 10 km, and from over 40,000 feet altitude.

1.18.2.1.5 Laser Marker. The laser marker is a class 3b continuous wave laser producing 400 milliwatts of power, and flashes three times per second for target area illumination visible to users wearing NVGs. The laser marker is boresighted to closely match the target tracker LOS.

1.18.2.1.6 Inertial Sensor Unit (ISU). The ISU is attached to the gimbaled sensor head assembly, and is comprised of two dynamically tuned gyros and three accelerometers. The ISU contains an alignment algorithm that calculates sensor head LOS attitude relative to the aircraft INS.

1.18.2.2 Rear Section. The rear section of the TPOD consists of the wired rear section and electronic units of the TPOD, including the CCD camera control assembly, FLIR electronics, video control, computer processor, IMU controller, EO tracker, and VCR. This section provides the electrical interfaces between all pod sections and units as well as between the pod and the aircraft. The electronic units control and support the functionality of the forward section and the ECU, and provide the entire functionality of the TPOD system. The rear section WRAs include the VCR, FLIR Electronic Unit (FEU), System Electronics Unit (SEU), Power Servo Unit (PSU), and the Interface Unit (IU) as shown in Figure 1−255. The rear section WRAs and VCR cassette loading are accessed through a drop−down door in the side of the pod.

CAUTION

To avoid damaging the rear section access door hinges, do not allow the door to drop open.

1.18.2.2.1 Video Cassette Recorder (VCR). The pod VCR is an off−the−shelf 8mm Hi8 format VCR in a ruggedized pod installation box. The VCR is capable of recording 2 hours of TPOD video or video/metry data using commercial Hi8 videocassette tapes. The VCR is software controlled via MPCD pushbuttons on the MPCD VCR display page.

1.18.2.2.2 FLIR Electronic Unit (FEU). The FEU provides the electronics for controlling the FLIR sensor, processing the video image, and communicating with the central computer processor.

1.18.2.2.3 System Electronics Unit (SEU). The SEU contains the main electronic cards for the TPOD system. This unit manages pod operation through an operational software package in the Central Processing Unit (CPU). The SEU also contains the electronic controllers necessary for controlling and monitoring pod functions through various communications channels and discrete lines, including the servo electronics, the IMU controller, the CCD camera controller assembly, and the EO tracker electronics.

1.18.2.2.4 Power Servo Unit (PSU). The PSU contains the DC power supply and power amplifiers used by the servo subsystem. The PSU is the control unit for sightline maintenance and management within the TPOD system, and receives servo commands from the system CPU and provides the high power required for the servo motors.

1.18.2.2.5 Interface Unit (IU). The IU is an aircraft specific interface unit consisting of power management, data management, and video management to and from the TPOD. The IU is mounted on the rear wall of the rear section. All external power and signals go through the IU; its main functions are:

(a) Interfacing with the ECU.

(b) Converting aircraft 115VAC power to 28VDC for TPOD use.

(c) Protecting pod power supply lines

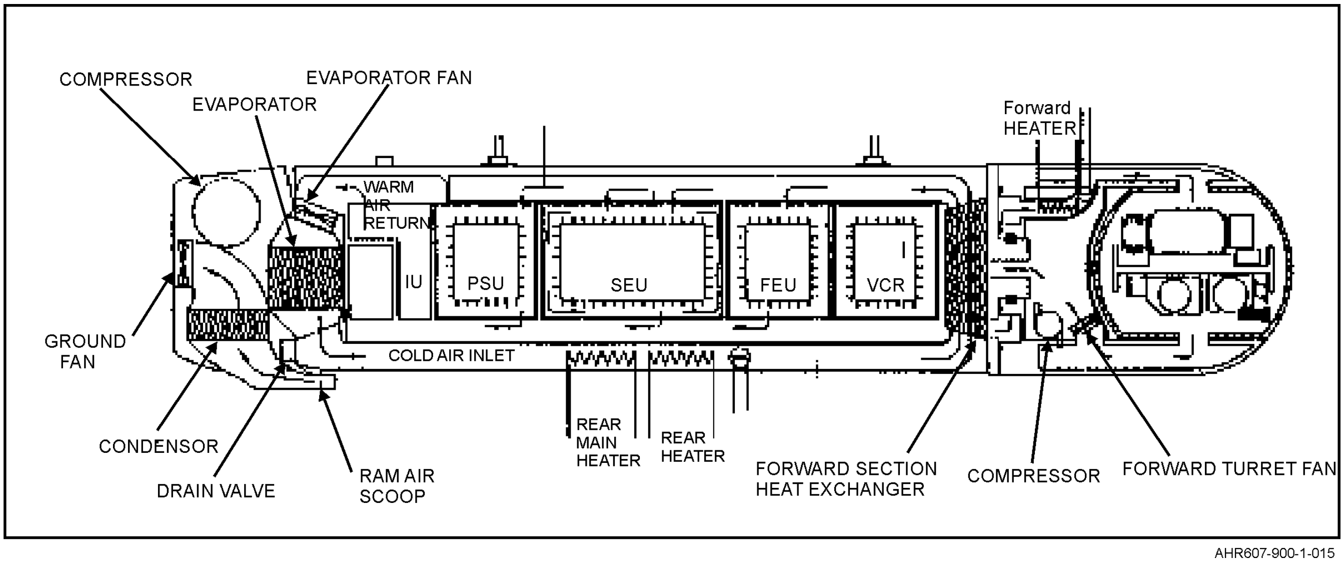


Figure 1-255. Environmental Control System Functional Diagram

against electromagnetic interference using an EMI Filter.

(d) Connecting electronic WRAs to the external umbilical connectors and to the utility/test connector.

1.18.2.3 Environmental Control Unit (ECU). The ECU is the major component of the environmental control system (see Figure 1–255). The ECU provides temperature control for the internal space of the TPOD. The ECU WRA is attached to the external rear of the pod, and is a cooling machine based on a conventional vapor cycle refrigerator. Its two main functions are:

(a) Control of the temperature in the forward section and the electronic WRAs.

(b) Control of the pressure and humidity in the forward section.

1.18.3 TPOD System Operations

1.18.3.1 Field–of–Regard. The TPOD gimbal system provides a Field–Of–Regard (FOR) with the capability of pointing everywhere except a 40° half angle cone directly behind the pod. The pod provides video imagery and lasing within the FOR except where the LOS is blocked by aircraft structure or external stores as defined by the laser mask zone (see Figures 1–256 and 1–257). The gimbal system is limited to ±400° in roll angle, and requires a pilot initiated gimbal unwind action or aircraft maneuver at approximately ±380° of sensor head rotation to keep a target within the FOR. The pilot is provided a visual warning of approach to gimbal limits. As the pod sensor head reaches ±200° of rotation, GIMB ROLL is displayed and flashes above the reticle in the center of the MPCD display. The GIMB ROLL warning stops flashing when the sensor head rotation exceeds ±240°. The pilot can correct the gimbal roll condition by either taking the pod out of the target tracking mode or by rolling the aircraft. The direction of aircraft roll is displayed as either a roll left (<) symbol or a roll right (>) symbol displayed on either side of GIMB ROLL. If the sensor head has rotated more than +200°, GIMB ROLL> is displayed; conversely, if the sensor head has rotated more than −200°, <GIMB ROLL is displayed. If the pilot takes no action and the sensor head reaches gimbal limits, the sensor head bumps against the gimbal stops resulting in the flashing of the pod look indicator, a small display spot that shows the pilot where the pod is looking. In addition to the flashing pod look indicator, there is also a possibility that the pod will temporarily transition into the backup inertial tracking mode when the pod sensors are no longer able to maintain optical target tracking.

1.18.3.2 Field−of−View. The TPOD provides three sensor FOVs: super−wide FOV (NAV mode), wide (WD), and narrow (NR). The NAV mode super−wide 24° x 24° FOV functions as a complimentary FLIR night navigation sensor to the existing NAVFLIR and is only available on the MPCD. In the NAV mode, the FLIR goes to pod boresight, depressed 2°, and is stabilized to the aircraft platform. The image is displayed on the MPCD and is not slewable. WD FOV is 4° x 4° for the FLIR, and 3.5° x 3.5° for the CCD. NR FOV is 1° x 1° for both FLIR and CCD. FLIR and CCD video scenes are horizon stabilized and slewable, and both WD and NR FOVs have a digital zoom capability that has 10 incremental steps that are represented and displayed as a range of 0 to 9.

1.18.3.3 Lasers. The TPO'Ds two operational lasers, the laser designator and the laser marker, and a non−firing training laser, are available in the TPOD A/G mode but not in the NAV mode. The laser designator also functions as a range finder. The training laser operation is identical to the laser designator operation with the exception of energy emission. This enables an eye−safe mode for training on ranges that do not permit laser firing. The pilot goes through all the switchology used for the tactical laser. Only one laser can be operated at a time.

1.18.3.3.1 Laser Eye Safety. The Nominal Ocular Hazard Distance (NOHD) for the laser designator is 12 miles. The NOHD for the laser marker is 621 feet. The lasers are considered eye−safe at ranges beyond these distances for direct exposure not exceeding 10 seconds.

WARNING

Direct exposure to the laser energy beam from the laser designator or laser marker within their respective NOHD may result in permanent eye damage or blindness.

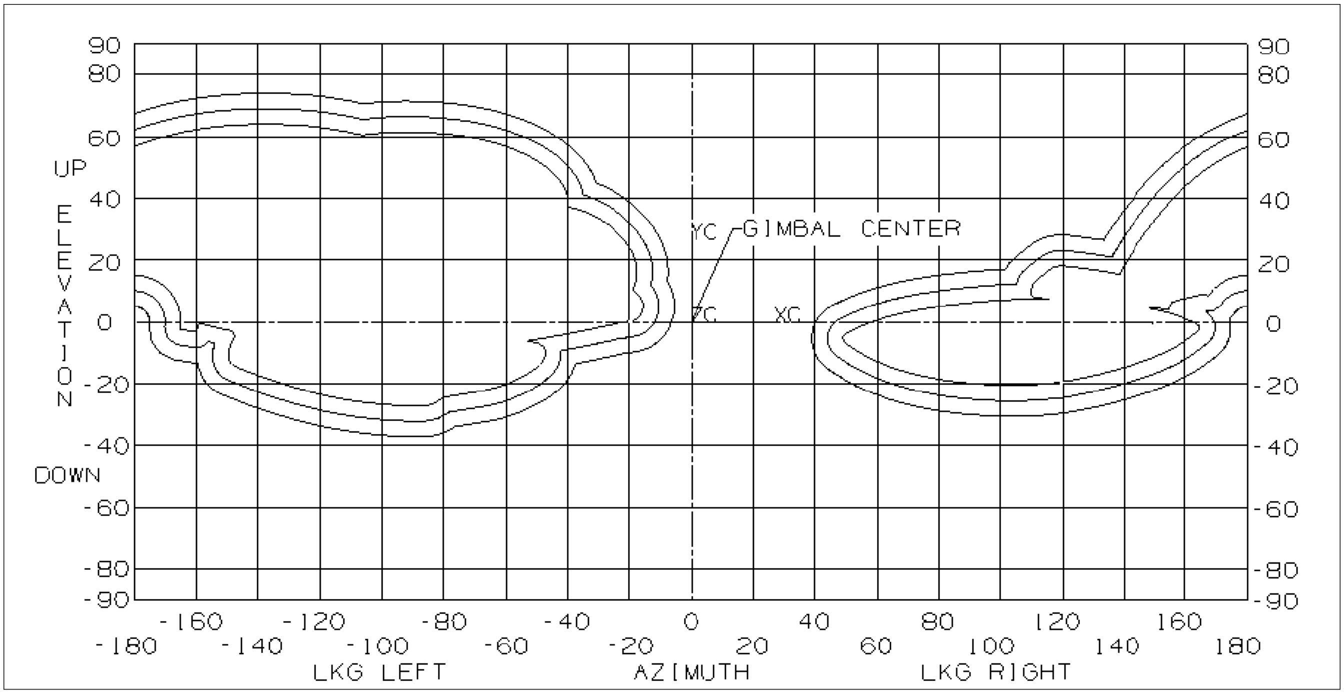
1.18.3.3.2 Laser Masks. Since the lasers are not eye−safe at distances less than NOHD, even for scattered/reflected energy, laser masks are provided to insure the laser energy does not strike the aircraft or its stores. To accommodate this safety consideration, two separate laser masks are stored in the pod, which are pilot selectable with PB 14 (TNK or ORD) on the TPOD data display page. These laser masks, which represent the masking zones plus a margin of safety, restrict laser firing when the pod LOS encounters the laser−masking zones. The default mask (TNK), which is automatically selected at pod power−up, accounts for the aircraft and a 300−gallon fuel tank on the adjacent pylon (station 6). The second mask (ORD) is for the aircraft and a composite worst−case ordnance load on the adjacent pylon consisting of the following weapons and ITER loadouts: AGM−65E/F, GBU−12/16, CBU−99/100, Mk−82 (all configurations), Mk−83 (all configurations), JDAM, and AIM−9L/M. See Figures 1−256 and 1−257.

The laser masks have two limits with reference to the pod's LOS approach to the aircraft and its stores:

(a) Warning Zone, within 10° of the airframe and station 6 stores.

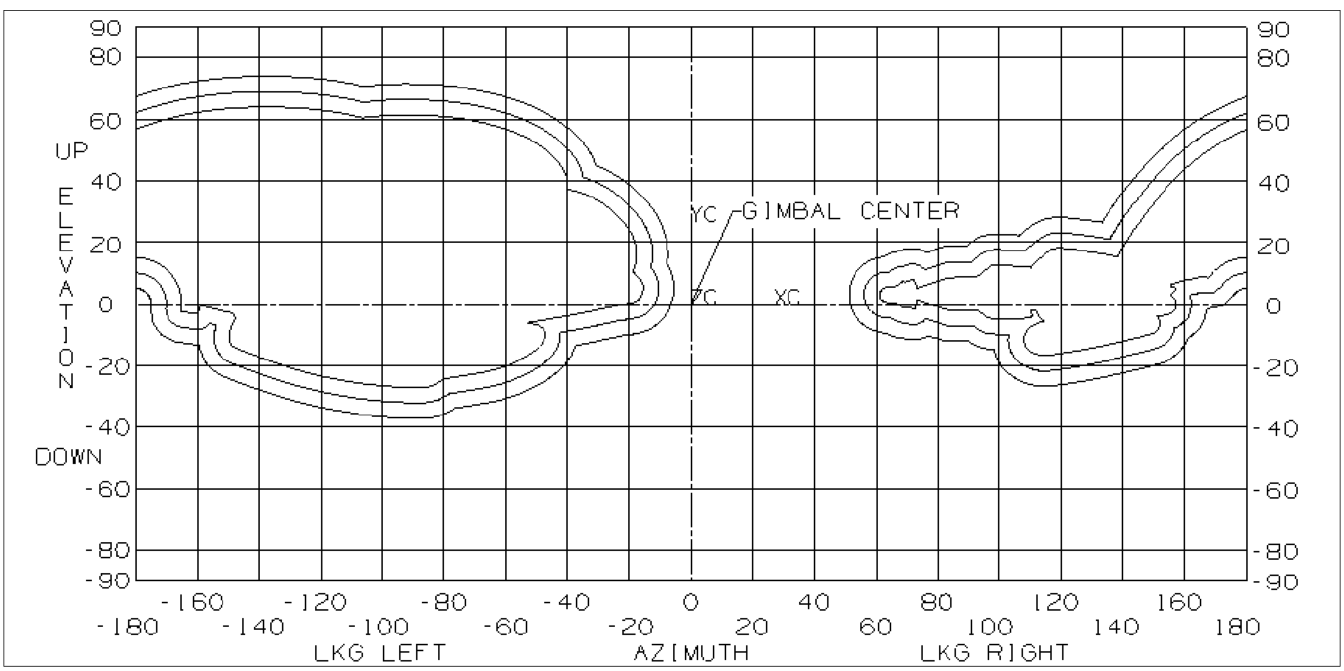
(b) Stop Firing Zone (Mask), within 5° of the airframe and station 6 stores.

1.18.4 Functional Description – Controls and Displays. The TPOD is controlled by or responds to MPCD pushbutton commands and HOTAS commands.



AHR607-901-1-015

Figure 1-256. Laser Mask TNK for Aircraft and 300-Gallon Tank on Station 6



AHR607-902-1-015

Figure 1-257. Laser Mask ORD for Aircraft and Worst Case Stores

1.18.4.2 MPCD Pushbutton Controls. The TPOD provides the legends for each MPCD pushbutton except for PB 10 and PB 18. These two pushbuttons are controlled by the MC, and when pressed, deselect the TPOD display page and return to the aircraft BIT display page and main menu display page, respectively. Using the video signal to the MPCD, the TPOD provides various legends next to the MPCD pushbuttons. When TPOD video is selected, the pod reacts to all pushbutton commands selected on the appropriate MPCD. See Figure 1−258 for a complete list of MPCD pushbutton commands and their functions.

The TPOD provides three separate display pages that provide video presentation and pod control; primary display page, data display page, and VCR display page. These displays include legends next to the MPCD pushbuttons for controlling pod functions, sensors, lasers, and VCR. Also, when on the TPOD primary display page, certain TPOD sensor functions can be controlled when in the TPOD HOTAS control mode.

NOTE

With a TPOD format page displayed, if the Display Alternate Toggle (DAT) pushbutton on the HUD control panel is selected, the MPCD displays are reversed. The TPOD display remains, however, the HOTAS control mode defaults to normal aircraft HOTAS control mode (TDC) and the target−tracking mode defaults to the slave mode, with the primary display page PB 14 and PB 16 legends displaying TDC and SLAVE, respectively.

1.18.4.2.1 Fields−of−View (FOVs). The TPOD's wide (WD) and narrow (NR) FOVs for the CCD and FLIR are selectable by PB 1 (WD/NR) on the primary display page and with the control stick Sensor Select Switch (SSS) when in the TPOD HOTAS control mode by pressing SSS−left for less than 0.8 second. The selected FOV is underlined. WD is the default FOV following pod power−up. WD FOV provides an image of a large area of interest. Four corner brackets around the reticle appear within the WD FOV display to indicate the area displayed when NR FOV is selected. The WD/NR pushbutton is also used to command a wide or narrow search (WSRCH/NSRCH) pattern when the Laser Spot Search (LSS) mode is selected. The NAV mode is available on the data page with PB 16 (NAV). In the NAV mode, the system is not slewable and the video display is stabilized to the aircraft platform. The FOVs are described below:

(a) CCD WD FOV is 3.5° x 3.5°

(b) FLIR WD FOV is 4° x 4°

(c) FLIR/CCD NR FOV is 1° x 1°

(d) NAV FLIR FOV is 24° x 24°

(e) LSS FOV diameter is 2.3°.

(f) LSS WSRCH provides a 4 x 4 km search pattern.

(g) LSS NSRCH provides a 2.5 x 2.5 km search pattern.

1.18.4.2.2 Electronic−Optical Zoom. The TPOD provides an electronic zoom of the image of the NR and WD FOVs for both the CCD and the FLIR sensors. This zoom feature effectively magnifies the central portion of the displayed video on the MPCD. The zoom increases in nine incremental steps for both sensors. When the sensor is changed, the zoom values are reset. Zoom is controlled with PB 3 (ZM+) and PB 4 (ZM−) on the primary display page for either the FLIR or CCD, or, if in the TPOD HOTAS control mode, by use of the throttle radar antenna elevation control wheel, where EL down = ZM+ and EL up = ZM− (radar aircraft only). Zoom values are 0 to 9, and are displayed between the ZM+ and ZM− legends.

1.18.4.2.3 FLIR Calibration. The FLIR has the capability to perform upon command a one−point, short calibration (SCAL), and two−point, long calibration (LCAL), after the FLIR camera has reached its operating temperature, when the TPOD is in standby mode on the primary display page. Calibration allows correction of a degraded FLIR image and can be accomplished airborne or on the ground. During a CAL, the outputs of the individual detectors in the FLIR are adjusted against known temperatures to produce a uniform picture. FLIR calibration should only be required if maintenance has been performed on the TPOD (i.e., forward section or FLIR EU has been replaced) or if the picture is degraded. The CCD does not require calibration. SCAL or LCAL can be selected by toggling PB 12, which displays the SCAL or LCAL legend next to PB 13 for 5 seconds. SCAL or LCAL must be selected within the 5 seconds or the legend returns to blank. Once started, neither SCAL nor LCAL can be deselected. SCAL adjusts the FLIR against a single temperature and takes 0.5 to 1.5 minutes. SCAL is intended to be the primary calibration method if the image appears to have minor blemishes or non−uniformities that are not a result of the scene, or when significant ambient temperature changes occur. LCAL adjusts the FLIR against two temperatures and requires 6 to 9 minutes to complete. When the SCAL or LCAL is selected, SHRT CAL or LONG CAL, respectively, is displayed in the center of the MPCD.

NOTE

The TPOD must be in STBY and the FLIR cooled down to perform a calibration. In addition, SCAL must not be performed within 30 minutes after LCAL. This may severely degrade the FLIR image requiring another LCAL to be performed.

1.18.4.2.4 FLIR Integration Time. The integration time setting determines the length of time the IR energy is processed on the FLIR to obtain the best picture quality (integration time is analogous to shutter speed on a camera). Hot Scene Integration (HINT) yields a processing time of 2.3 ms; while Cold Scene Integration (CINT) yields a processing time of 4.6 ms. Integration settings should be based on the predicted target area temperatures. Selection of HINT or CINT is via PB 13 on the FLIR data display page. HINT is the default setting. The recommended integration settings are as follows:

(a) Background temperatures of 20°C or less should use CINT,

(b) Background temperatures of 30°C or more should use HINT, and

(c) Background temperatures between 20°C and 30°C can use either setting at the pilot's preference.

NOTE

Calibrations for each integration setting must be performed to produce the best FLIR images. When a calibration is required, LCAL should be performed when airborne. FLIR calibrations on the ground may corrupt the FLIR image. If time does not permit LCAL in both integration settings, LCAL should be performed on the integration setting corresponding to the target area background temperature. SCALs may or may not improve the FLIR image.

1.18.4.2.5 FLIR Focus. The FLIR is manually focused using PB 11 (FCS−) and PB 12 (FCS+) on the FLIR data display page in the pod operate mode. The focus setting ranges from 0 to 99, and is displayed between the FCS− and FCS+ legends next to pushbuttons 11 and 12, respectively. Decreases or increases in FLIR focus are made by pressing and holding, or by clicking for fine adjustment, PB 11 or PB 12, respectively. The FLIR focus is reset using PB 19 (FRST) on the FLIR data display page in the pod operate mode. FRST provides both an auto−focus capability and the ability to select the factory default focus setting as follows:

1. Press PB 19 (FRST) for less than 0.8 second to initiate the 3−second auto−focus refinement of the FLIR image display.

2. Press PB 19 (FRST) for more than 0.8 seconds to initiate FLIR focus reset to reset the FLIR focus back to the factory determined best setting. This default setting is unique to each TPOD and may vary slightly between pods.

1.18.4.2.6 FLIR Gain. The FLIR gain is manually adjusted using PB 12 (GN−) and PB 13 (GN+) on the FLIR primary display page in operate mode. The gain setting ranges from 1 to 8, and is displayed between the GN− and GN+ legends next to pushbuttons 12 and 13, respectively. Clicking PB 12 decreases gain to a minimum setting of 1, and then wraps to 8. Clicking PB 13 increases gain to a maximum setting of 8, and then wraps to 1.

1.18.4.2.7 FLIR Display Polarity. The TPOD FLIR video represents differences in temperature between objects. The TPOD has the capability to change the FLIR video display polarity so that black represents objects that are hotter than the surrounding objects (BH), or white represents objects that are hotter than the surrounding objects (WH). Pressing PB 11 on the FLIR primary page, or, if in TPOD HOTAS control mode, by pressing SSS−right for less than 0.8 second, toggles between the settings. The selected polarity legend next to PB 11 is underlined - <u>WH</u>/BH or WH/<u>BH</u>. <u>WH</u> is the default polarity following pod power−up.

1.18.4.2.8 Gray Scale. To help properly optimize the MPCD brightness (BRT) and contrast (CONT) settings, the pod includes a selectable gray scale. The gray scale is selected via PB 14 (GRAY) on the VCR control page. When the gray scale is selected, it is displayed across the bottom of the display along with the current video. The optimal way to set the gray scale is as follows:

1. Set the brightness and contrast to minimum.

2. Bring up the brightness until a raster just appears. Then reduce the brightness until it is dark again.

3. Bring up the contrast until the two rightmost bars run together at peak brightness. Reduce contrast until they are separable again.

4. Fine adjustments to the BRT and CONT should be made until all gray scales are separable.

1.18.4.3 MPCD Pushbutton Menu. Figure 1−258 defines TPOD MPCD pushbutton PB functions that are dependent upon sensor/display page and pod standby or operate status. Most pushbuttons have different definitions between FLIR and CCD. The VCR page is identical regardless of the sensor selected.

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PB	FLIR		CCD		VCR	DESCRIPTION
	PRI-MARY	DATA	PRI-MARY	DATA	DATA	
1	WD/NR	VCR	WD/NR	VCR	VCR	When PB 1 is selected, the TPOD performs the following functions: FLIR/CCD Primary Page - Toggles between wide and narrow (WD/NR) FOVs. The current FOV is underlined. The selected FOV remains unchanged when toggling between FLIR and CCD sensors. The default FOV is WD following pod power-up, after running IBIT, or going from NAV to A/G mode. When in LSS, PB 1 toggles between wide and narrow search patterns. Data Page - VCR is displayed on all data pages. VCR Data Page - The VCR button, which is only available on a data page, selects the VCR page and underlines the VCR legend. Selection of the underlined VCR legend returns to the previous data page. The VCR page remains selected until DATA or VCR legends are selected. If the aircraft deselects the TPOD display page, subsequent selection of the TPOD page returns to the primary page for the selected sensor - CCD or FLIR.
2	DATA	DATA	DATA	DATA	DATA	When PB 2 is selected, the TPOD performs the following functions: FLIR/CCD Primary Pages - This PB selects the data page and underlines the DATA legend. FLIR/CCD/VCR Data Pages - Selection of the DATA legend pushbutton from either the data or VCR page returns to the primary page, and removes the underline from the DATA legend. If the VCR page is selected from the data page, the legend DATA remains selected until the DATA or VCR legend is selected. If the aircraft deselects the TPOD display page, subsequent selection of the TPOD page returns to the primary page for the selected sensor - CCD or FLIR.

Figure 1-258. MPCD Menu Description (Sheet 1 of 11)

PB	FLIR		CCD		VCR	DESCRIPTION
	PRI-MARY	DATA	PRI-MARY	DATA	DATA	
3	ZM+	SYM+	ZM+	SYM+	<blank>	When PB 3 is selected, the TPOD performs the following functions: FLIR/CCD Primary Page - Increase zoom (zoom-in) to a maximum setting of 9. The zoom setting ranges from 0 to 9, and is displayed between PB 3 and PB 4. The TPOD resets the zoom setting when changing to and from track and slave modes, and when changing FOVs. The zoom setting does not change when toggling between FLIR and CCD sensors. The PB 3 legend is blank in TPOD standby mode. Data Page - Increases symbology intensity. VCR Data Page - Leave blank.
4	ZM+	SYM+	ZM+	SYM+	<blank>	When PB 4 is selected, the TPOD performs the following functions: FLIR/CCD Primary Page -Press and hold decreases zoom (zoom-out) to a minimum setting of 0. The zoom setting ranges from 0 to 9, and is displayed between PB 3 and PB 4. The TPOD resets the zoom setting when changing to and from track and slave modes, and when changing FOVs. The zoom setting does not change when toggling between FLIR and CCD sensors. The PB 4 legend is blank in TPOD standby mode. Data Page - Decreases symbology intensity. VCR Data Page - Leave blank

Figure 1-258. MPCD Menu Description (Sheet 2 of 11)

PB	FLIR		CCD		VCR	DESCRIPTION
	PRI-MARY	DATA	PRI-MARY	DATA	DATA	
5	FLIR	FLIR	CCD	CCD	UN-TRD	When PB 5 is selected, the TPOD performs the following functions: FLIR/CCD Primary/Data Pages - Toggles between FLIR and CCD sensor operation - displaying the current sensor in use. Changing sensors does not change the current display settings. CCD is the default sensor. VCR Data Page - Unthreads the videotape for cassette removal.
6	SAFE ARM	SAFE ARM	SAFE ARM	SAFE ARM	SAFE ARM	When PB 6 is selected, the TPOD performs the following functions: FLIR/CCD/VCR All Pages - The current arming state is displayed for the Training Laser (TRNL), Laser Marker (MRKR), or Laser Designator (LASR). Pressing this PB toggles between SAFE and ARM. With SAFE displayed, pressing this PB arms the selected laser (ARM displayed) provided all laser safety interlocks have been met. If any safety interlock is not met, the arming state remains SAFE. The default is SAFE.
7	LRNG	LRNG	LRNG	LRNG	LRNG	When PB 7 is selected, the TPOD performs the following functions: FLIR/CCD/VCR All Pages - This option is only available when LASR or MRKR is selected and armed (ARM). This option is disabled when the TRNL is the selected laser. When selected, the TPOD performs a short duration laser range measurement of less than 3 seconds. LRNG is underlined during laser range update, and laser symbol L below the reticle and on HUD flash. If MRKR is selected and LRNG is initiated, TPOD automatically switches to LASR, performs range measurement, and switches back to MRKR. PB 7 is ignored if LASR is already firing, or if selected on the VCR page.

Figure 1-258. MPCD Menu Description (Sheet 3 of 11)

PB	FLIR		CCD		VCR	DESCRIPTION
	PRIMARY	DATA	PRIMARY	DATA	DATA	
8	FIRE	FIRE	FIRE	FIRE	FIRE	When PB 8 is selected, the TPOD performs the following functions: FLIR/CCD Primary/Data Pages - This option, with the FIRE legend displayed, is only available when the selected laser is armed (ARM). When selected, the laser fires (training laser dry fires), and the FIRE legend is underlined. When selected again, the selected laser firing and the FIRE underline is removed. While the laser is firing (training laser dry firing), the laser symbology below the reticle and on the HUD flash. VCR Data Page - The pod only stops firing the selected laser when this PB is selected. Initiating laser fire from the VCR page is prohibited.
9	TRNL MRKR LASR	TRNL MRKR LASR	TRNL MRKR LASR	TRNL MRKR LASR	TRNL MRKR LASR	When PB 9 is selected, the TPOD perform the following functions: FLIR/CCD/VCR All Pages - The TPOD toggles through the three available laser types. The default laser following power-up is the training laser. The order of laser selection is TRNL, Laser MRKR, and LASR. This PB is non-functional when the selected laser is firing, with the PB 8 FIRE legend displayed.
10	STOP	STOP	STOP	STOP	STOP	When PB 10 is selected, the TPOD performs the following functions: FLIR/CCD/VCR All Pages - The MC controls this PB, and when selected, exits the TPOD page and goes to the aircraft BIT page. The TPOD does not write anything in this area.

Figure 1-258. MPCD Menu Description (Sheet 4 of 11)

PB	FLIR		CCD		VCR	DESCRIPTION
	PRI-MARY	DATA	PRI-MARY	DATA	DATA	
11	WH/BH	FCS-	<blank>	<blank>	MT/VD	When PB 11 is selected, the TPOD performs the following functions: FLIR Primary Page - Toggles polarity between white hot and black hot (WH/BH). Current state of polarity is underlined. WH is the default. Data Page - Pressing and holding PB 11 decreases image focus to a minimum setting of 0. The focus setting, from 0 to 99, is displayed between PB 11 and PB 12. The default setting is factory set to approximately 50-60. CCD Primary Page - Leave blank. Data Page - Leave blank. VCR Data Page - Selects either metry or video (MT/VD) for VCR recording. VD is the default setting after power-up. The appropriate selection is underlined. When MT is initially selected, VCR record (REC) is automatically command.
12	CAL GN -	FCS+	<blank>	<blank>	<blank>	When PB 12 is selected, the TPOD performs the following functions: FLIR Primary Page - In the TPOD standby mode (STBY), CAL is displayed. Pressing PB 12 toggles between blank, SCAL, and LCAL PB 13 legends. In the TPOD Operate mode (STBY), GN - is displayed. Clicking PB 12 decreases gain to a minimum setting of 1, and then wraps to 8. The gain setting, from 1 and 8, is displayed between PB 12 and PB 13. Data Page - Pressing and holding PB 12 increases image focus to a maximum setting of 99. The focus setting, from 0 to 99, is displayed between PB 11 and PB 12. CCD Primary Page - Leave blank. Data Page - Leave blank. VCR Data Page - Leave blank.

Figure 1-258. MPCD Menu Description (Sheet 5 of 11)

PB	FLIR		CCD		VCR	DESCRIPTION
	PRI-MARY	DATA	PRI-MARY	DATA	DATA	
13	<blank> SCAL LCAL GN+	HINT CINT	<blank>	<blank>	REJ	When PB 13 is selected, the TPOD performs the following functions: FLIR Primary Page - In the TPOD standby mode (STBY), <blank>, SCAL, or LCAL is displayed. Pressing this PB commands the pod to perform the selected calibration run. If the PB 13 legend is blank this PB is non-functional. With SCAL or LCAL displayed, if no PB action is detected within 5 seconds, the TPOD blanks the legend. In the TPOD operate mode, GN+ is displayed. Clicking PB 13 increases gain to a maximum setting of 8, and then wraps to 1. The gain setting, from 1 and 8, is displayed between PB 12 and 13. Data Page - Pressing this PB toggles between HINT and CINT, which sets the integration time for FLIR image processing. HINT is the default setting. CCD Primary Page - Leave blank. Data Page - Leave blank. VCR Data Page - Selection of REJ (reject) declutters the TPOD video displays of the following items on all display pages in which they appear: UTC time, target location data in the upper right corner of the MPCD, pod-to-target bearing and range in the lower left corner, and the aircraft command LOS (A/C CMD LOS) offset in the lower right corner.

Figure 1-258. MPCD Menu Description (Sheet 6 of 11)

PB	FLIR		CCD		VCR	DESCRIPTION
	PRI-MARY	DATA	PRI-MARY	DATA	DATA	
14	TDC TDC HTS	TNK ORD	TDC TDC HTS	TNK ORD	GRAY	When PB 14 is selected, the TPOD performs the following functions: FLIR/CCD Primary Page - Selecting TDC underlines the TDC legend (TDC) and tells the TPOD to read the TDC slew rates in the normal MUX BUS location. The TPOD responds to no-action slew commands. TPOD HOTAS mode is selected or deselected by double clicking SSS-down in less than 0.8 sec. When selected, HTS replaces TDC or TDC. Selection or de-selection of HTS is not controlled via this PB. Data Page - Pressing this PB toggles between laser masks for aircraft and fuel tank (TNK) and aircraft and worst-case ordnance (ORD) load. VCR Data Page - Selection displays gray scale and underlines the GRAY legend (GRAY). The gray scale is automatically removed when this PB (GRAY) is reselected or upon leaving the VCR page.
15	STBY	STBY	STBY	STBY	REC	When PB 15 is selected, the TPOD performs the following functions: FLIR/CCD Primary/Data Page - Cycles between standby (STBY) and operate (STBY) modes. TPOD stows sensor head when STBY is selected and underlines STBY. STBY is automatically entered following IMU alignment. Selecting this PB while in STBY, the pod goes to the current aircraft master mode; if aircraft is in A/G mode or A/A mode, the pod goes to A/A mode.

Figure 1-258. MPCD Menu Description (Sheet 7 of 11)

PB	FLIR		CCD		VCR	DESCRIPTION
	PRI-MARY	DATA	PRI-MARY	DATA	DATA	
16	SLAVE	NAV	SLAVE	NAV	FF	When PB 16 is selected, the TPOD performs the following functions: FLIR/CCD Primary Page - In STBY, NAV, and BIT modes this PB legend is blank. In A/G and A/A modes, pressing this PB commands TPOD to slave sensor head to A/C CMD LOS, and underlines SLAVE (SLAVE). Selecting SLAVE from any track mode re-slaves TPOD to CMD LOS. If a CMD LOS does not exist, TPOD cages pod sensor head to pod boresight, depressed 2°. Data Page - Pressing this PB commands the pod to NAV operating mode, primary display page, and removes the NAV legend. This action cages pod sensor head to boresight depressed 2°. Selection of DATA goes to NAV data display page, and restores and underlines NAV. Selection of NAV returns the pod to the current aircraft master mode. VCR Data Page - Pressing this PB commands pod VCR to fast-forward (FF). A counter is displayed on the VCR page to indicate the current tape run-position. If any other VCR function was selected except playback, when FF is selected, the TPOD stops that function and starts the FF function.

Figure 1-258. MPCD Menu Description (Sheet 8 of 11)

PB	FLIR		CCD		VCR	DESCRIPTION
	PRI-MARY	DATA	PRI-MARY	DATA	DATA	
17	LSS	BIT	LSS	BIT	PLAY	When PB 17 is selected, the TPOD performs the following functions: FLIR/CCD Primary Page - Pressing this PB commands the TPOD to LSS operating mode and underlines the legend as LSS. When the TPOD automatically transitions to LST mode upon detecting a laser energy spot, the LSS legend is removed. If in LST mode and the laser energy spot is lost, the TPOD reverts to LSS for 10 seconds. If LST is not reestablished, the TPOD switches to SLAVE mode. This legend is blank when the training laser is dry firing, or the laser designator or laser marker is firing. Data Page - Pressing this PB, with weight-on-wheels, commands an initiated BIT for the TPOD, goes to the primary display page, displays the IBIT countdown timer in the upper center of display page, and removes the BIT legend. Upon completion of an IBIT, the TPOD returns to STBY mode. Any aircraft movement while IBIT is running results in an incomplete BIT check and BIT failures, which must be cleared with PB 20 (DPFL) on the data display page, STBY mode. TPOD operation is not affected. This PB legend is only available with weight-on-wheels. VCR Data Page - Pressing this PB commands the pod VCR into the playback (PLAY) mode. Except for PB 10 and PB 18, selection of any VCR display page PB stops the pod VCR playback mode and displays VCR data page. Pressing PB 10 does nothing; PB 18 stops the playback mode and reverts to normal aircraft displays.
18	MENU	MENU	MENU	MENU	MENU	When PB 18 is selected, the TPOD performs the following functions: FLIR/CCD/VCR All Pages - The MC controls this PB, and when selected, exits the TPOD page and goes to the aircraft menu page. The TPOD does not write anything in this area.

Figure 1-258. MPCD Menu Description (Sheet 9 of 11)

PB	FLIR		CCD		VCR	DESCRIPTION
	PRI-MARY	DATA	PRI-MARY	DATA	DATA	
19	INR	SRVC FRST	INR	SRVC	STOP	When PB 19 is selected, the TPOD performs the following functions: FLIR/CCD Primary Page - Pressing this PB drives the pod into the Inertial Navigation Reference Track mode (INR). The pod displays the appropriate symbology and underlines INR. This PB is non-functional with INR displayed. FLIR Data Page - In the pod standby mode (STBY), SRVC (Service) is displayed. When selected, the pod sensor head unstows for maintenance access for sensor head window cleaning and desiccant bag replacement. The SRVC legend is only available with weight-on-wheels. In the pod operate mode (STBY), FRST (Focus Reset) is displayed. Pressing PB 19 for less than 0.8 second initiates the auto-focus function for a 3-second refinement of the displayed FLIR image. Depressing PB 19 for more than 0.8 second resets the FLIR focus to the factory default setting. CCD Data Page - In the pod standby mode (STBY), the SRVC function is the same as described for the FLIR data page. In the pod operate mode (STBY), the PB 19 legend is blank. VCR Data Page - Selection of STOP with this PB commands the pod VCR to stop current recorder mode operation and underlines the STOP legend.

Figure 1-258. MPCD Menu Description (Sheet 10 of 11)

PB	FLIR		CCD		VCR	DESCRIPTION
	PRI-MARY	DATA	PRI-MARY	DATA	DATA	
20	AR/PT	DPFL	AR/PT	DPFL	REW	When PB 20 is selected, the TPOD performs the following functions: FLIR/CCD Primary Page - Displays EO track mode options: Area and Point (AR/PT). Selecting this PB from slave or INR track mode causes the TPOD to enter the PB 20 underlined track mode. Selecting this PB while in track mode causes the TPOD to cycle to the next track mode. The desired sequence is from AR to PT. The default track mode is AR. Data Page - Selecting DPFL (Display Pod Fault List) commands TPOD to display all faults TPOD BIT has detected, cycle through faults, and remove fault list when pressed for more than 0.8 second. Pod fault list displays maintenance fault listings (hard failures requiring WRA replacements) and pilot fault listings (non-critical faults that reduce pod performance). VCR Data Page - Pressing this PB commands the pod VCR to the tape rewind mode and underlines the REW legend. A counter is displayed in the lower right corner of the VCR page to indicate the current tape run-position. If any other VCR function was selected, except playback, when REC is selected, then the pod stops that function and starts the REC function.
Notes: 1. All pushbuttons, except 6 thru 9, that are not applicable to the current mode of operation are blanked. Pushbuttons 6 thru 9 display the legends described above. 2. When master arm is selected to safe the laser, the TPOD resets the armed condition (ARM) to SAFE (as displayed below PB 6). 3. When the laser is firing and enters a masked area, the TPOD stops firing the laser. When the TPOD unmasks, the TPOD resumes laser firing.						

Figure 1-258. MPCD Menu Description (Sheet 11 of 11)

1.18.4.4 HOTAS/TDC Controls. The current state of TPOD control is displayed on the TPOD Primary display page next to PB 14 HOTAS control options include the following:

1. Aircraft HOTAS Control Mode (TDC),
2. TPOD Slew Control Mode (TDC), or
3. TPOD HOTAS Control Mode (HTS).

1.18.4.4.1 Aircraft HOTAS Control Mode (TDC). The TDC mode, which is the default control mode, is available when the TPOD format is displayed on either MPCD, and HOTAS control is assigned to the aircraft, not to the TPOD. In this mode, pod sensors are slaved to the aircraft command LOS (A/C CMD LOS). If no A/C CMD LOS exists, the TPOD slaves pod sensors to pod boresight, depressed 2° in elevation. The pod provides an indication of aircraft HOTAS assignment by displaying the TDC legend next to PB 14. See Figure 1–273.

In this mode, the pod monitors MC to DC signals for target range north, east, and down commands and slaves pod sensors to the aircraft designated target represented by the target location displayed in the upper right corner of the MPCD. In this mode, HOTAS is assigned to the aircraft and the TPOD does not react directly to HOTAS commands. However, when in this mode, and the TDC switch is pressed down, an aircraft designation is set. Movement of the TDC affects the aircraft system designation and pod sensors are slaved to the aircraft designated target. The TDC mode is exited when the TPOD display format is no longer displayed on either MPCD after expiration of the 15−second grace period timer; however, TDC is reestablished with return to the TPOD display. The TDC mode is changed to another control mode from the primary display page by selecting PB 14, which selects the TDC mode and replaces the TDC legend with TDC; or by double clicking SSS−down in less than 0.8 second, which selects the HTS mode and replaces the TDC legend with HTS.

1.18.4.4.2 TPOD Slew Control Mode (TDC). In the TDC mode, which is selected with PB 14 on the TPOD primary display page, the pod monitors aircraft sensor TDC slew signals and slews pod sensors to the TDC slew commands. TPOD sensor slew rates are up to 1.2 FOVs per second. The pod provides an indication of TPOD slew control assignment by displaying TDC next to PB 14. See Figure 1−274. In this mode, HOTAS control is assigned to the aircraft, not to the TPOD, and normal aircraft HOTAS controls are valid. The pod only reacts to TDC commands, not to any other HOTAS commands. If, when in this mode, the TDC switch is pressed down, an aircraft designation is set. Movement of the TDC affects the aircraft system designation, and the pod slews the pod sensors to this aircraft designated target. The TDC mode is exited when the TPOD format is no longer displayed on either MPCD after expiration of the 15−second grace period timer; however, the TDC mode is reestablished with return to the TPOD format display within 15 seconds of TPOD display exit. If return to the TPOD format display is initiated after expiration of the 15−second grace period timer, the TDC default mode is entered and the TDC legend is replaced by TDC. The TDC mode is changed to another control mode by selecting PB 14, which selects the TDC mode and replaces the TDC legend with TDC; or by double clicking the SSS−down in less than 0.8 second, which selects the HTS mode and replaces the TDC legend with HTS.

1.18.4.4.3 TPOD HOTAS Control Mode (HTS). The HTS mode is available when the TPOD primary display page is displayed, and HOTAS control is assigned to the TPOD. HOTAS control is assigned to the TPOD by double clicking SSS−down in less than 0.8 second. The pod provides an indication of HOTAS assignment to the TPOD by replacing the current legend (TDC or TDC) with the HTS legend. See Figure 1−286. In the HTS mode, the TPOD slews pod sensors in direct response to TDC slew commands. Slew rates are up to 1.2 FOVs/second. In this mode, the TPOD reacts to all assigned HOTAS commands, including applicable HOTAS controls in the TPOD master modes. TPOD HOTAS controls are listed in Figure 1−259, and shown in Figures 1−260 and 1−261.

NOTE

When in HTS mode, pressing the TDC does not set an aircraft system designation.

To refine the aircraft system designation when in the HTS mode, HTS is deselected by again double clicking the SSS−down in less than 0.8 second. The pod returns to the previous PB 14 displayed mode, TDC or TDC, and tracks the aircraft designated target. This allows the pilot to refine the aircraft system designation using TDC aircraft sensor slewing, and then double clicking the SSS−down to return to HTS. The TPOD can be returned to the previous control mode by double clicking SSS−down in less than 0.8 second, which exits HTS and select the previous PB 14 displayed mode (TDC or TDC). PB 14 is non−operative with the HTS legend displayed, and pressing PB 14 has no effect on the state of HOTAS control. The HTS mode is exited when a TPOD format is no longer displayed on either MPCD, however, HTS is reestablished with return to the TPOD format display within 15 seconds of TPOD display exit. If return to the TPOD format display is initiated after expiration of the 15−second grace period, the TDC default mode is entered and TDC replaces the PB 14 HTS legend. The HTS mode is also exited with selection of SSS−forward, which, if in A/G, VSTOL or NAV master modes, selects air−to−ground ranging for radar aircraft or selects the INS sensor mode for night attack aircraft; SSS−forward in A/A master mode selects aircraft boresight; or selecting STOP or MENU exits the HTS mode.

HOTAS	ACTION	RESULT	COMMENTS
Sensor Select Switch	Double clicked down In < 0.8 sec	Selects or deselects TPOD HOTAS mode when pod video is displayed.	
	Clicked aft < 0.8 sec	Toggles between area and Point Track modes (AR/PT).	
	Held aft > 0.8 sec	Selects INR Inertial Track mode.	
	Clicked left < 0.8 sec	Toggles between wide and narrow FOV (WD/NR).	
	Held left > 0.8 sec	Enters LSS mode.	LST automatically entered.
	Clicked right < 0.8 sec	Toggles between White Hot and Black Hot (WH/BH) FLIR polarity.	
	Held right > 0.8 sec	Toggles between FLIR and CCD sensors.	
	Pressed forward	Deselects TPOD video and returns to normal aircraft HOTAS mode.	
Air Program Switch	Pressed	Fires Laser Designator and Laser Marker, and dry fires Training Laser; and stops firing of all lasers.	Radar aircraft only.
Undesignate	Pressed	Slaves pod sensors to A/C CMD LOS.	
Throttle Antenna Elevation Wheel	Increment (Up)	Initiates CCD/FLIR video zoom-out.	Radar aircraft only.
	Decrement (Down)	Initiates CCD/FLIR video zoom-in.	
Target Designator Control	X-, Y-Axis movement	Slews pod sensors.	
	Z-Axis (pressed down)	No change in pod sensor slew rate.	

Figure 1-259. Litening II Pod HOTAS Controls

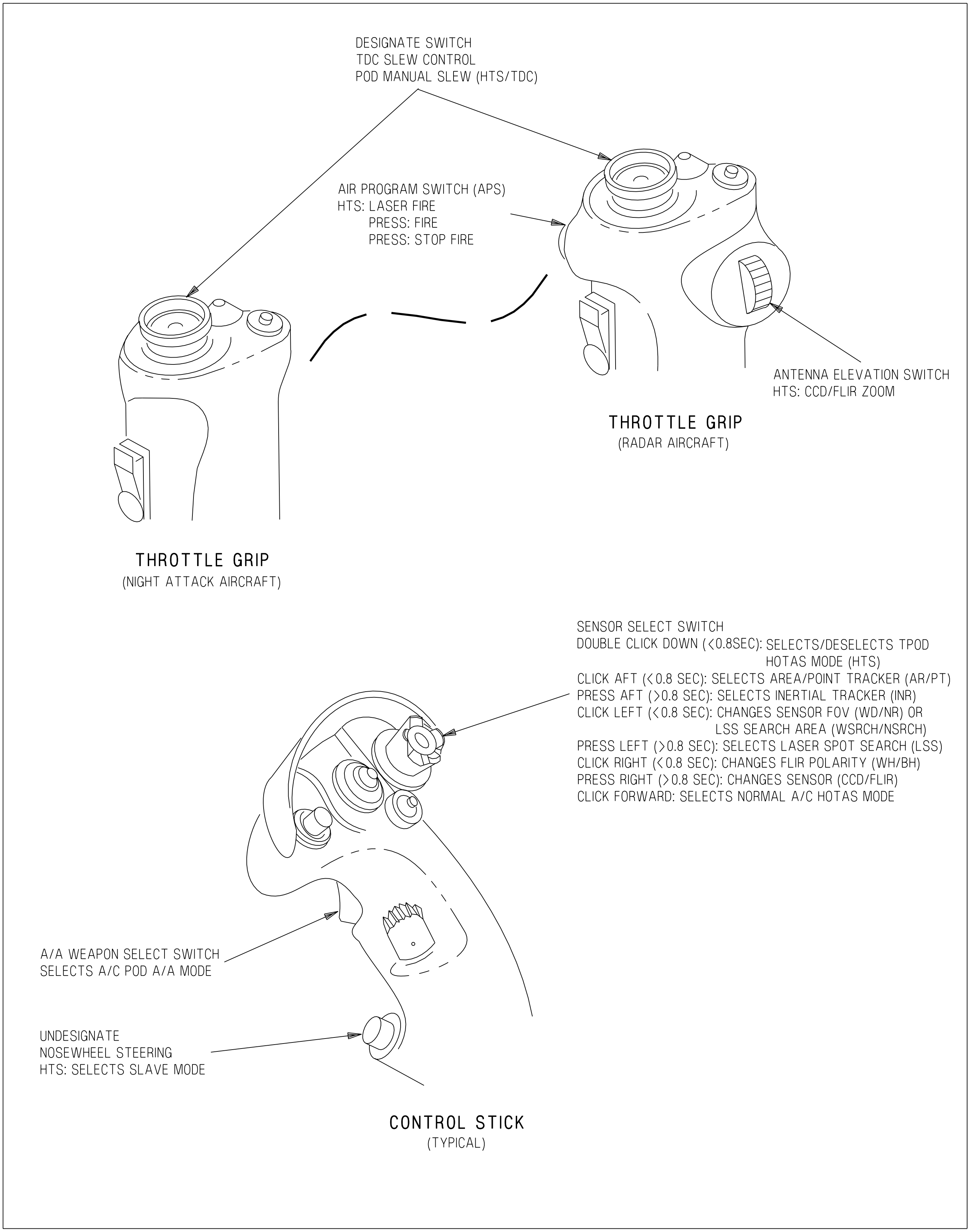


Figure 1-260. HOTAS Controls

1.18.4.5 TPOD Modes of Operation

1.18.4.6 General Operation Description. The Litening II system is used in different operational modes of the aircraft, each of them demanding different pod functions and behavior. Consequently, operation of the TPOD system is divided into various modes, which operate interactively with the aircraft modes. The TPOD provides six main operating modes: power–up initialization, standby, air–to–ground, navigation, air–to–air, and BIT. The aircraft master modes, along with MPCD pushbutton selection, control the TPOD operating modes. The TPOD automatically enters standby mode after it has completed the power–up initialization sequences. See Figures 1–261 and 1–262.

AIRCRAFT MASTER MODES	TPOD MAIN MODES
(ACFT, PARKED)	INIT mode - Power-up initialization mode: pod powers-up, initializes pod subsystems, IMU alignment, and power-on BIT.
VSTOL, NAV, A/G	STBY mode - Default mode following completion of initial pod power-up. Selection of standby mode overrides subsequent aircraft mode changes and retains the pod standby mode. NAV mode - selection of NAV mode overrides subsequent aircraft master mode changes and retains pod NAV mode. A/G mode - selection of A/G mode from A/A mode is automatic upon selection of the aircraft A/G master mode. If A/G mode is the selected pod mode, it is retained as the aircraft master mode is changed between VSTOL, NAV, and A/G.
A/A	A/A mode - Selection of A/A mode from A/G mode is automatic upon selection of the aircraft A/A master mode. Pod A/A mode cages pod sensors to pod boresight and depressed 2° in elevation. If A/A mode is the selected pod mode, it changes to A/G mode when the aircraft master mode is changed to VSTOL, NAV, or A/G.
(ACFT WEIGHT-ON-WHEELS)	BIT mode - Includes pod self-initiated Power-on BIT (PBIT) and operator selected Initiated BIT (IBIT), both of which only run in STBY mode with weight-on-wheels; and Continuous BIT (CBIT), which runs continuously in the background in all pod modes following completion of PBIT.

Figure 1-261. AV-8B/TPOD Main Operational Modes

Each TPOD mode includes a different set of sub–modes and functions, each involving a different pod LOS behavior. The interactions between the TPOD modes, sub–modes, functions and LOS behavior are summarized in Figure 1–263.

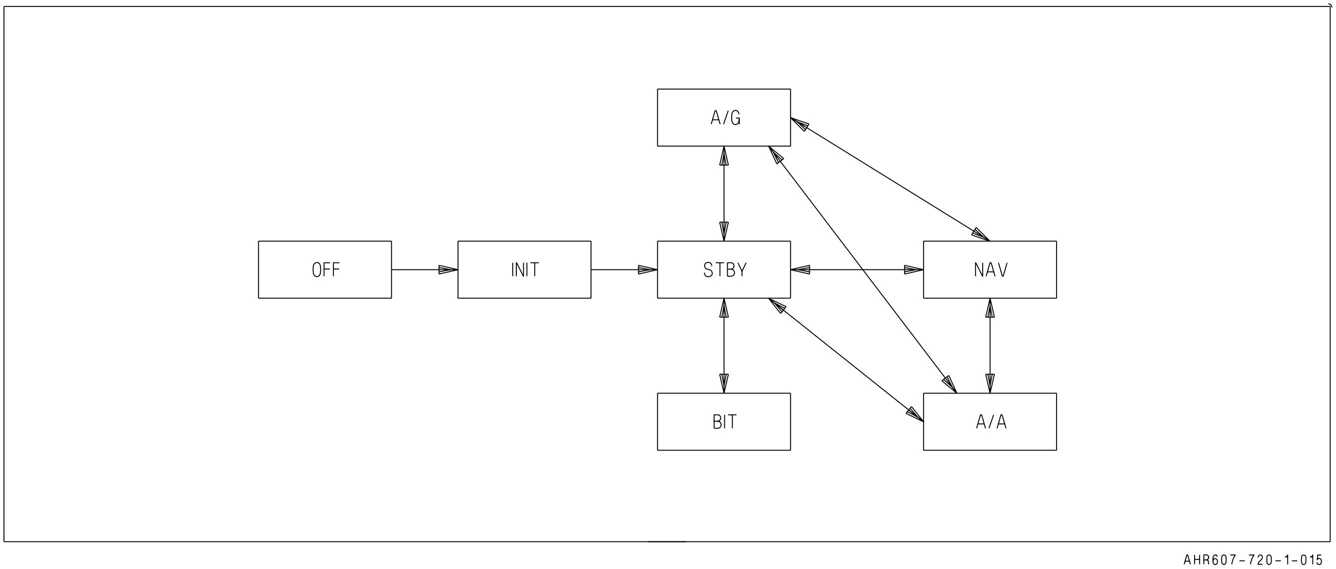


Figure 1-262. TPOD Main Operating Modes Diagram

POD MAIN MODES	POD SUB-MODES/ FUNCTION	POD LOS BEHAVIOR
INIT	System Initialization and Power-on BIT	Sensor head locked in stowed position.
STBY	Service, BIT, and FLIR Calibration	Service: Forward section rotates to service position for desiccant bag replacement; sensor head unstows for window cleaning. IBIT: Servo tests cause forward section to rotate. FLIR Cal: Sensor head stowed.
A/G	Slave	Sensor head slaved to A/C CMD LOS, or if no A/C CMD LOS, caged to pod boresight, depressed 2°.
	Manual Slew	Sensor head slaved or slewed to TDC slew commands.
	A/G Track	Sensors track designated target or pod point of interest if slewed off designated target. Manual slew enabled to change the locked point. At end of slew, the new point is locked and tracking is renewed.
	Laser Designation	Laser 1 illuminates pod LOS point of interest (target).
	Laser Marker	Laser marker illuminates, for night vision goggles, the aircraft or pod point of interest, if different.
	Laser Spot Search	Sensor performs wide/narrow search pattern.
	Laser Spot Track	Sensor tracks laser energy spot.
A/A	Cage	Sensor head caged to pod boresight, depressed 2°.
NAV	Cage	Sensor head caged to pod boresight, depressed 2°, and automatically selects FLIR.

Figure 1-263. TPOD Operating Modes and Functions

1.18.4.7 Power–Up/Initialization. Power is applied to the TPOD by engaging the power on–off toggle switch in the umbilical after aircraft power has been applied. With power on, the pod performs initialization sequences and the pod's subsystems are initialized before entering a quiescent, ready configuration standby mode, with STBY displayed next to PB 14 on TPOD primary and data display pages. The initialization, which includes initialization of set–up parameters, followed by PBIT, and then IMU alignment, takes approximately 3 minutes, the last 15 seconds of which the TPOD initialization display, showing the pod configuration, is displayed in the center of the MPCD screen. The pod then changes to STBY and responds to commands to enter IBIT, A/G, or NAV sub–modes. Figure 1–264 shows the initial power–up default MPCD legends set by the TPOD during the initialization process.

WARNING

All personnel should maintain a safe distance separation from the forward section of the pod within 1 minute of start–up as it moves with extreme force that could cause personal injury.

NOTE

Because the pod uses inputs from the aircraft INS for aligning the pod IMU, the IMU will not start its alignment process, even though it has power, until the aircraft INS has completed alignment. Also, the pod does not have to be stationary or on the ground to complete its IMU alignment. When the IMU alignment is complete, the pod automatically switches to STBY.

PARAMETER	DEFAULT	DISPLAY
Display Page	Primary	
Sensor	CCD Camera	CCD (PB 5)
Laser State	Laser Safe	SAFE (PB 6)
Laser Mode	Training Laser	TRNL (PB 9)
Sensor Tracking Control	Aircraft HOTAS Control Mode	TDC (PB 15)

Figure 1-264. Initial Power-up Defaults

The initialization display is also displayed for approximately 15 seconds when the standby mode is selected from any operational primary or data display page.

1.18.4.7.1 Initialization Display. The initialization display (see Figure 1–266), which is displayed for 15 seconds after initial pod power–up or selection of standby mode, includes the following:

(a) Software Version. Current TPOD software (S/W) version is displayed as: SW_VER_XXXX, where XXXX is 0013 or greater.

(b) Laser Mask Version. Current laser mask version is displayed as MASK_VER_XXX, where XX is 10 or greater, or ERR is displayed if the mask version is bad.

(c) Laser Code Table Version. Current laser code table version is displayed as LSR_VER_XXX, where XX is 10 or greater, or ERR is displayed if the laser code table version is incorrect.

(d) Software Checksum. Current S/W checksum is displayed as SW_CHSUM_XXX, where OK is displayed if the S/W checksum is good, or ERR if the S/W checksum is bad.

(e) Aircraft Type. Current aircraft type is displayed as AC_TYPE_XXX, where NA is displayed for night attack, or RDR for radar aircraft.

1.18.4.7.2 Universal Time Code (UTC) Time. The TPOD displays the UTC time in the top left corner of the MPCD, in between the pushbutton 5 and 6 legends on all three display pages. The format is HH:MM:SS, i.e., 12:35:24. The TPOD monitors GPS MUX BUS signals for the UTC time. UTC time is not displayed when the declutter option (REJ PB 13) has been selected on the VCR display page.

1.18.4.7.3 Aircraft Commanded Laser Code. The TPOD displays the aircraft commanded laser code under the PB 7 legend to the right of the UTC time on all three display pages when the pod is in standby or A/G mode. The default laser code following pod power−up is 1111; however, after an aircraft laser code has been entered, it becomes the default code.

1.18.4.7.4 FLIR Not Ready Indication. The TPOD displays the FLIR not ready indication, F−NOTRDY, to the right of the FLIR legend (next to PB 5), centered on the MPCD on the FLIR primary and data display pages. FLIR not ready is displayed when the FLIR is not ready for operation due to the FLIR not being cooled down. FLIR cooling normally takes 6−8 minutes after pod power−up. In flight, this indication display would warn of a degraded FLIR video display capability.

1.18.4.7.5 Alignment Quality Indicator (AQI). The TPOD injects an AQI in the lower left corner of the MPCD, left of the pushbutton 20 legend on the primary and data display pages. The TPOD calculates the AQI number. The AQI range is initialized at 10 and decrements to 1 as the alignment quality improves. An AQI of 1 indicates that the IMU alignment has reached a good quality. The AQI is displayed on both the primary and data display pages, in standby and operate modes, independent of sensor selection.

NOTE

The AQI may remain at 10 following IMU alignment until the IMU senses aircraft movement at which time, the AQI starts decreasing. An AQI of 1 may not be displayed until the aircraft is airborne and has made a 20° to 30° turn.

If, during flight, the AQI degrades to where it remains above 3, the aircrew should perform the specific in−flight maneuvers listed below, and as shown in Figure 1−265, for the pod to perform an alignment update.

1. Straight and level for 20 seconds
2. Turn left 30° from initial heading
3. Return to initial heading for 20 seconds
4. Turn right 30° from initial heading
5. Return to initial heading
6. Maintain initial heading for 20 seconds

1.18.4.8 STBY (Standby) Mode. The TPOD enters the standby mode automatically at the completion of the power−up initialization sequences or on command from any operational mode by the selection of the STBY pushbutton on any primary or data display page (see Figure 1−266). When selected, the STBY legend is underlined. The standby mode provides access to the STBY functions, and the A/G, A/A, and NAV modes. IBIT, FLIR calibration, and pod servicing functions are available only when the pod is in the standby mode. With STBY displayed, the forward section is locked in the stowed position, except during SRVC or IBIT, to protect the sensor windows from damage. All lasers are disabled on the ground via the software interlocks.

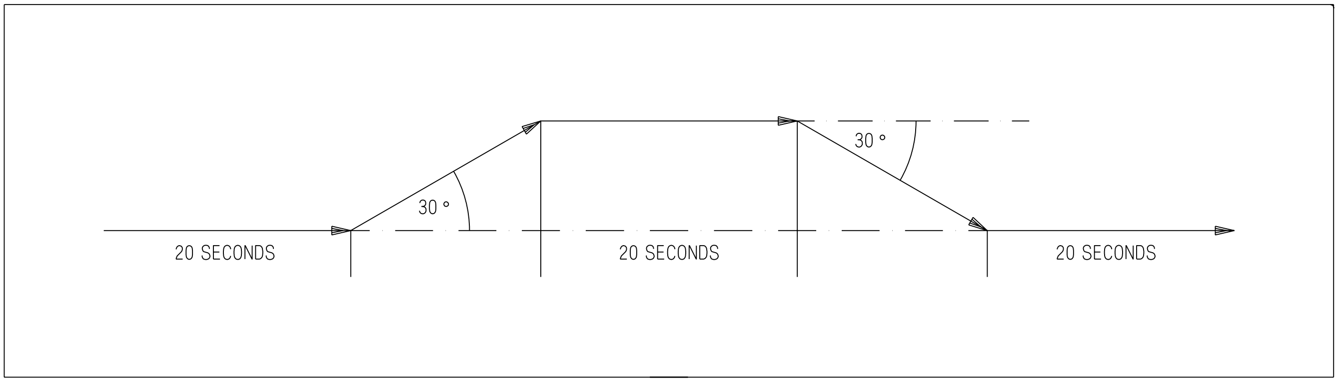


Figure 1-265. IMU Alignment Maneuver

When the STBY pushbutton is selected from any operating mode, on any primary or data display page, the pod stows the sensor head, underlines the STBY legend, displays the initialization page for 15 seconds, and then switches to the standby mode display page with STBY displayed. The current display page, primary or data, and current selected sensor, CCD or FLIR, do not change when PB 15 (STBY) is selected.

The standby mode is exited by selecting the STBY pushbutton, which removes the legend underline, commands the pod to unstow the sensor head, and places the TPOD in the appropriate operate mode, A/G or A/A, based on the current aircraft master mode, A/G, VSTOL, or NAV, or A/A, respectively.

1.18.4.9 Pod Servicing. When the aircraft is on the ground and the pod is in STBY, the pod servicing function can be accessed (SRVC - PB 19 on the DATA page). SRVC is underlined and the pod forward section unstows for window cleaning and replacement of the desiccant bag. To prevent inadvertent movement of the pod forward section after selecting the SRVC mode, the pod power must be switched off. Select SRVC to deselect the service mode and return to the standby mode. See Figure 1–267.

CAUTION

The pod must be in the STBY mode with the forward section stowed before taxi, takeoff, and landing to prevent possible FOD to the sensor windows.

1.18.4.10 Built–In Test (BIT) Modes. The TPOD system incorporates three types of BIT, power–up BIT, initiated BIT, and continuous BIT:

1.18.4.10.1 Power–Up BIT (PBIT). PBIT is pod initiated during the pod power–up initialization process, following initialization of pod set–up parameters, and before alignment of the IMU. PBIT includes the self–testing procedures necessary to reach the pod's operational functionality, with special concerns for the servo system functionality test. The full PBIT is performed on the ground at static conditions only, and takes approximately 80 seconds. This BIT does not contain all servo tests.

1.18.4.10.2 Initiated BIT (IBIT). IBIT is performed by pressing PB 17 (BIT) on the data display page, with the aircraft stationary, weight–on–wheels, and in standby mode only. The IBIT takes approximately 3 minutes, and displays the IBIT time remaining countdown timer in the upper center of the display page when IBIT is running. This number represents the amount of time remaining to complete IBIT. The countdown timer starts at 180 plus seconds and counts down to 0 when IBIT is complete. IBIT is a much more extensive self–testing procedure than PBIT, and includes testing that cannot be included in the CBIT because it would interfere with the pod's functionality. The pod executes a CPU test, followed by the sightline servo, sensor and tracker test in parallel. Pod video appears scrambled for the first 30 seconds. Once selected, IBIT cannot be interrupted. IBIT detects at least 95 % of pod failures and isolates

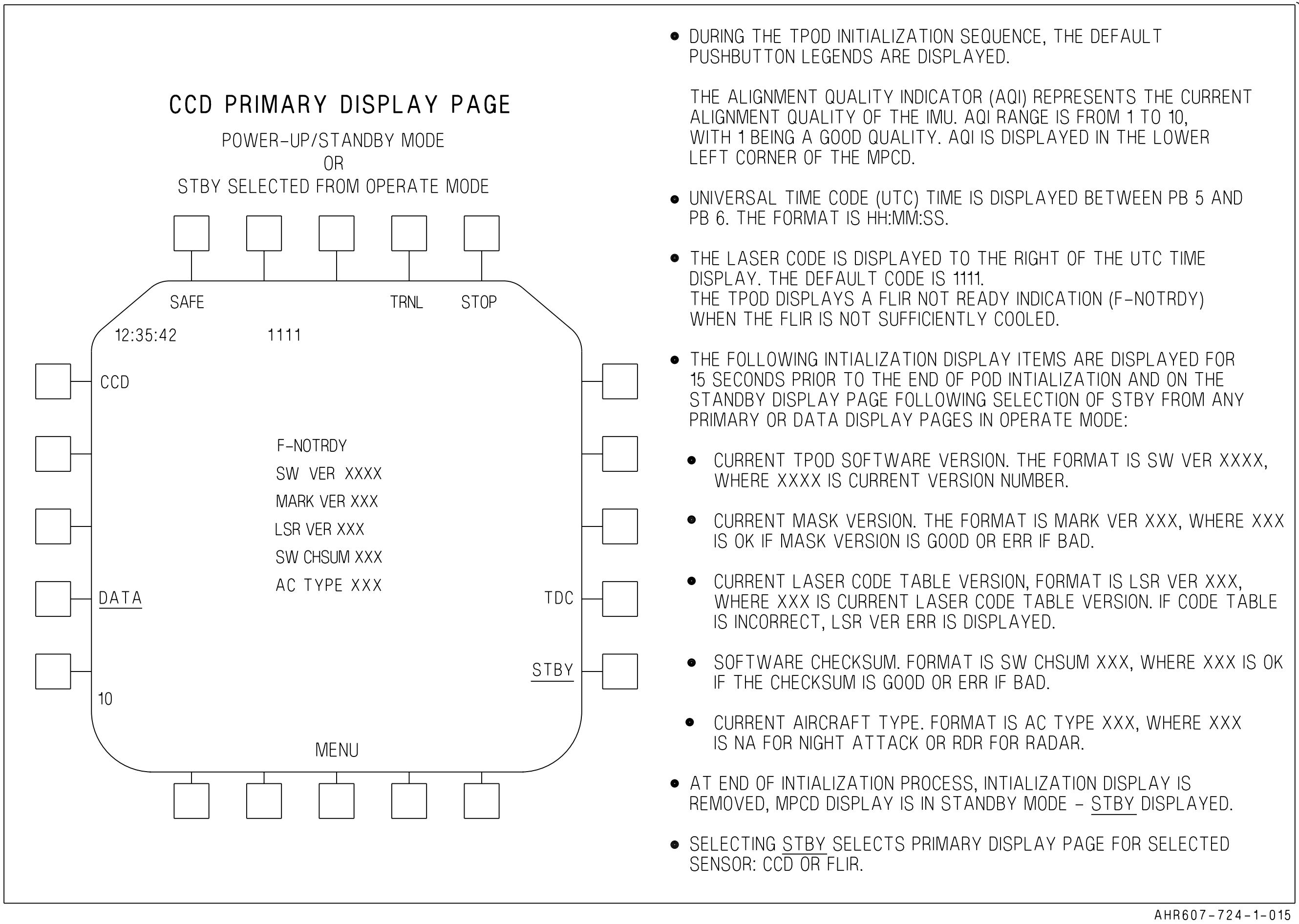


Figure 1-266. TPOD Initialization Display

90 % of pod failures to WRA level. The false failure detection rate is 3 % or less. Upon completion of IBIT, the pod automatically returns to STBY mode, stows the sensor head, and displays the initialization display in the center of the page for 15 seconds.

1.18.4.10.3 Continuous BIT (CBIT). CBIT is an integral part of the pod's operational modes that starts after completion of PBIT. CBIT continuously monitors the pod for failures during system operation by monitoring all possible interfaces in the operational environment. These tests monitor subsystem units while running in operational mode, or initiate interface manipulation to sub–units which are idle at specific operational times or missions.

1.18.4.10.4 Built–In Test (BIT) Fault Display Page. If a BIT fault is detected during PBIT, by IBIT or by CBIT in any pod mode of operation, a BIT fault indicator and BIT failure warning are displayed in the top left corner of the MPCD. A BIT Pod Fault List (PFL) is available for viewing in the pod Standby mode on the data display page. The BIT fault indicator replaces the UTC time in the upper left corner of the MPCD on all three TPOD display pages, and displays a BIT failure warning FAIL above the BIT fault indicator. The BIT fault indicator identifies the source of the failure and flashes for 10 seconds, and then the UTC time is redisplayed. The FAIL warning continues to be displayed until the pilot initiates the PFL LIST display, which removes the FAIL warning.

1.18.4.10.5 PFL LIST. The PFL LIST is displayed by selecting DATA on either the primary or VCR display page, and then selecting STBY if the STBY legend is not already displayed, then selecting DPFL (Display Pod Fault List), PB 20, which displays the PFL LIST in the center of the

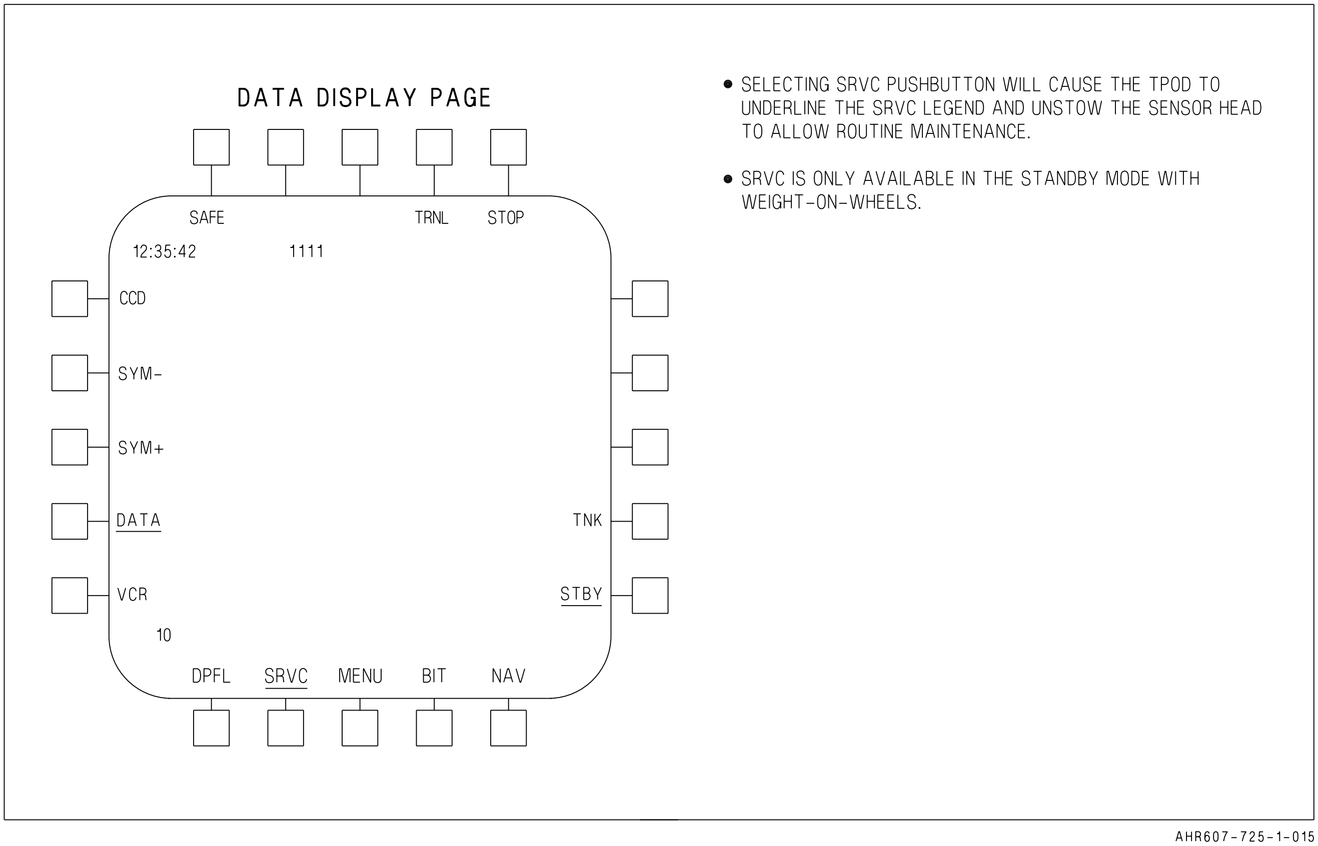


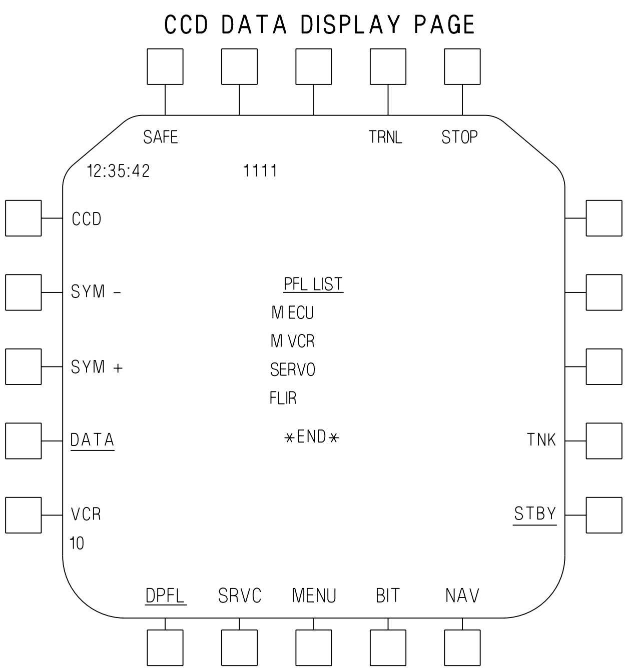
Figure 1-267. TPOD Standby Mode - Service Function

MPCD. See Figure 1–269. The PFL LIST displays up to two Maintenance Fault Listings (MFLs) and two PFLs at one time. A PFL is usually a minor item that indicates degraded pod performance, while an MFL is usually a major item that indicates a hard WRA failure that disables the pod or a component, and requires ground maintenance. An MFL is preceded by an M in the fault listing. If there are more faults than the ones listed, * CONT * is displayed under the last listed fault. Continuing to press the DPFL pushbutton toggles through the faults, displaying a maximum of two MFLs and two PFLs per display, until all have been displayed and * CONT * is replaced by * END *. Pressing DPFL for more than 0.8 second removes the PFL LIST display and returns the TPOD to the previous selected operating mode. The fault list can be repeated by selecting DPFL again. The complete list of BIT faults is retained for display until primary power to the pod is removed. See Figure 1–268 for MFL messages, and Figure 1–270 for PFL messages.

1.18.4.10.6 POD OVERHEAT Warning. If, at any time, the TPOD overheats, it triggers the BIT fault indicator function, and is processed and displayed as if generated by the BIT process. Additionally, a flashing POD OVERHEAT warning is displayed near the center of the MPCD display for as long as the overheat condition exists. Even if an overheat condition is only momentary, a record of the event is made in the BIT fault list.

MFL MESSAGE	MEANING
M FS	Replace Forward Section (FS)
M SEU	Replace Systems Electronics Unit (SEU)
M FEU	Replace FLIR Electronics Unit (FEU)
M PSU	Replace Power Servo Unit (PSU)
M IU	Replace Interface Unit (IU)
M ECU	Replace Environmental Control Unit (ECU)
M DSC	Replace Desiccant Bag
M VCR	Replace Video Cassette Recorder (VCR)
M A/C BUS 1	1553 BUS 1 Failure
M A/C BUS 3	1553 BUS 3 Failure

Figure 1-268. Maintenance Fault Listing (MFL)



- THIS DATA DISPLAY PAGE, WITH POD STANDBY MODE (STBY) SELECTED, DISPLAYS A LISTING OF BIT DETECTED POD FAULTS.
- SELECTING DPFL (DISPLAY POD FAULT LIST) UNDERLINES THE LEGEND (DPFL), REMOVES THE FAIL WARNING ABOVE THE UTC TIME, AND DISPLAYS THE BIT POD FAULT LISTING (PFL LIST).
- THE BIT FAULT DISPLAY LISTS UP TO TWO MAINTENANCE FAULT LISTINGS AND TWO PILOT FAULT LISTINGS. IF THERE ARE MORE BIT FAULTS INDICATED BY * CONT *, DEPRESSING PB 20 CYCLES THROUGH THEM. AFTER ALL BIT FAULTS HAVE BEEN VIEWED AS INDICATED BY * END * AT END OF LIST, THE BIT FAULT DISPLAY AND DPFL UNDERLINE ARE REMOVED BY DEPRESSING PB 20 FOR MORE THAN 0.8 SECONDS.
- IF A MORE EXTENSIVE BIT IS DESIRED, SELECTING BIT (PB 17) RUNS THE INITIATED BIT (IBIT) PROGRAM.

AHR607-726-1-015

Figure 1-269. Standby Mode - TPOD BIT Fault Display

PFL MESSAGE	VIDEO MESSAGE	EFFECT OF FAULT ON SYSTEM	PILOT ACTION
ELECTRONIC FAIL	ELECTRONIC	Total loss of pod function	None
POWER SUPPLY FAIL	POWER SUPPLY	Loss of at least one power supply or three-phase frequency problem	None
TRACKER FAIL	TRACKER	No tracker capability or reduced tracking performance	None
INERTIAL SENSORS FAIL	INERTIAL SEN	Pod IMU failures	None
VIDEO INTERFACE FAIL	VIDEO	Loss of video synchronization	None
CCD FAIL	CCD	Loss of one/both CCD FOVs video	None
FLIR FAIL	FLIR	Loss of FLIR video	None
LASER DESIGNATOR FAIL	LDR	No laser designation	None
LDR PIM FAIL	LDR PIM	Loss of PIM codes designation	None
LASER ENERGY	LDR LOW ENR	Laser low energy emission	None
LASER RECIVER FAIL	LRF	No spot detection or range finding	None
LASER BORESIGHT FAIL	BORESIGHT	Loss of laser boresight parameters	None
ECU FAIL	ECU	Loss of ECS control or loss of one of ECS elements	None
SERVO SYSTEM FAIL	SERVO	Loss or degradation in servo system	None
LOW PRESSURE	LOW PRESSURE	Low pressure in FS. Cannot operate the laser	None
LASER MARKER FAIL	LSR MARKER	Loss of laser marker	None
POD OVERHEAT	POD OVERHEAT	High temperature in pod	In-flight - Fly cooler profile. On ground - Takeoff or have pod powered down.
VCR FAIL	VCR F	Loss of VCR	None
FS OVER HEATED	POD HOT	High temperature in the FS of the pod	In-flight - Fly cooler profile. On ground - Takeoff or have pod powered down.

Figure 1-270. Pilot Fault Listing (PFL)

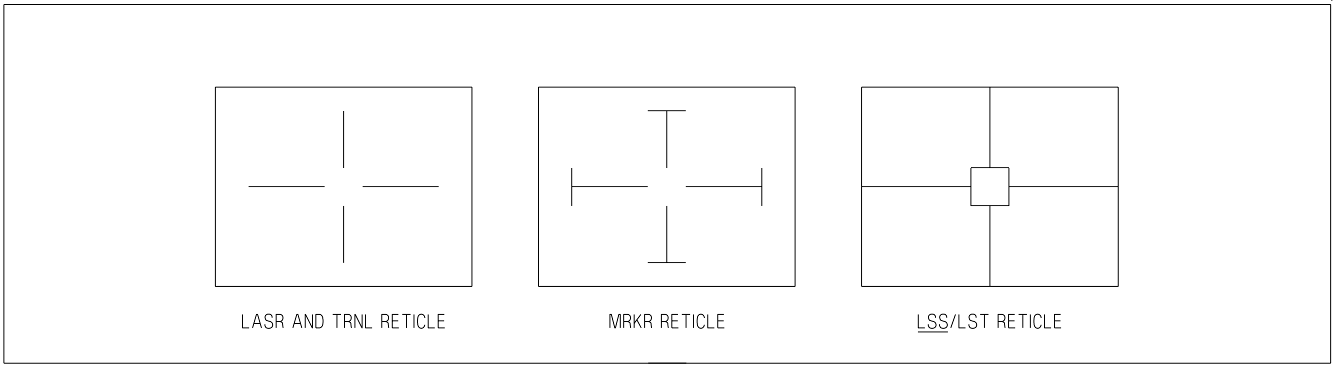


Figure 1-271. TPOD Reticles

1.18.4.11 Air–to–Ground (A/G) Mode. The A/G mode is the main operational mode of the TPOD. It is used for acquisition and designation of ground targets in A/G missions. The A/G mode is tied to aircraft master modes of VSTOL, NAV, and A/G. Unless the aircraft is in A/A master mode, the pod automatically selects A/G pod mode upon de–selection of STBY.

1.18.4.11.1 Air–to–Ground Mode - Primary Display Page. The CCD and FLIR primary display pages provide scene video, target information, laser information and MPCD pushbutton controls for the CCD or FLIR sensors. The displays associated with both CCD and FLIR primary displays include: standby, slave, and track. The CCD/FLIR primary display page is entered as follows:

1. Select PB 15 (STBY) on the CCD/FLIR standby mode display page after initial power–up or if the CCD/FLIR primary or data display page was the previously selected operating mode/display, or

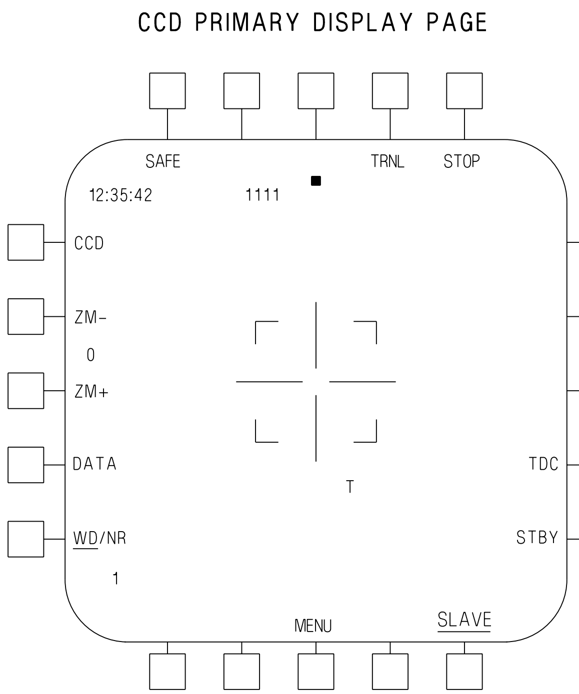
2. Select PB 2 (DATA) on the data or VCR display page for the respective sensor, or

3. Select FLIR on the FLIR primary display page to go to the CCD primary display page, or

4. Select CCD on the CCD primary display page to go to the FLIR primary display page. From the CCD/FLIR standby display page or from another primary or data display page, the initial operate mode is the slave mode, from which one of several track modes can be selected. When the pod transitions out of the pod standby mode, the TPOD displays a reticle in the middle of the MPCD on all three TPOD display pages: primary, data, and VCR. The TPOD provides three different reticles (see Figure 1–271): One for the LASR and TRNL, one for the MRKR, and one for the LSS and LST modes. When in a target tracking mode, the reticle decreases in size, except for the LSS/LST reticle. In the LSS/LST mode the reticle arms extend to the display page borders.

1.18.4.11.2 Air–To–Ground Slave Mode Display. The A/G slave mode display has SLAVE displayed above PB 16 and provides indication of when the TPOD sensor head is either slaved to the aircraft command LOS (A/C CMD LOS) with an aircraft target designation or the sensor head is caged to pod boresight, depressed 2° (not horizon stabilized), without an aircraft target designation. Figure 1–272 and Figure 1–273 show the pushbutton legends and displays associated with the CCD slave mode display without a designated target and the FLIR slave mode display with a designated target, respectively.

The slave mode can be exited by going into a tracking mode (INR with PB 19, or area or point with PB 20) for target tracking, A/C CMD LOS aim–point refinement, or to establish a pod LOS aim point. If the slave mode is exited by going to a CCD or FLIR track mode, the SLAVE underline is removed, the slave mode can then be re–entered by selecting SLAVE from any CCD or FLIR track mode. This re–slaves the TPOD to the A/C CMD LOS. If an A/C CMD LOS does



- IN A/G MODE, WHEN POD GOES FROM STANDBY MODE (STBY) TO OPERATE MODE (STBY), IT ENTERS SLAVE MODE - SLAVE DISPLAYED.
- IN SLAVE MODE WITH NO DESIGNATED TARGET, THE SENSOR HEAD CAGES TO POD BORESIGHT, DEPRESSED 2°.
- WD/NR TOGGLES BETWEEN WIDE AND NARROW FOV, AND LASER SPOT SEARCH WIDE AND NARROW SEARCH PATTERNS. WIDE IS THE DEFAULT. SELECTED SETTING IS UNDERLINED. IN WIDE FOV, THE "BOX" CORNERS AROUND THE RETICLE INDICATE AREA CONTAINED IN NARROW FOV, AND ARE REMOVED WHEN NARROW FOV IS SELECTED.
- DATA SELECTS THE DATA DISPLAY PAGE AND UNDERLINES DATA.
- ZM + INCREASES ZOOM (ZOOM-IN) TO A MAXIMUM SETTING OF 9.
- ZM - DECREASES ZOOM (ZOOM-OUT) TO A MINIMUM SETTING OF 0.
- ZOOM SETTING, FROM 0 TO 9, IS DISPLAYED BETWEEN THE PB 3 AND PB 4 LEGENDS, I.E., 0.
- SELECTING CCD SELECTS FLIR AS THE ACTIVE SENSOR.
- SELECTING SAFE PB ARMS LASER (ARM), PROVIDED ALL SAFETY INTERLOCKS ARE MET. PB 6 TOGGLES BETWEEN SAFE AND ARM.
- SELECTING TRNL TOGGLES THROUGH THE THREE LASER TYPES- TRAINING (TRNL), MARKER (MRKR), AND DESIGNATOR (LASR). TRNL IS THE DEFAULT. THE SELECTED LASER IS INDICATED BELOW THE RETICLE AS T (TRNL), MRK (MRKR), OR "BLANK " (LASR).
- TDC TOGGLES BETWEEN TDC (AIRCRAFT HOT AS CONTROL MODE) AND TDC (TPOD SLEW CONTROL MODE) FOR POD SENSOR SLEWING.
- SELECTING STBY TOGGLES BETWEEN POD OPERATE MODE (STBY) AND STANDBY MODE (STBY).
- PB 16 HAS NO FUNCTION WHEN POD IS IN SLAVE MODE (SLAVE).
- THE SENSOR HEAD LOOK INDICATOR, A SQUARE DOT (■) SHOWS WHERE THE SENSOR HEAD IS POINTED (HORIZONTAL VIEW).

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Figure 1-272. CCD Primary Display Page - Slave Mode - No Designated Target

not exist, the TPOD cages the pod sensor head to pod boresight, depressed 2°.

a. TPOD Look Indicator. The TPOD displays a look indicator (■) on the primary and data display pages indicating where the pod sensor head is looking from a horizontal viewpoint.

b. Target Latitude. The TPOD displays the target slave or track point latitude under PB 9 and to the right of the laser code on the primary and data display pages. A target latitude of N 35° 46.187', for example, is displayed as N 3546187. The TPOD calculates this position from either the A/C CMD LOS to the target or aim point slew tracking data. Target latitude is not displayed when an aircraft system designation does not exist or when the declutter option (PB 13 REJ) on the VCR display page has been selected.

c. Target Longitude. The TPOD displays the target slave or track point latitude under the target latitude on the primary and data display pages. A target longitude of W117° 47.246', for example, is displayed as W11747246. The TPOD calculates this position from A/C CMD LOS or aim point slew tracking data. Target longitude is not displayed when an aircraft system designation does not exist or when the declutter option (PB 13 REJ) on the VCR display page has been selected.

d. Target Height. The TPOD displays the target height under the target longitude on the

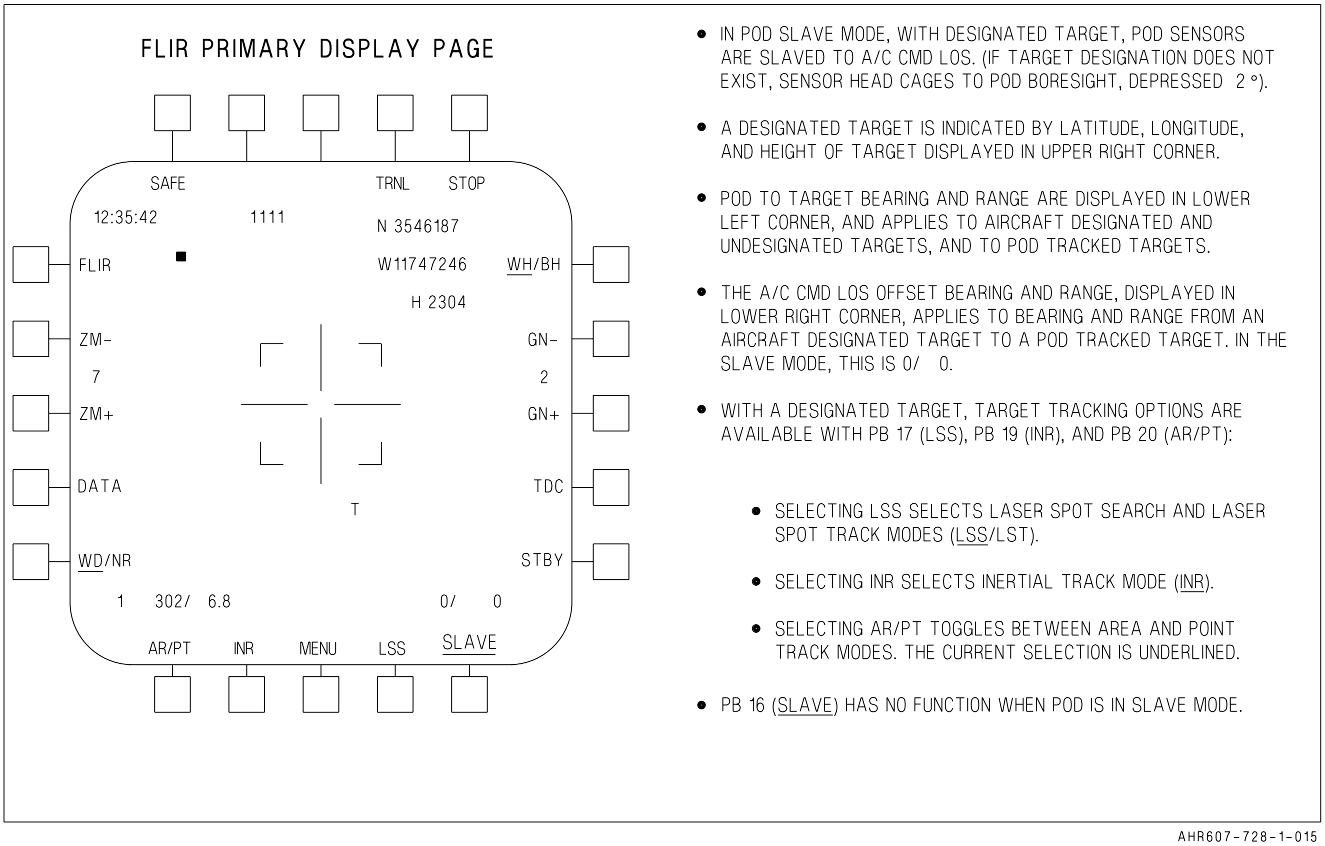


Figure 1-273. FLIR Primary Display Page - Slave Mode Designated Target

primary and data display pages. The target height is in feet (MSL). A target height of 2304 feet MSL, for example, is displayed as H 2304. The TPOD calculates this position from A/C CMD LOS or aim point slew tracking data. Target height is not displayed when an aircraft system designation does not exist or when the declutter option (PB 13 REJ) on the VCR display page has been selected.

e. Pod to Target Bearing and Range. The TPOD provides the bearing and range from the pod to the A/C CMD LOS for designated, or previously designated targets, when the pod is in the slave mode, or from the TPOD to pod tracked targets when the pod is in a target−tracking mode. The distance to the target when greater than 1 nautical mile (NM) is displayed in nautical miles plus tenths of a nautical mile. Distances of less than 1 NM are displayed in hundreds of feet. The TPOD displays the pod to target bearing and range above the PB 20 legend on the primary and data display pages. A pod to target bearing and range of 302° at 6.8 NM, for example, is displayed as 302/ 6.8. The pod to target bearing and range is not displayed when an aircraft system designation does not exist or when the declutter option (PB 13 REJ) on the VCR display has been selected.

f. Aircraft Command Line–of–Sight Offset Bearing and Range. The TPOD provides an A/C CMD LOS offset bearing and range for a designated target, when the pod is in a track mode. The offset bearing and range represents the bearing and range from the A/C CMD LOS aim point to the pod LOS aim point, and is displayed as magnetic bearing and range in meters. The TPOD displays the A/C CMD LOS offset bearing and range above the PB 16 and PB 17 legends on the primary and data display pages. A bearing and range from the A/C CMD LOS aim point to the pod sensor tracking/ pointing aim point of 209° at 42 meters is displayed as 209/ 42. When the pod is in the slave mode (SLAVE) with an aircraft system designation, the A/C CMD LOS offset bearing and range display is 0/ 0. An A/C CMD LOS offset bearing and range is not displayed when an aircraft system designation does not exist or when the declutter option (PB 13 REJ) on the VCR display page has been selected.

1.18.4.11.3 A/G Track Mode. A/G tracking is used to lock the pod LOS on a desired target image on the MPCD and automatically track it with no need for manual slewing. When A/G tracking is activated, the pod performs an EO lock on the current video picture, and moves the LOS according to picture movements so that the locked point is continuously displayed at the FOV center. During tracking, the offset from the aircraft system designation to the pod LOS is inserted in the pod video as well as the bearing and range to the current target. In the CCD/FLIR track mode, the pod tracks a designated target using the area or point tracker, or, as a temporary backup, tracks a target's position using the INR tracker. The CCD/FLIR track mode is selected by selecting PB 20 (AR/PT) for area or point track when on the CCD/FLIR primary display page, and the INR track mode is selected with PB 19 (INR).

a. CCD/FLIR Track Mode. When the track mode is selected from the slave mode (SLAVE) on the primary display page, the SLAVE underline is removed. Selecting PB 20 (AR/PT) causes the TPOD to enter the area track mode, which is the default−tracking mode. Selecting PB 20 while in a track mode toggles to the next track mode, which in this case would be point track. The selected tracking mode is underlined: AR or PT. The desired sequence in normal operations is from area track to point track. Area track is used to track stationary targets by scene lock, usually in narrow FOV for aim point refinements. Area track uses scene correlation techniques to track a location. Upon entering area track, the pod uses a scene stabilization mode, which monitors multiple windows in the FOV to maintain the target LOS in the center of the FOV. Point track, which is used for static or moving targets, provides tracking of single targets with well−defined contrasts using the EO tracker central window, which is a small FOV correlation tracker. Point track is normally used in narrow FOV for aim point refinements. Selecting PB 1 (WD/NR) toggles between the wide and narrow FOVs. The FOVs are also selectable in HTS mode by clicking the SSS−left for less than 0.8 second. Improvements to tracking can be made by manually firing the laser to improve the height above target estimator. This is the recommended method for improving track fidelity. The EO tracking is backed up by the INR tracker in cases where EO tracking conditions are lost. If commanded to area or point track but unable to lock onto a target, or if the pod is masked, being slewed or otherwise cannot maintain optical track, the pod automatically transitions to INR track. The pod returns to the commanded track mode from INR track when it can again establish optical track on the ground. At any time, the pilot may select PB 5 (FLIR or CCD) to select the other sensor for aid in reacquiring a target or for target tracking. The TPOD displays the current target tracking mode indication, AREA, POINT, or INR, below the reticle on the primary display page. The track mode can be exited at any time by selecting the slave mode, with PB 16 or the undesignate button on the control stick.

(1) Aircraft HOTAS Control Mode (TDC) For Target Tracking. The TDC mode is the default mode and is indicated by the TDC legend displayed next to PB 14 (see Figure 1−273). In this mode, the TPOD sensors are slaved to the A/C CMD LOS. The pilot uses the TDC to slew aircraft sensors to refine target designations. These target designations provide a LOS to the target, and rather than responding to the TDC slew commands, the TPOD responds to changes in the A/C CMD LOS and slews the pod sensors accordingly. If no CMD LOS exists, the sensor head is caged to the pod boresight, depressed 2°. Selecting TDC (PB 14) toggles to the TPOD slew control mode.

(2) TPOD Slew Control Mode (TDC) For Target Tracking. Pressing PB 14 (TDC) toggles to the TDC mode, and replaces the TDC legend with TDC (see Figure1−274). In the TDC mode, the aircraft HOTAS is the controller and the pod monitors TDC aircraft sensor slewing commands as slaving commands to slew the pod sensors. The pod does not respond to any other HOTAS commands. If the TDC switch is pressed

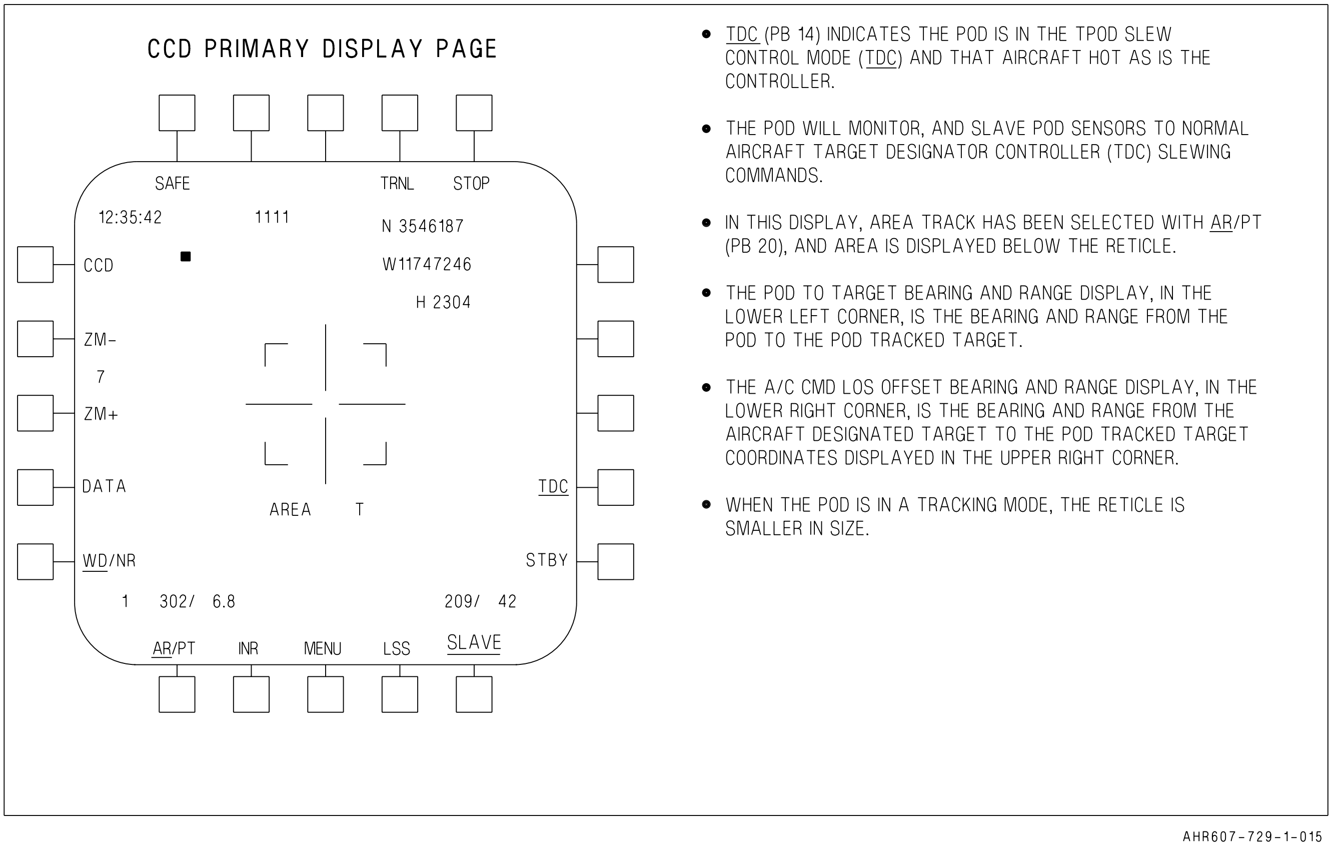


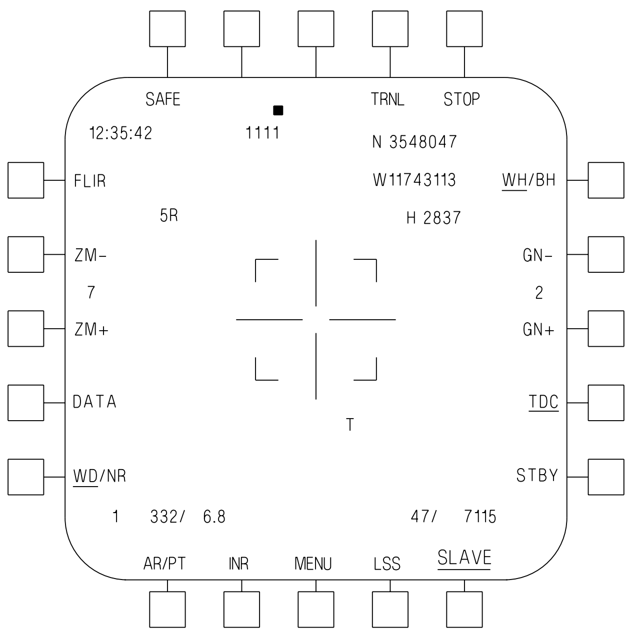
Figure 1-274. TPOD Slew Control Mode (TDC) - Area Track Selected

down, an aircraft designation is set. Movement of the TDC affects the aircraft system designation and pod sensor slewing. The pod slews at up to 1.2 FOVs per second. Selecting TDC returns to the TDC mode.

(a) Slew Indicator. The TPOD displays a slew indicator on the primary and data operate display pages when pod slew control has been activated in the TDC or HTS modes. The slew indicator is displayed to the right and slightly below the CCD/FLIR legend. The slew indicator is a feedback indication that represents the force (0 to 9) and direction (L, R, D, or U) of a slew action. For example, 5R would indicate a medium slew rate to the right. During sensor slewing, the pod temporarily exits the track mode while slewing is in progress, and then returns to the track mode when slewing stops. Another indication of sensor slewing is that simultaneously with the slew indicator being displayed, the track legend (AR, PT, or INR) underline is removed, as is the corresponding track legend (AREA, POINT, or INR) from below the reticle (see Figures 1−274 and 1−275). These legends and underlines return when sensor slewing stops and target tracking resumes.

(3) TPOD HOTAS Control Mode (HTS) For Target Tracking. The HTS mode is entered by double clicking the SSS−down in less than 0.8 second, which replaces the TDC or TDC legend with HTS − indicating that HOTAS control is assigned to the pod (see Figure 1−286). In this mode, the pod responds to HOTAS slewing commands and all other assigned HOTAS commands. The pod slews at up to 1.2 FOVs per second. When in HTS mode on the primary and data display pages, PB 14 is non−functional. The HTS mode display is identical to the TDC display, except that the HTS legend is displayed instead of TDC. Double clicking the SSS−down in less than 0.8 second while in HTS mode returns to the previous TDC or TDC mode. Also,

FLIR PRIMARY DISPLAY PAGE



- IN THIS DISPLAY THE POD WAS IN AREA TRACK MODE, AND TDC SLEWING IS IN PROGRESS AS SHOWN BY THE PRESENCE OF THE SLEW INDICATOR BETWEEN AND TO THE RIGHT OF THE PB 4 AND PB5 LEGENDS, AND CHANGING TARGET COORDINATES AND A/C CMD LOS OFFSET BEARING AND RANGE NUMBERS.
- SLEW INDICATOR SHOWS FORCE AND DIRECTION OF THE SLEW, I.E., 5R–MEDIUM FORCE TO THE RIGHT. MAXIMUM FORCE IS 9.
- WHEN SENSOR SLEWING, POD TEMPORARILY EXITS THE TRACK MODE AND REMOVES UNDERLINE FROM PB 20 TRACK LEGEND (AR/PT).
- WHEN SLEWING CEASES, THE POD RETURNS TO TRACK MODE, UNDERLINES THE PREVIOUS PB 20 TRACK LEGEND, AND RETURNS THE PREVIOUS TRACK MODE LEGEND DISPLAYED BELOW RETICLE.
- THE POD TO TARGET BEARING AND RANGE DISPLAY, IN LOWER LEFT CORNER, IS BEARING AND RANGE FROM THE POD TO THE POD LOS POINT OF INTEREST.
- A/C CMD LOS OFFSET BEARING AND RANGE DISPLAY, IN LOWER RIGHT CORNER, IS BEARING AND RANGE FROM THE AIRCRAFT DESIGNATED TARGET TO THE POD LOS POINT OF INTEREST COORDINATES DISPLAYED IN UPPER RIGHT CORNER.
- SELECTING SLAVE RETURNS THE DISPLAYED TARGET REFERENCES TO THE A/C CMD LOS REFERENCES.

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Figure 1-275. TPOD Slew Control Mode (TDC) - FLIR Sensor Slewing

HTS is also exited under the following conditions:

(a) Pressing the SSS–forward for the normal aircraft HOTAS mode, or

(b) When a TPOD format page is no longer displayed on either MPCD, or

(c) Selecting the STOP or MENU pushbuttons.

NOTE

If in TDC or HTS mode and the TPOD format page is exited for more than 15 seconds before returning to the TPOD page, the pod sensor slave/slew mode changes to normal aircraft HOTAS control, with the TDC legend displayed next to PB 14.

(4) Air–to–Ground Tracking Procedures.

1. To refine a designated target:

(a) Verify TPOD is in SLAVE.

(b) Select AR/PT via PB 20 or by SSS–aft for less than 0.8 second.

(c) Select TDC mode via PB 14 (TCD changes to TDC).

(d) Slew to desired track point. AREA is displayed below the reticle.

(e) If POINT track desired, press PB 20 or SSS–aft (<0.8 sec) again. POINT is displayed below the reticle.

2. To slew to a new target without affecting the designated target:

(a) Verify TPOD is in SLAVE.

(b) Select AR/PT via PB 20 or by SSS–aft for less than 0.8 second.

(c) Select HTS mode via double click SSS−down in less than 0.8 second.

(d) Slew to desired track point. AREA is displayed below the reticle.

(e) If POINT track desired, press PB 20 or SSS−aft (<0.8 sec) again. POINT is displayed below the reticle.

b. Inertial Navigation Reference Track Mode. The INR track mode is a TPOD IMU supported automatic back−up tracking mode for the EO sensor tracking system. Also, during the target tracking process, the pilot may find it necessary to select INR to drive the pod into the INR track mode if there is a chance the CCD track may be lost due to atmospheric conditions or physical LOS obstructions. In INR, the pod uses IMU data to track the target's last known position and to maintain the pod's LOS relative to the ground. When INR is selected, the pod underlines the INR legend above PB 19 and displays INR below the reticle. The pod does not respond to PB 19 if INR is already displayed.

c. Laser Spot Search (LSS)/Laser Spot Track (LST). When the TPOD is in an A/G track mode or the slave mode, the pod has the capability of searching the selected FOV for a target that is illuminated by an external laser source. Since the laser energy used to illuminate the target is coded, an LSS/LST code, which matches the illuminator, must be set. The LSS/LST code can be set in one of the follow ways:

1. Go to the EHSD page to set the CODE via PB 5 and enter through the UFCS.

2. Use an ATHS CAS card to change the current code.

3. Select LMAV on a station and set the code via UFCS.

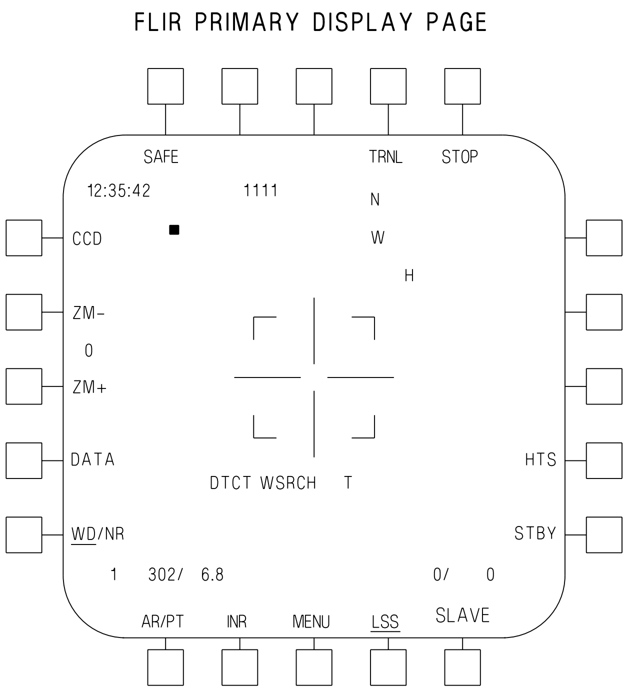
4. In a night attack aircraft, select DMT and set the code via UFCS.

NOTE

The set LSS/LST laser code is not displayed on the TPOD display page.

(1) Laser Spot Search Mode. The LSS mode is initiated by pressing the LSS pushbutton on the primary display page from either the A/G SLAVE or track mode. When the LSS mode is selected, the current WD or NR FOV video image is frozen until LST tracking occurs. When LSS is selected from the slave mode, the SLAVE underline is removed, LSS is underlined, and the pod enters the default wide search pattern, which searches a 4 km x 4 km area around the current LOS in eight seconds. WSRCH is displayed below the reticle. When LSS is selected from a target track mode, LSS is underlined, and the pod enters the default narrow search pattern, which searches a 2.5 km x 2.5 km area around the current LOS in 4 seconds. NSRCH is displayed below the reticle. See Figure 1−276. Selecting PB 1 toggles between the wide and narrow search patterns. The search pattern is also selectable in HTS mode by clicking the SSS−left for less than 0.8 second. Keep in mind that toggling between wide and narrow search patterns does not change the frozen video display. The LSS search pattern can be out of sync with the PB 1 legend, i.e., if LSS is initiated from the slave mode in NR FOV, the pod is in WSRCH with NR displayed, then if PB 1 is toggled for NSRCH, the PB 1 legend is WD. The same out of sync situation occurs when LSS is initiated from a track mode in WD FOV and the pod starts a NSRCH. During the laser spot search, the sensor head look indicator oscillates. The pod continues in this mode until a laser energy spot is detected and the pod transitions to the LST mode, or the pilot exits the LSS mode by selecting the slave mode or a target track mode. Figure 1−277 depicts the LSS/LST mode. When the LSS mode is active and a laser energy spot is detected, the pod displays DTCT to the left of the WSRCH or NSRCH legend for approximately 5 seconds before the pod switches to LST mode. If the detected laser energy spot is lost, the DTCT legend is removed from the display.

(2) Laser Spot Track Mode. When a laser energy spot is detected with the correct code in the LSS mode, the pod automatically switches (5 seconds after displaying DTCT) to the LST mode, removes the LSS legend and DTCT legend, WSRCH or NSRCH is replaced by LTRCK



- LASER SPOT SEARCH IS INITIATED FROM PRIMARY DISPLAY PAGE, SLAVE MODE (SLAVE) OR FROM ANY TRACK MODE–AB, PT, OR INR.
- WHEN LSS (PB 17) IS SELECTED FROM THE SLAVE MODE, THE TPOD UNDERLINES THE LSS LEGEND AND ENTERS WIDE SEARCH WITH WSRCH DISPLAYED IN THE LOWER CENTER OF THE MPCD.
- WHEN LSS (PB 17) IS SELECTED FROM A TRACK MODE, TPOD UNDERLINES THE LSS LEGEND AND ENTERS NARROW SEARCH WITH NSRCH DISPLAYED IN THE LOWER CENTER OF THE MPCD.
- DURING LASER SPOT SEARCH, THE VIDEO IMAGE IS FROZEN AND THE SENSOR HEAD LOOK INDICATOR (■) OSCILLATES.
- SELECTING PB 1 (WD/NR) TOGGLES BETWEEN WIDE AND NARROW SEARCH PATTERNS.
- DTCT IS DISPLAYED TO THE LEFT OF WSRCH OR NSRCH WHEN TPOD DETECTS A LASER ENERGY SPOT.
- TPOD AUTOMATICALLY ENTERS THE LASER SPOT TRACK (LST) MODE APPROXIMATELY 5 SECONDS AFTER A LASER ENERGY SPOT IS DETECTED.

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Figure 1-276. Laser Spot Search Display on CCD Primary Display Page

(laser track), and the frozen video image returns to a normal CCD or FLIR video image display. Area or point tracking can be commanded at any time during spot tracking which terminates LST and commands a stabilized track on the illuminated target. If in the LST mode and the laser energy spot is lost, LTRCK is replaced by NOLSR (no laser), the reticle flashes, and the pod goes to LSS wide search for 10 seconds. If LST is not reestablished within 10 seconds, the pod goes to the slave mode (SLAVE) and returns the LSS pushbutton legend. The pilot has the option to manually exit the LST mode by selecting the slave mode or a target track mode. Figure 1-277 diagrams the LSS/LST mode; Figure 1-278 shows the LST display when LSS mode was selected from the FLIR point track mode in narrow search.

1.18.4.11.4 Air–to–Ground Mode – Data Display Page. The CCD/FLIR data display page supplements the CCD/FLIR primary display page. The CCD/FLIR data display page is entered as follows:

1. Select DATA (PB 2) on the primary display page, standby mode (STBY), following power–up initialization, or

2. Select DATA (PB 2) on the primary display page in operate mode for the respective sensor, or

3. Select VCR (PB 1) on the VCR display page for the respective sensor, or

4. Select FLIR (PB 5) on the FLIR data display page to go to the CCD data display page, or

5. Select CCD (PB 5) on the CCD data display page to go to the FLIR data display page. In addition to the same TV video display and information, target information, and laser information shown on the CCD/FLIR primary display page, the CCD/FLIR data display page provides additional MPCD pushbutton controls. The FLIR data display page provides additional MPCD pushbutton controls for the

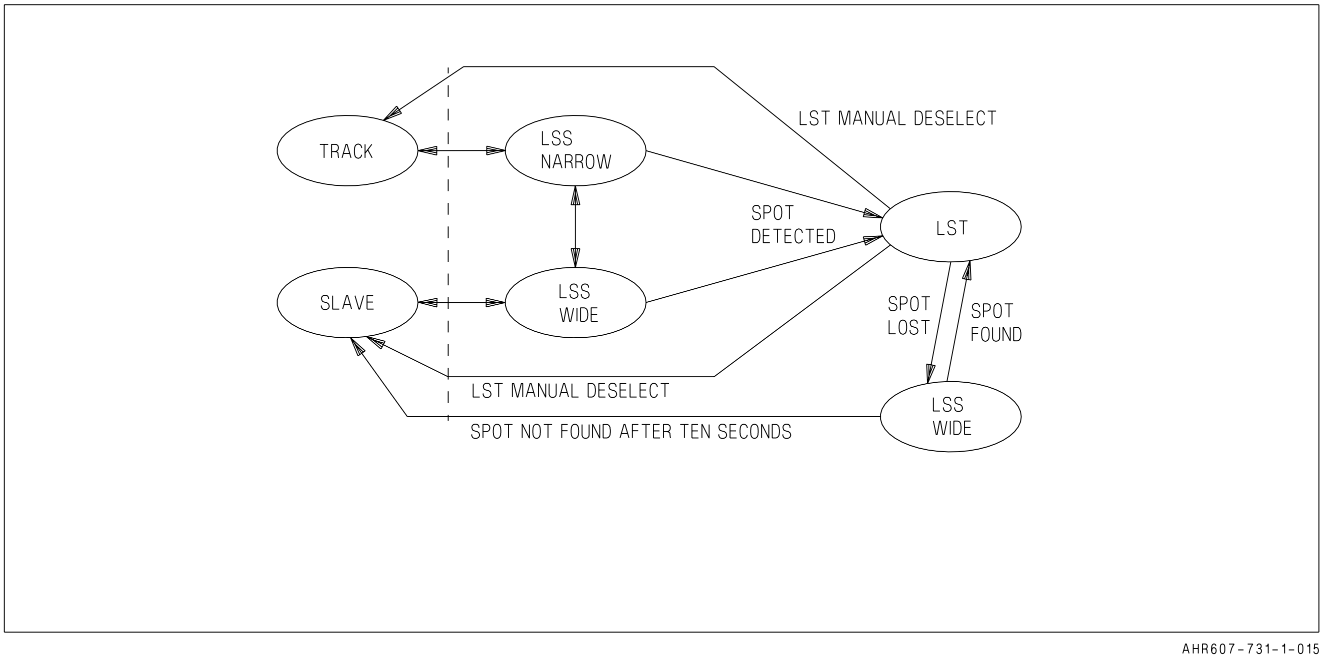


Figure 1-277. A/G LSS/LST Modes

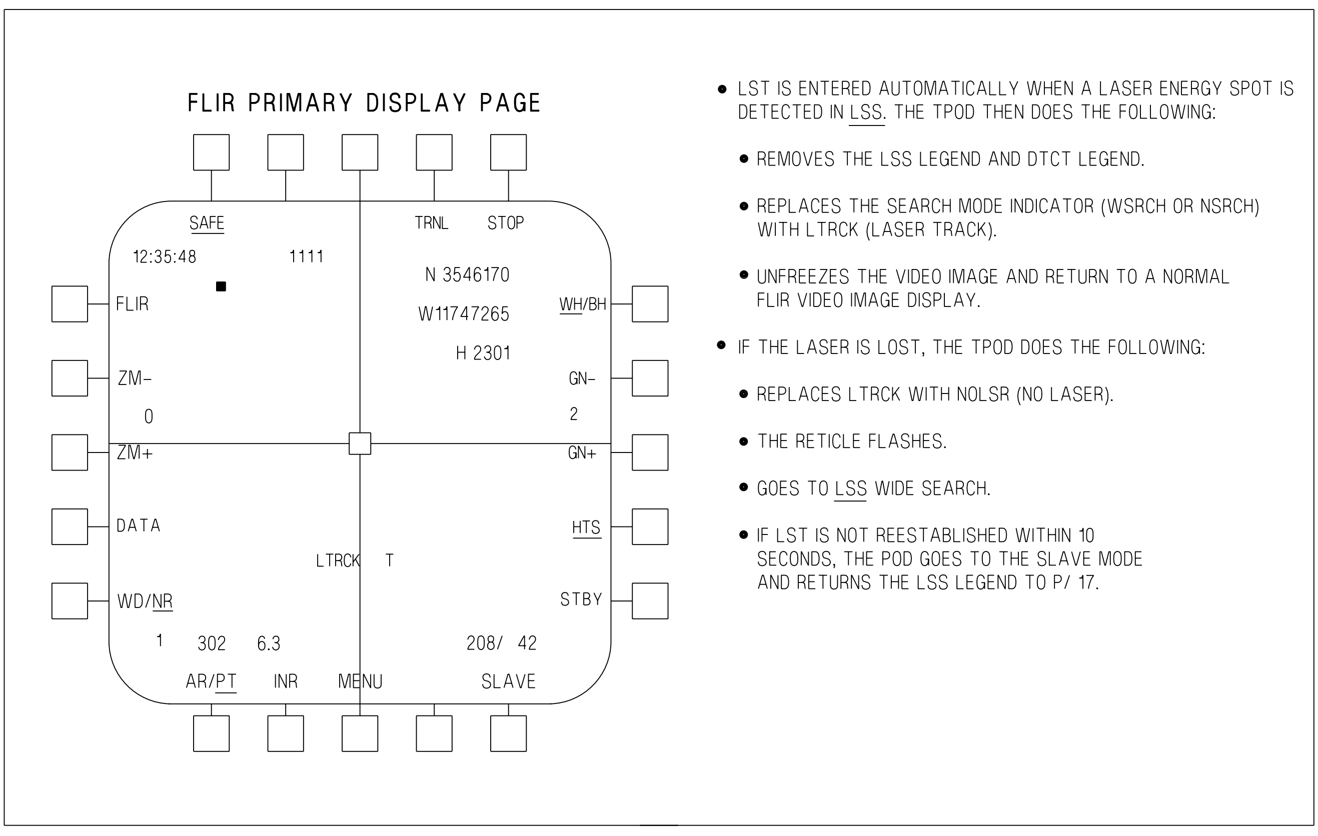


Figure 1-278. Laser Spot Track Display on FLIR Primary Display Page

IR sensor, including the capability to select one of two FLIR video integration times, and FLIR auto−focus and focus reset options. Figure 1−279 shows the CCD data display page, and Figure 1–280 shows the FLIR data display page.

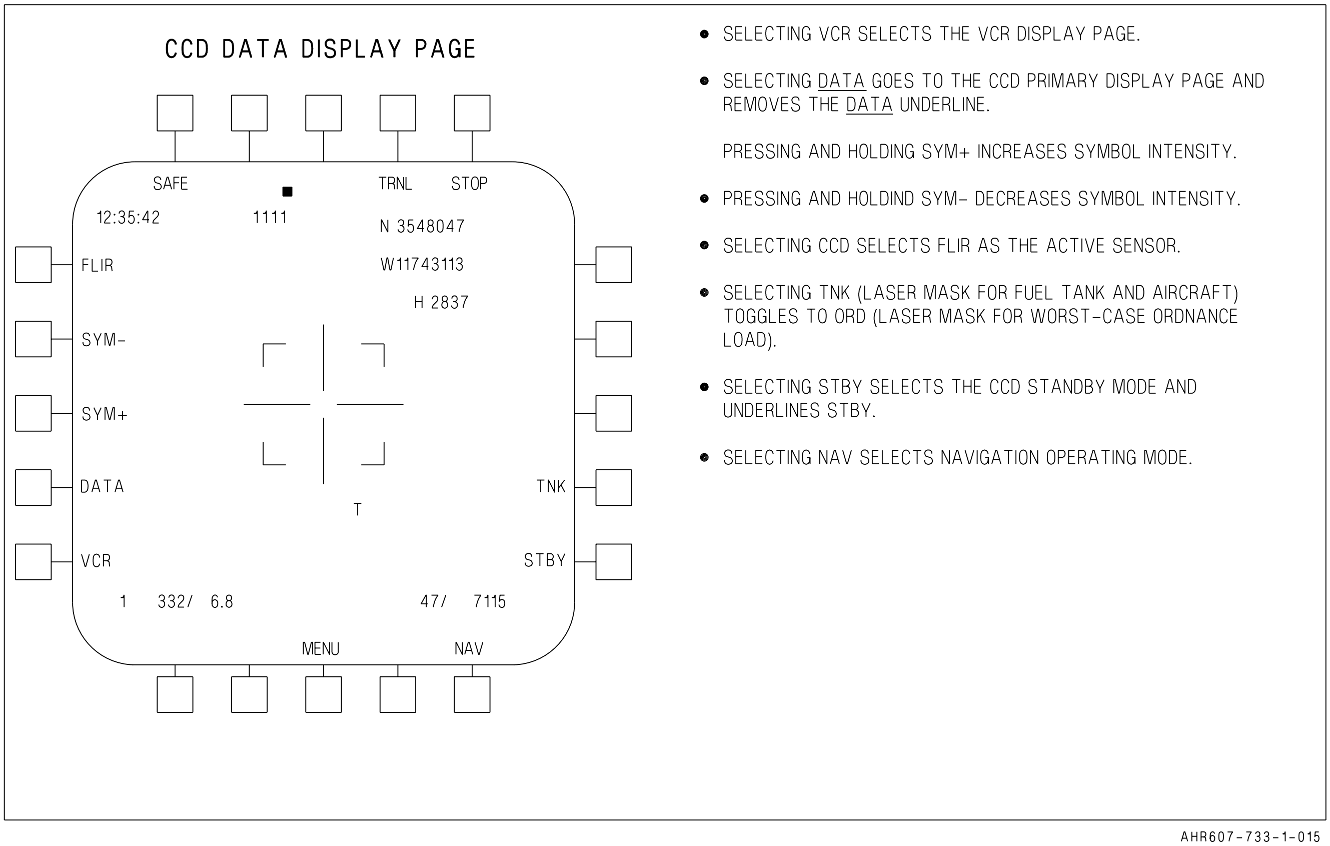


Figure 1-279. CCD Data Display Page - Operate Mode

1.18.4.12 Navigation Mode. NAV mode is used to enhance situational awareness with a super–wide, 24° by 24°, FOV FLIR video image. This mode is initiated by selecting NAV (PB 16) on CCD/FLIR data display page in operate mode. The pod laser is disabled in this mode.

1.18.4.12.1 Navigation Mode - Primary Display Page. When selected, the NAV primary display page is displayed, the DATA underline is removed, and the NAV legend is removed. The TPOD LOS is caged to pod boresight, depressed 2°, and the scene imagery is horizon stabilized. The video display provides a de–magnified image on the MPCD (0.5:1 magnification). See Figure 1–281.

1.18.4.12.2 Navigation Mode Data Display Page. The NAV data display page is displayed by selecting DATA (PB 2) on the NAV primary display page. When the data page is selected, the DATA and NAV legends are underlined. The NAV data display page provides different MPCD pushbutton controls for the IR sensor, including the capability to select one of two FLIR video integration times and FLIR auto–focus and focus reset options. See Figure 1–282. To exit the NAV mode, the NAV data page must first be selected, and then NAV (PB 16) selected, which returns the display to the previous selected sensor display page or to the sensor display page dictated by the aircraft mode, if different from when the pod went to NAV mode.

NOTE

This is not a primary flight display as no pitch ladder will be overlaid and it is not matched to the existing NAVFLIR display.

1.18.4.13 Air–to–Air Mode. This mode is tied to the aircraft A/A master mode. The TPOD A/A mode provides a CCD/FLIR video display slaved to boresight depressed 2°. The A/A mode has no

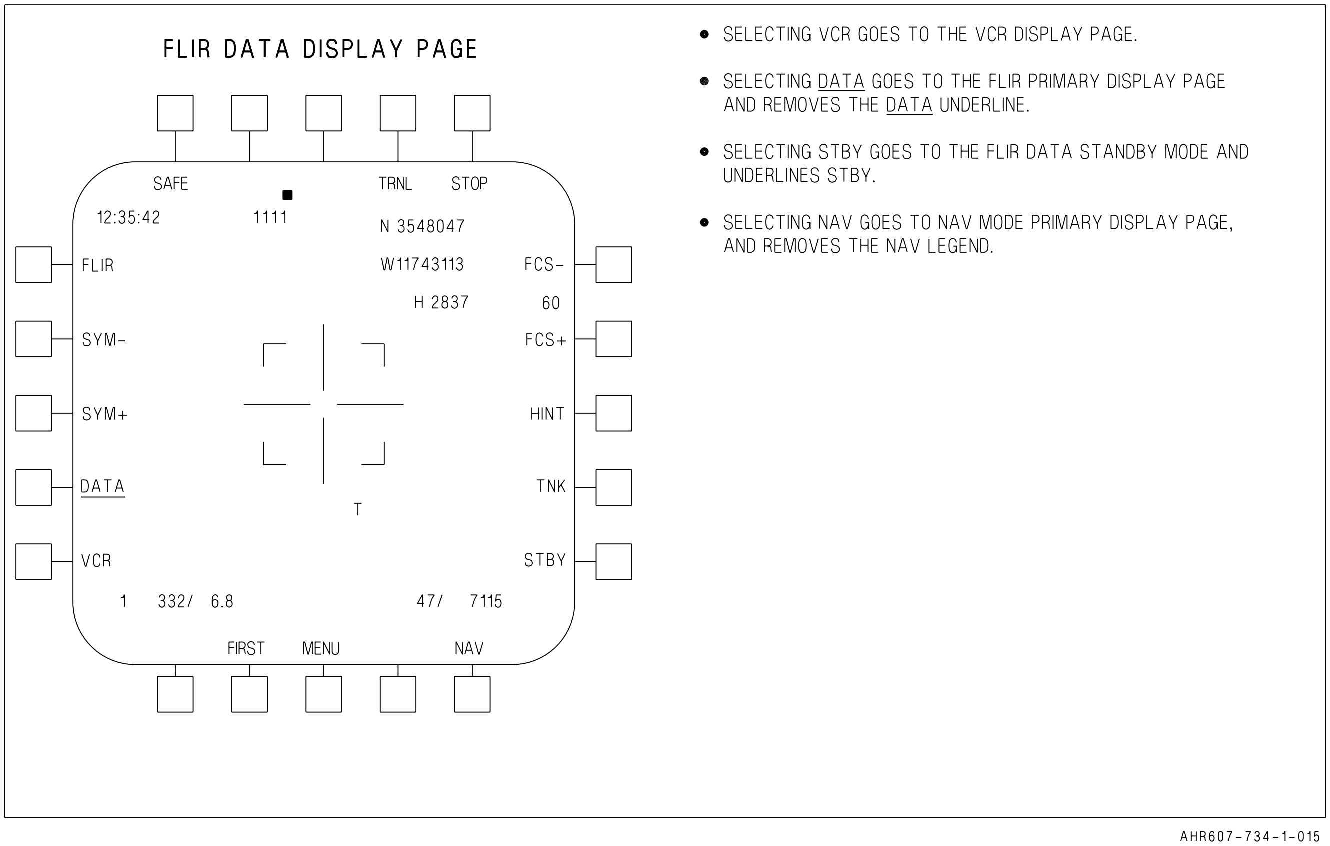


Figure 1-280. FLIR Data Display Page - Operate Mode

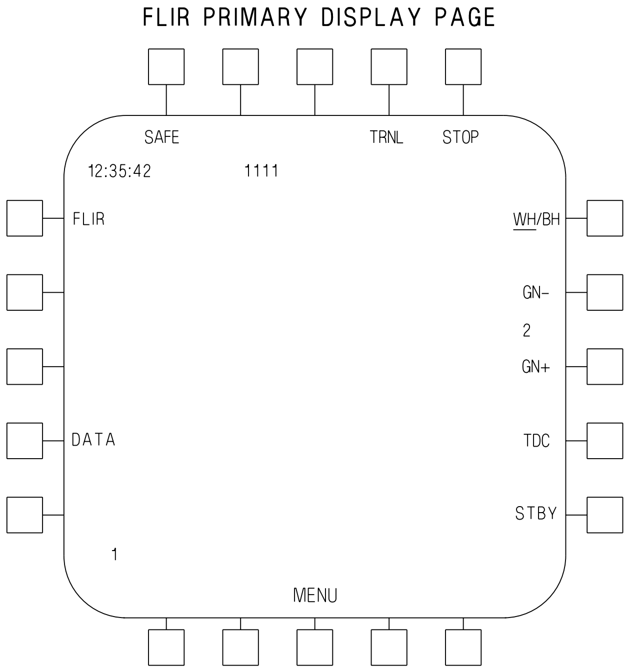
sensor slewing or target tracking capability. The pod laser is disabled in this mode.

1.18.4.13.1 Air–to–Air Mode – CCD/FLIR Primary Display Page. The TPOD A/A mode is selected by the aircraft A/A master mode with the aircraft control stick A/A weapon select switch. The CCD and FLIR primary display pages have the same pushbutton legends displayed as on the air–to–ground CCD and FLIR primary display pages, respectively. See Figure 1–283 for the CCD primary display page.

1.18.4.13.2 Air–to–Air Mode - CCD/FLIR Data Display Page. The A/A mode data display page is selected by PB 2 (DATA) on the A/A mode CCD/FLIR primary display page, and supplements the primary display page with additional pushbutton selectable options. The CCD and FLIR data display pages have the same pushbutton legends displayed as on the air–to–ground CCD and FLIR data display pages, respectively. See Figure 1–284 for the FLIR data display page. The A/A mode is exited by selecting an aircraft A/G master mode: A/G, VSTOL, or NAV.

1.18.4.14 VCR Display Page. The VCR display page is displayed by selecting VCR with PB 1 on the data display page, which underlines the VCR legend. Access to this display is independent of sensor selection. The VCR display page provides all the legends that allow software control of the TPODs VCR. In addition to VCR control, legends for gray–scale and symbology rejection are provided. Laser fire cannot be activated, but can be stopped on this page with PB 8 when the FIRE legend is underlined (FIRE). See Figure 1–285.

If a videotape cassette is not loaded into the pod VCR, the pod power–on BIT indicates a BIT fault. This fault is displayed as VCR F in the normal location for BIT faults; also NO CASS is displayed in the lower right corner of the display page.



- THE DISPLAY SHOWS THE PRIMARY DISPLAY NAVIGATION MODE WHICH IS SELECTED BY SELECTING NAV (PB 16) ON THE FLIR OR CCD DATA DISPLAY PAGE.
- IN NAV MODE, THE FLIR SENSOR IS CAGED TO POD BORESIGHT, DEPRESSED 2°.
- THE NAV DISPLAY HAS ONLY A WIDE FOV AND IS HORIZON STABILIZED.
- SELECTING DATA GOES TO THE NAV DATA DISPLAY PAGE AND UNDERLINES DATA, AND DISPLAYS NAV.
- PB 5 (FLIR) IS NON−FUNCTIONAL IN NAV MODE.
- SELECTING WH/BH TOGGLES THE POLARITY OF THE FLIR SENSOR BETWEEN WHITE HOT AND BLACK HOT. THE SELECTED POLARITY IS UNDERLINED.
- CLICKING GN− DECREASES FLIR GAIN TO A MINIMUM SETTING OF 1, AND THEN WRAPS THE SETTING TO 8.
- CLICKING GN+ INCREASES FLIR GAIN TO A MAXIMUM SETTING OF 8, AND THEN WRAPS THE SETTING TO 1.
- THE GAIN SETTING, FROM 1 TO 8, IS DISPLAYED BETWEEN THE PB 12 AND PB 13 LEGENDS, I.E., 2.
- TOGGLING BETWEEN TDC AND TDC IS NON−FUNCTIONAL IN NAV MODE.
- SELECTING STBY GOES TO STANDBY MODE (STBY). SELECTION OF STBY EXITS THE STANDBY MODE AND THE NAV MODE, AND GOES TO CCD PRIMARY DISPLAY PAGE.

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Figure 1-281. Navigation Mode - FLIR Primary Display Page

The VCR display page is exited by selecting PB 1 (VCR) or PB 2 (DATA). If the aircraft deselects the TPOD display page, subsequent selection of the TPOD page returns to the primary display page for the selected sensor – CCD or FLIR.

(a) VCR Run−Time Counter. When the VCR display page is selected, the pod displays the VCR run−time counter in place of the A/C CMD LOS offset display in the lower right corner of the MPCD. The VCR run−time counter indicates how long the pod VCR has run. The format is HH:MM:SS.

1.18.4.15 Laser Operations. Laser operations are only available in the TPOD A/G mode. The TPOD provides the pilot laser selection, arming, and firing options for the training laser, laser marker, and laser designator, when in the TPOD A/G mode and on any of the three TPOD display pages on either left or right MPCD. The training laser is the default laser mode following pod power−up.

1.18.4.15.1 Laser Safety. The TPOD is responsible for laser safety. The TPOD displays the SAFE legend below PB 6 when power is applied to the pod to indicate the laser's safe status, and when the pod has automatically safed an armed or firing laser. The TPOD monitors aircraft Avionics Multiplex Data Bus (AVMUX BUS) signals to determine when the aircraft is in an unsafe lasing condition. The TPOD automatically safes the laser when the aircraft is landing, on the ground, the pod is not in A/G mode, or the pod goes from a target track mode to the slave mode. AVMUX BUS signals from different remote terminals are monitored to provide a safety network. The TPOD safes the laser when any of the following conditions are true:

(a) Aircraft is weight−on−wheels,

(b) Aircraft landing gear is down,

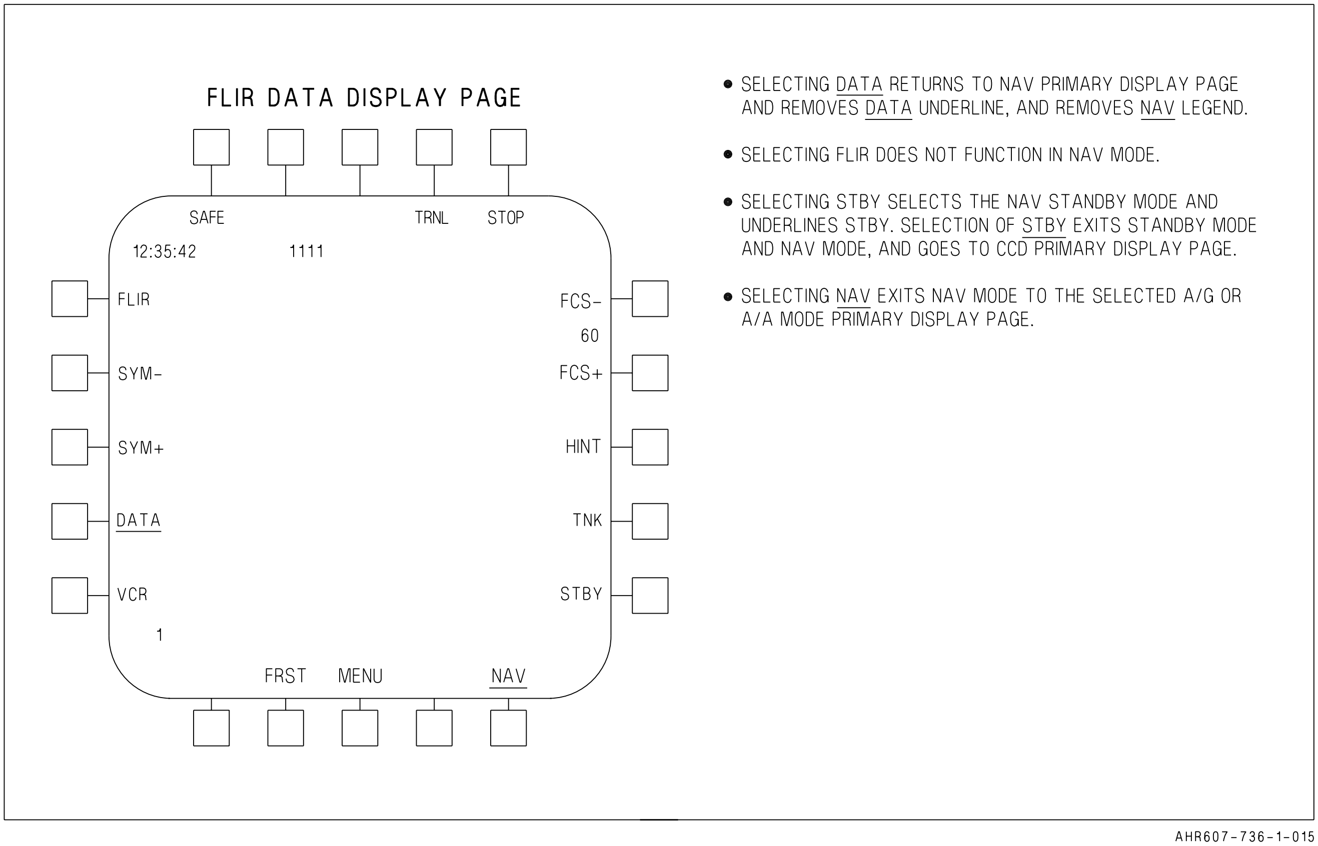


Figure 1-282. Navigation Mode - FLIR Data Display Page

(c) Aircraft indicated airspeed is less than 100 knots,

(d) MC indicates the aircraft is not in−flight,

(e) TPOD is in NAV or A/A mode,

(f) No target designation,

(g) Master Arm is in the OFF position, or

(h) TPOD format is not displayed on either the left or right MPCD following expiration of the 15−second TPOD page exit grace period. See note in the laser firing section.

1.18.4.15.2 Laser Control and Arming Displays. MPCD pushbutton controls are displayed on all three TPOD display pages for the TRNL, MRKR, LASR, LRNG, and laser masks. The order of laser selection with PB 9 is TRNL, MRKR, and LASR. Upon selection of the laser mode and a laser SAFE or ARM state, the TPOD displays a laser mode specific reticle in the center of the MPCD, and a laser symbol is displayed below the reticle. The displayed symbol is a T for TRNL, MRK for MRKR, or blank/L for LASR SAFE/ARM, respectively.

NOTE

The laser marker cannot be used for range finding or guiding LGBs/ LMAVs.

a. Laser Arming. The TPOD arms the selected laser and replaces the SAFE legend with ARM on the TPOD display page when the SAFE pushbutton (PB 6) is selected, provided all of the following conditions are met prior to pressing PB 6 and the pod is in a target track mode (See Figure 1−286):

(a) Aircraft is weight−off−wheels,

(b) Aircraft landing gear is up,

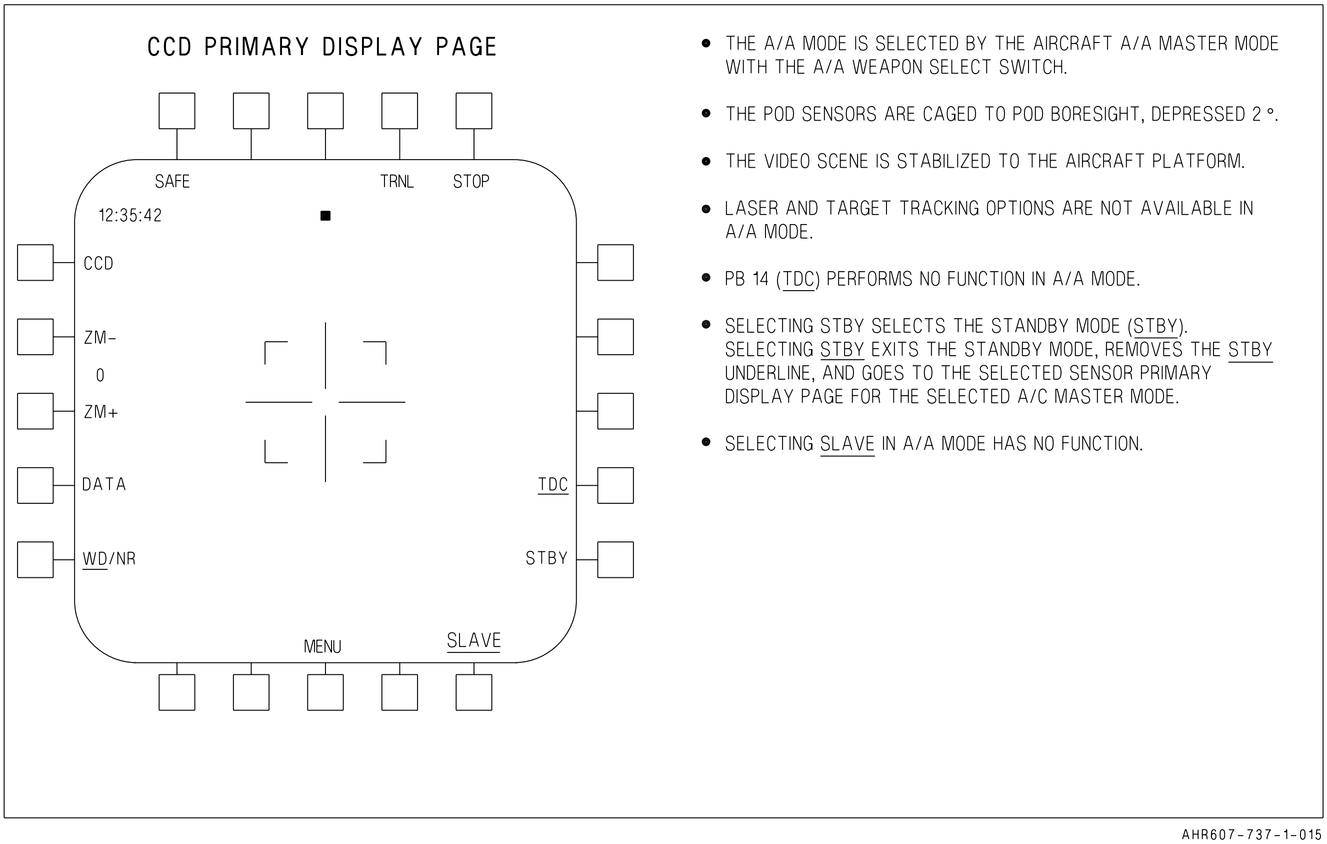


Figure 1-283. A/A Mode - CCD Primary Display Page

(c) Aircraft indicated airspeed is greater than 100 knots,

(d) MC indicates the aircraft is in−flight,

(e) TPOD is in A/G mode,

(f) Designated target,

(g) TPOD format is displayed on either the left or right MPCD.

(h) Master arm is in the ARM position.

NOTE

If any of the above conditions is not true when PB 6 is pressed, the TPOD does not arm the laser, and continues to display the SAFE legend.

An armed laser is automatically safed (unarmed) by the pod if any of the above arming conditions becomes invalid, the ARM legend is replaced with SAFE, PB 6 resets, and the laser symbols are removed from below the reticle on the MPCD and from the HUD. The pilot can unarm the laser by reselecting PB 6, or by switching the master arm switch from ARM to OFF. When the selected laser is armed, two additional pushbutton options are displayed on all TPOD operate mode display pages: LRNG and FIRE (laser fire). LRNG is displayed below PB 7, and FIRE is displayed below PB 8. When PB 6 is pressed, and the arming conditions are met, the DC displays a laser armed L symbol in the lower left corner of the HUD.

b. Laser Mask Activation With Laser Safe or Armed. When the laser LOS enters the 10° warning zone around the aircraft and its stores, the reticle and laser symbol below the reticle start flashing. If a laser mask is activated by the laser LOS entering the 5° mask zone, and the selected laser is in either SAFE or ARM state, the T, MRK, or blank/L symbol is replaced with TM, M MRK, or M, respectively. When laser masking stops, laser symbology returns to the previous display.

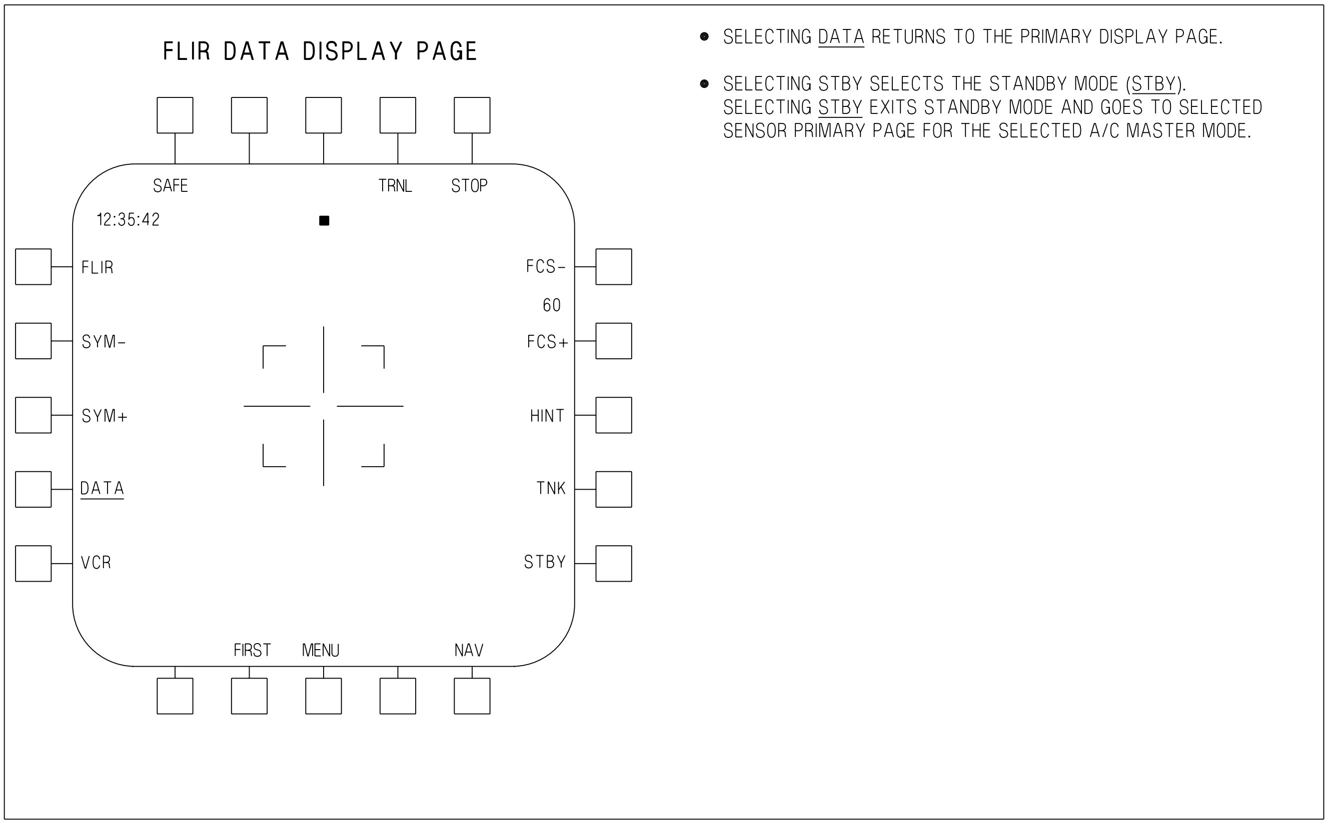
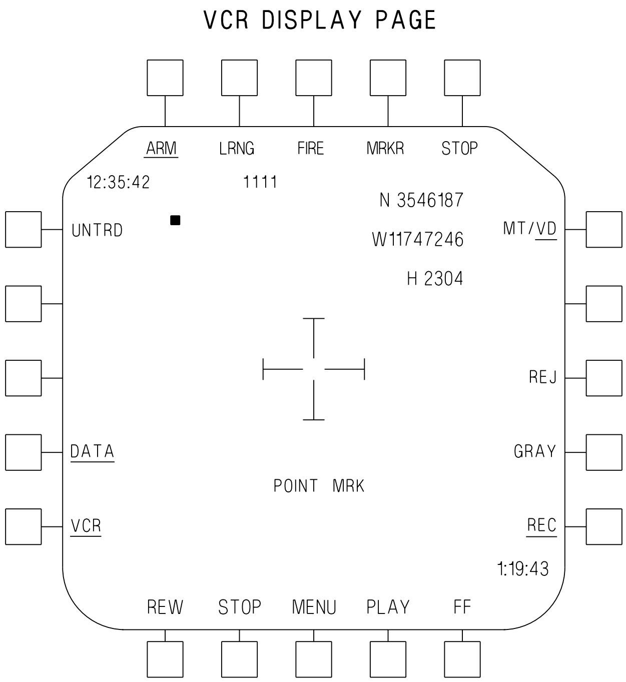


Figure 1-284. A/A Mode - FLIR Data Display Page

c. Laser Firing. A selected laser can only be fired (dry fired for training laser) or the laser range finder fired, if the selected laser is in the armed state, with ARM displayed below PB 6, and the laser LOS is not in a laser mask zone. See Figure 1−287. The training laser is dry fired and the laser marker and laser designator fired, and firing stopped, by pressing the FIRE pushbutton. However, on the VCR page, the selected laser can only be commanded to stop firing. Also, the training laser can be dry fired and the laser marker and laser designator fired, and firing stopped, by pressing the throttle APS switch in radar aircraft, when in the TPOD HOTAS control mode (HTS legend displayed next to PB 14 on the TPOD primary display pag)e. On night attack aircraft, the lasers can only be fired and the training laser dry fired with the FIRE pushbutton. When a laser is fired or the training laser dry fired, FIRE is displayed and the laser symbols on the MPCD and HUD flash. When firing/dry firing is stopped by pressing FIRE or APS, the FIRE underline is removed and the laser symbols below the reticle on the MPCD and HUD stop flashing. The TPOD stops laser firing and the training laser stops dry firing, if any required laser arming condition becomes invalid, except for temporary exits from the TPOD page for periods not exceeding a 15−second grace period as described in the following note. When an invalid arming condition occurs, including TPOD page exit for more than 15 seconds, the pod safes the laser and resets PB 6, which is indicated by the ARM legend changed to SAFE, removal of the FIRE and LRNG legends, and the



- DISPLAY SHOWS THE LASER MARKER (MRKR) IS THE SELECTED LASER WITH MRK DISPLAYED BELOW THE MARKER RETICLE, THE POD IS IN POINT TRACK, NARROW FOV, AND VCR IS RECORDING (REC).
- VCR DISPLAY PAGE IS SELECTED WITH PB 1 (VCR) ON ANY DATA DISPLAY PAGE. VCR IS UNDERLINED, AND THE VCR RUN-TIME COUNTER IS DISPLAYED BELOW THE REC LEGEND.
- SELECTING VCR RETURNS TO THE PREVIOUS DISPLAY PAGE.
- SELECTING DATA RETURNS TO THE PRIMARY DISPLAY PAGE FOR THE ACTIVE SENSOR (CCD OR FLIR).
- UNTRD UNTHREADS VCR TAPE FOR CASSETTE REMOVAL, AND UNDERLINES UNTRD. UNTRD UNDERLINE IS NOT REMOVED UNTIL STOP (PB 19) IS SELECTED.
- RANGE FINDER (LRNG) CANNOT BE INITIATED FROM VCR PAGE.
- SELECTING FIRE (PB 8) ONLY COMMANDS LASER STOP FIRE.
- MT/VD IS USED TO SELECT METRY OR VIDEO FOR RECORDING, SELECTION UNDERLINED, VCR STARTS RECORDING. VD IS DEFAULT.
- REJ DECLUTTERS POD VIDEO DISPLAY AND UNDERLINES REJ. REMOVED ITEMS ARE UTC TIME, TARGET LOCATION, POD TO TARGET BEARING AND RANGE, A/C CMD LOS OFFSET BEARING AND RANGE.
- GRAY DISPLAYS GRAY SCALE AND UNDERLINES GRAY.
- REC STARTS VCR RECORD AND UNDERLINES REC.
- FF STARTS VCR FAST FORWARD AND UNDERLINES FF.
- PLAY STARTS VCR PLAYBACK AND UNDERLINES PLAY.
- STOP (PB 19) STOPS CURRENT VCR FUNCTION.
- REW STARTS VCR REWIND AND UNDERLINES REW.

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Figure 1-285. VCR Display Page

removal of the laser symbols from below the reticle on the MPCD and from the HUD.

NOTE

If a laser is armed or firing (or the training laser dry firing), the TPOD page may be exited for up to 15 seconds before the laser is automatically safed. This is a programmed grace period to provide uninterrupted laser firing when the TPOD page is exited during weapon selection for weapon release or due to inadvertent sensor selection, and thereby allows the pilot time to reselect the TPOD page for continued laser firing.

d. Laser Range Finder Firing. PB 7 (LRNG) is pressed to initiate a laser range update. When LRNG is selected with the LASR armed, but not firing, LRNG is underlined, and the LASR fires, performing a short duration laser range measurement of less than 3 seconds. If the MRKR is the selected laser, firing or not firing, when LRNG is selected, the PB 9 legend changes from MRKR to LASR during the laser range update, and then changes back to MRKR and the previous firing state upon completion of the range update. The laser range updates the pod to target range displayed above PB 20. If LASR is selected and firing when PB 7 is pressed, the command is ignored. LRNG (PB 7) does not function on the VCR page and is disabled when TRNL is selected.

e. Laser Fire Indicator. The TPOD flashes the laser mode symbol below the reticle when the TRNL is dry firing, or the LASR or MRKR is firing. When the pilot commands the selected laser to fire with either PB 8 or the APS, the DC flashes the laser L symbol on the HUD until the pilot commands the laser to stop firing with PB

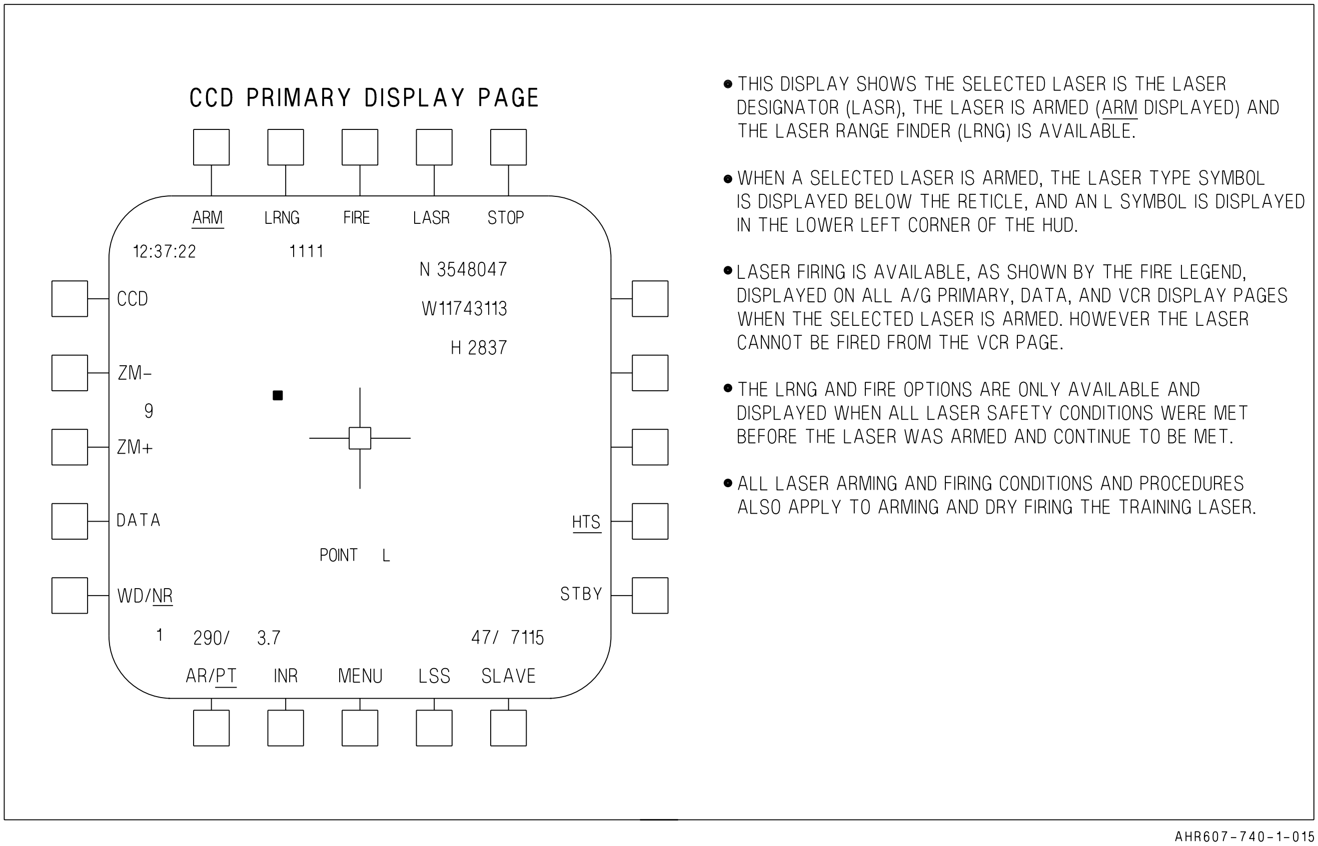


Figure 1-286. Laser Control Display After Laser Arming

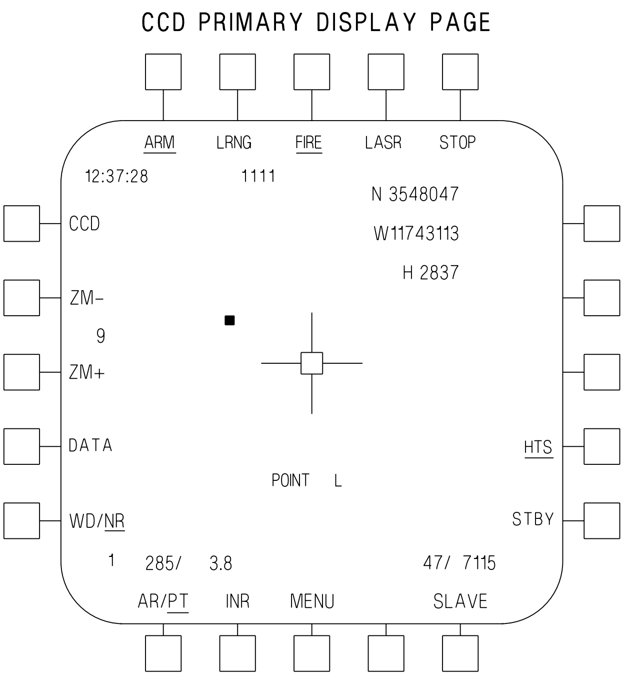
8 or the APS; or in the case of the LRNG being fired with PB 7, the DC flashes the L symbol for three seconds.

f. Laser Mask Activation With Laser Firing. During laser fire (TRNL dry fire), when a laser mask is activated by the laser LOS entering the 5° mask zone from the warning zone, the flashing T, MRK, or L symbol is replaced with TM, M MRK, or M, respectively, and the laser stops firing. When laser masking stops, laser symbology returns to the previous display, and the laser resumes firing (dry firing for the TRNL).

NOTE

When a laser that is firing enters a laser mask zone and stops firing, the DC controlled flashing L displayed on the HUD continues to flash even though the laser has stopped firing.

g. Gimbal Roll Warning. If the GIMB ROLL warning is displayed when the laser is firing, the pilot must take action to prevent the sensor head from hitting the gimbal stops, as indicated by the flashing of the sensor head look indicator. Exceeding the pod's sensor head rotation limits will drive sensor tracking off the target, losing the target designation criteria required for laser arming and firing, and safe the laser.



- THIS DISPLAY SHOWS THE SELECTED LASER IS THE LASER DESIGNATOR (LASR), THE LASER IS ARMED (ARM) AND FIRING-FIRE DISPLAYED AND THE FLASHING L "((L))" BELOW THE RETICLE. ALSO, THE LASER RANGE FINDER (LRNG) IS AVAILABLE.
- THE LRNG AND FIRE OPTIONS ARE ONLY AVAILABLE AND DISPLAYED WHEN ALL LASER SAFETY CONDITIONS HAVE BEEN MET AND THE LASER IS ARMED WITH ARM DISPLAYED.
- LASER FIRING CAN BE INITIATED ON ALL A/G PRIMARY AND DATA DISPLAY PAGES WHEN THE SELECTED LASER IS ARMED.
- FIRE, PB 8, FIRES (STOP FIRES) THE LASER (DRY FIRES TRAINING LASER) AND UNDERLINES FIRE LEGEND. THE LASER CAN ALSO BE FIRED (STOP FIRED) WITH THE APS IN RADAR AIRCRAFT IN TPOD HOTAS CONTROL MODE WITH HTS DISPLAYED AS PB 14 LEGEND.
- THE MRKR FIRING SHALL BE INDICATED BY A FLASHING MRK, AND THE TRNL DRY FIRING BY A FLASHING T BELOW THE RETICLE.
- SELECTING LRNG CAUSES THE LASER TO PERFORM A SHORT DURATION (LESS THAN 3 SECONDS) RANGE MEASUREMENT IF ALL LASER SAFETY INTERLOCKS HAVE BEEN MET. LRNG IS NOT INITIATED UNDER THE FOLLOWING CONDITIONS:
  - THE LASER IS FIRING.
  - WHEN SELECTED FROM THE VCR PAGE.
  - WHEN TRNL IS THE SELECTED LASER.

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Figure 1-287. Laser Firing Display

CHAPTER 2

Air-To-Surface Weapons Delivery Theory and Employment

2.1 INTRODUCTION

The AV-8B weapon delivery system provides the pilot with six A/G weapon delivery modes, several methods of target designation, and a weapon release program for each loaded weapon.

The A/G weapon delivery modes are AUTO, CCIP, AGM, DSL, DIR (direct), and DSL (1). A LOFT mode is provided as a submode to the AUTO mode.

The AUTO, CCIP and LOFT modes are computed delivery modes. Specialized aiming references are provided for releasing bombs or dispensers in the AUTO delivery mode. In the CCIP mode, specialized aiming references are provided for launching rockets, firing gun(s), and releasing bombs. In the LOFT mode a continuously computed release point is calculated and pullup cues are provided to ensure that the bomb toss occurs at the desired angle.

The AGM mode is basically a non-computed delivery mode dedicated to the air-to-ground missiles (Maverick and Sidearm). Dedicated aiming references and displays are provided for launching Maverick and Sidearm in the AGM delivery mode.

DSL, DIR, and DSL(1) are non-computed delivery modes. DSL is a backup delivery mode used with a full up SMCS. DIR and DSL(1) are backup bomb delivery modes used with a degraded weapon system. The DSL, DIR, and DSL(1) delivery modes require the manual selection of the roll stabilized sight or standby reticle.

In the A/G master mode with AUTO, CCIP or LOFT selected the pilot's workload is minimized by automation of the weapon delivery tasks. The MC controls the head-up and head-down attack display presentations and sensor positioning. It also performs the necessary weapon delivery computations. The SMCS automatically selects armament stations for weapon release. Together, the SMCS and MC control weapon delivery programming, store weapon delivery programs for future use, and provide cueing to assist the pilot in performing the attack. The pilot retains the ability to manually change weapon delivery parameters as the situation dictates. However, as discussed in Chapter 1 all weapon programming should be accomplished during preflight. This enables the pilot to make quick reaction weapon deliveries if the need arises. Functions such as weapon selection and setting the cockpit controls for a release should also be accomplished prior to executing the actual weapon delivery maneuver.

Target designation is required in the AUTO and LOFT delivery modes. This enables the MC to make a release point computation and automatically release the weapon at the appropriate point. Target designation is also helpful in other modes as an aid in finding the target. It also provides height above target in the CCIP mode if the ARBS (Day and Night Attack aircraft) is employed or the radar is employed in the air-to-ground ranging (AGR) mode.

It is important for the pilot to realize that since the primary AV-8B weapon delivery system is computer controlled, accuracy is dependent upon the correct information being supplied by the various subsystems and the pilot. The system will release a weapon or present a computed impact point based on pilot entered data and flight conditions, regardless of basic weapon considerations such as fuze arming and frag pattern. For this reason, basic weapon theory and delivery envelope parameters are an integral part of computed weapon delivery employment and precise weaponeering and tactics are essential for safe and successful weapon delivery. The AV-8B weapon delivery system is

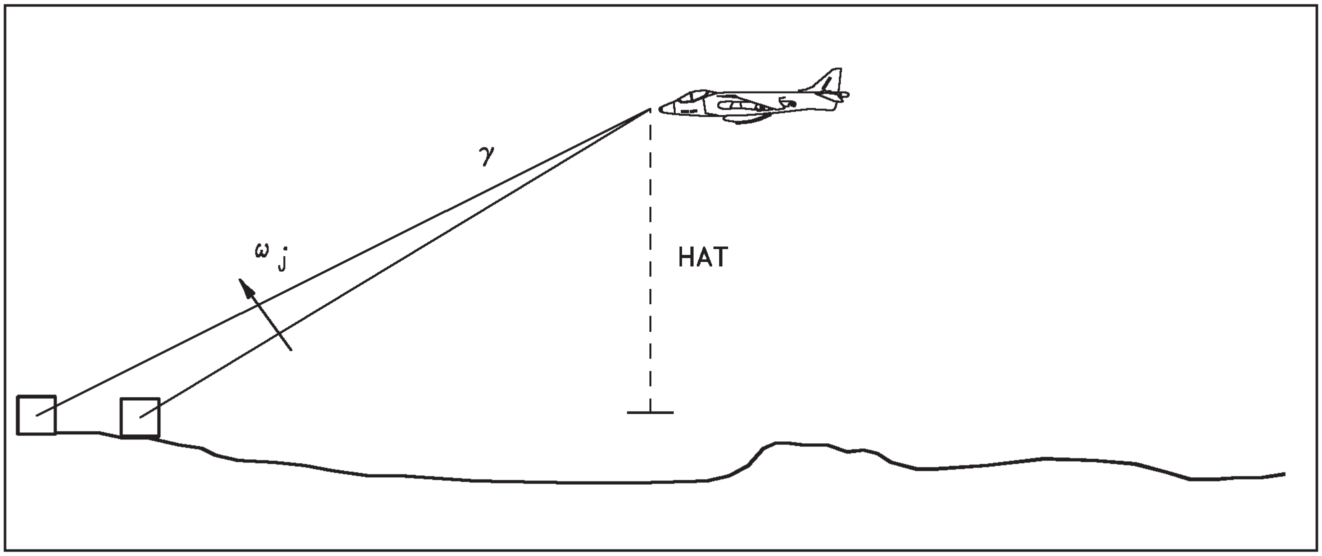


Figure 2-1. ARBS Height Above Target

therefore a highly accurate tool which is utilized in the framework of good weaponeering and tactics to accomplish its mission.

The TAV-8B has the same capabilities as the AV-8B for weapon release from stations two and six but not the same carriage authorization. See external stores limitations in NWP 3-22.5-AV8B, Vol. II, Chapter 5.

2.2 WEAPON SYSTEM THEORY

2.2.1 Altitude (Height Above Target) Management. Altitude management as it pertains to the weapon delivery solution is essential to achieve optimum weapon accuracy. Any time the pilot performs an attack using a computed delivery mode, the order of precedence for target altitude must be considered. This order of precedence and the altitude sources available differ between the three aircraft types and are as follows:

DAY	NIGHT	RADAR
ARBS RADAR ALT BARO	ARBS RADAR ALT GPS BARO	AGR/FTT/ GMTT RADAR ALT BARO

2.2.1.1 ARBS Height Above Target. The ARBS, when tracking is achieved, provides the primary height above target information. The ARBS provides the following critical measurements to the MC for use in weapons delivery calculations:

1. Gimbal azimuth LOS angle
2. Gimbal azimuth angular rate
3. Gimbal elevation LOS angle
4. Gimbal elevation angular rate

The MC compares these values to the motion of the aircraft in order to derive the true target LOS angles and rates. These rates can be used (via the ARBS equations) to solve for the kinematic slant range to the designated point. This slant range is resolved into X, Y, and Z components. The Z component is height above target (HAT). See Figure 2-1. Height above target is used to determine the down range travel (DRT) of the weapon. Height above target and DRT are independent of the designation position. If the designation is long or short of the target, calculated DRT will not be effected as long as designated altitude equals target altitude.

In AUTO deliveries the X and Y components define target location. This location is compared to aircraft location in order to determine range to

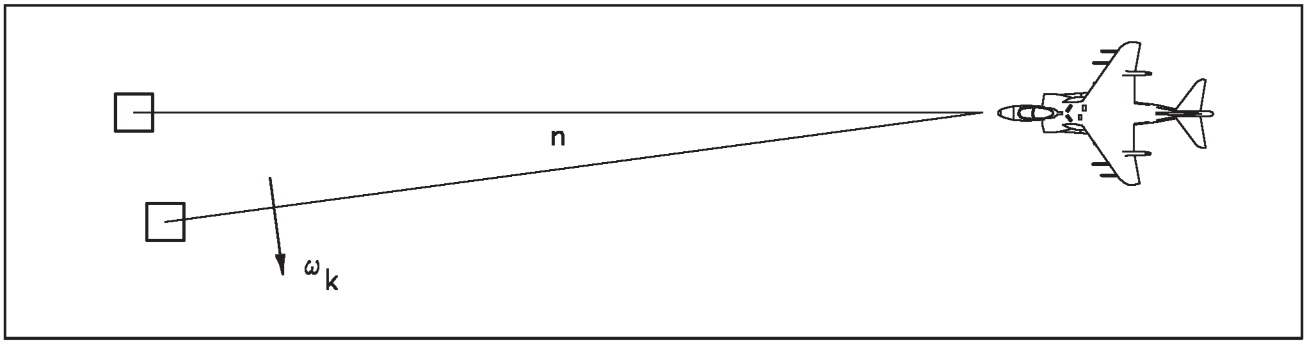


Figure 2-2. Lateral Offset Designation

the target and steering error. It should be apparent that, in the case of AUTO deliveries, location of the designation is essential to the accuracy of the weapons solution. Although DRT is still accurately calculated from height above target, the release will not occur until the DRT matches the range to target.

One might assume that since a CCIP delivery only needs the Z component then there would be no harm in having laterally offset locks. This is not true. Laterally offset locks will cause false cross winds to be displayed on the CCIP symbology. This results from the aircraft tracking out to the side of the designated point, causing lateral angles and angle rates to develop. This is the same phenomenon that permits the ARBS to compensate for moving targets by sensing target motion as wind. Sensitivity to laterally offset tracks increases as release altitude (SR) decreases. Lateral offset should be limited to less than 100 feet in low angle deliveries and less than 300 feet in high angle deliveries. These are conservative bounds, however, if designations are significantly short of the target then sensitivity to lateral offset will increase. See Figure 2-2.

The restrictions mentioned above define an acceptable "window" where CCIP designations may lie. This window is much more liberal than most pilots realize. Its presence provides relief from self-imposed restrictions to accurately place the designation on or very near the target (as long as target area is relatively flat). These restrictions can be difficult to follow in a tactical environment when targets often become visible at the last moment. See Figure 2-3. The designation window is bound at the top by minimum LOS rate position, at the bottom by gimbal limit (but more practically by the HUD limit), and at the left and right by the false crosswind limits. A pilot can make a determination of designation acceptability during the run by applying some HUD gouge. At the checkpoint, if the designation lies at least 2° underneath the wingspan of the velocity vector (velocity vector over the target), *then you will have sufficient angle rate.* Lastly, if the designation won't leave the FOV of the HUD, then you won't have an unknown

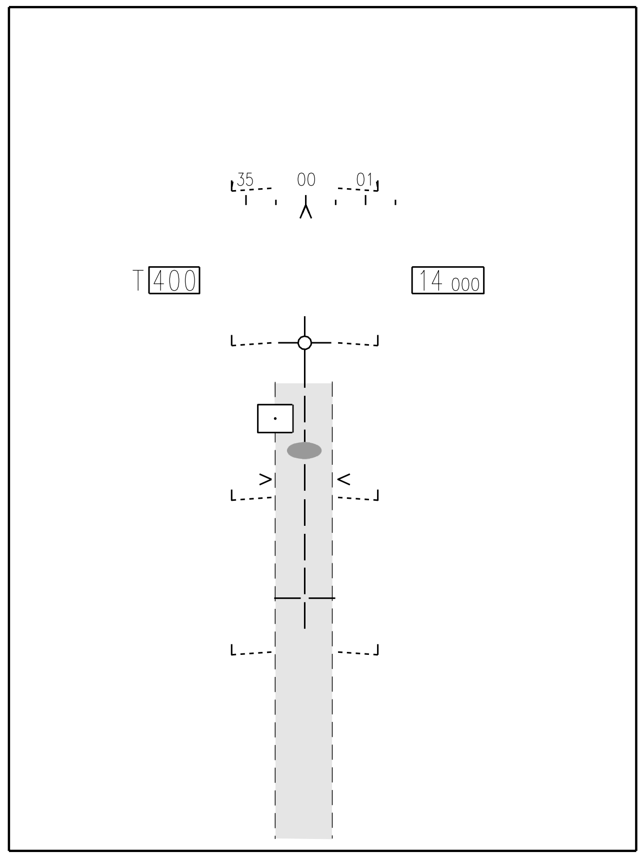


Figure 2-3. Designation Limits

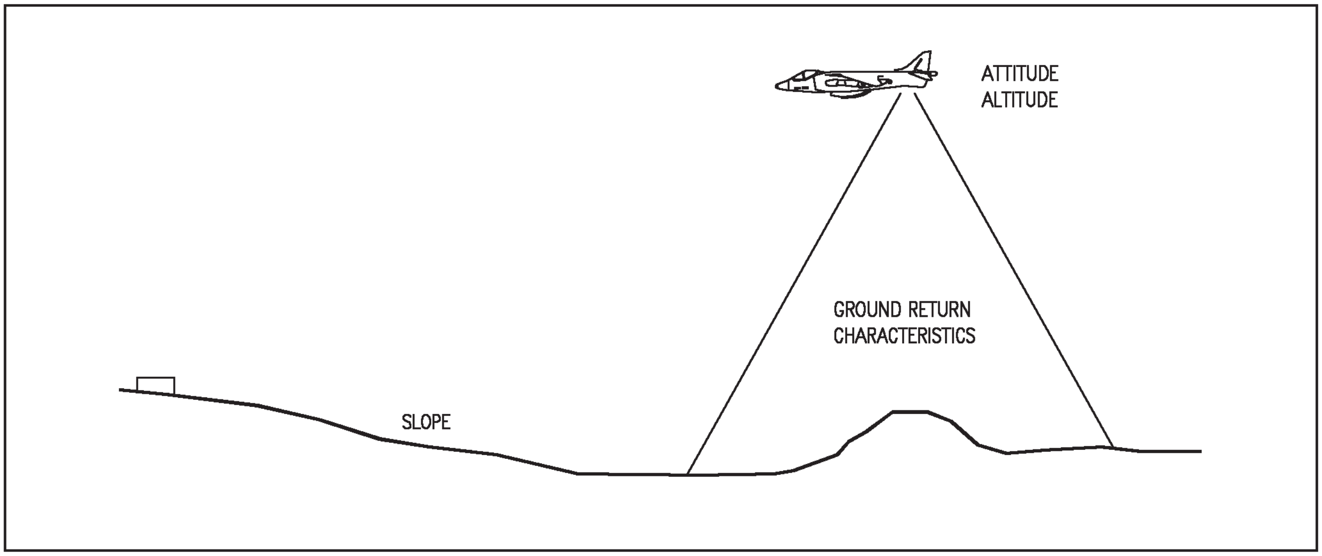


Figure 2-4. Radar Altimeter Limitations

break-lock. By taking advantage of this window, the pilot frees up time for the performance of other tasks such as tracking, target acquisition, and threat lookout.

On Day and Night Attack aircraft the ARBS is the only height-above-target measurement device available that is actually tied to the target. In light of the accuracy of the ARBS system, the limitations of the radar altimeter, and the inaccuracies involved in ADC measurement, *every weapons delivery should attempt use of a DMT designation*. In some scenarios lack of valid DMT designation should become one of your tactical abort criteria.

2.2.1.2 Radar Altimeter Altitude. The radar altimeter provides height above terrain to the MC where it is used in weapons delivery calculations. The radar altimeter is an FM ramped CW radar set. It emits an EM signal of varying frequency, receives a return from below the aircraft, and then analyzes the elapsed time to determine range in feet. Technically the distance from the aircraft to the ground underneath is of absolutely no value in determining weapon trajectory. However, we can use it as a substitute for height above target in certain *limited circumstances.*

Validity of radar altimeter data is dependent upon aircraft attitude, altitude, ground return characteristics, and terrain slope. See Figure 2-4. If the aircraft is banked or pitched significantly, the radar altimeter may provide erratic altitude information as various corner reflectors pass through its field of view. The radar altimeter does not provide range to the nearest piece of terrain. It provides range to the strongest signal in the field of view. Whenever the radar altimeter is used for system input, care must be taken to ensure that the terrain in the field of view is relatively flat or radar altimeter altitude will not equate to height above target. This applies for weapons deliveries and overfly updates. *The terrain between current aircraft position and the target must be relatively flat.*

Radar altimeter measurements are accurate to within 4 percent of aircraft AGL altitude (3 sigma or 99.73 %). Normally the radar altimeter errors are less than 4 percent. Two-thirds of the time, the error will be 1.33 percent. For this reason, radar altimeter measurements at altitudes above 3000 feet AGL (40 feet < error > 120 feet) are considered to be less suitable for use in weapons delivery than barometric data. See Figure 2-5. In AUTO deliveries the radar altimeter takes a single ″ping″ to determine aircraft height and then barometric altitude is used for the remainder of the release run. This initial ″ping″ might not represent the most accurate altitude source at the time and could set the height loop in error. All these limitations severely restrict the operational use of the radar altimeter as a

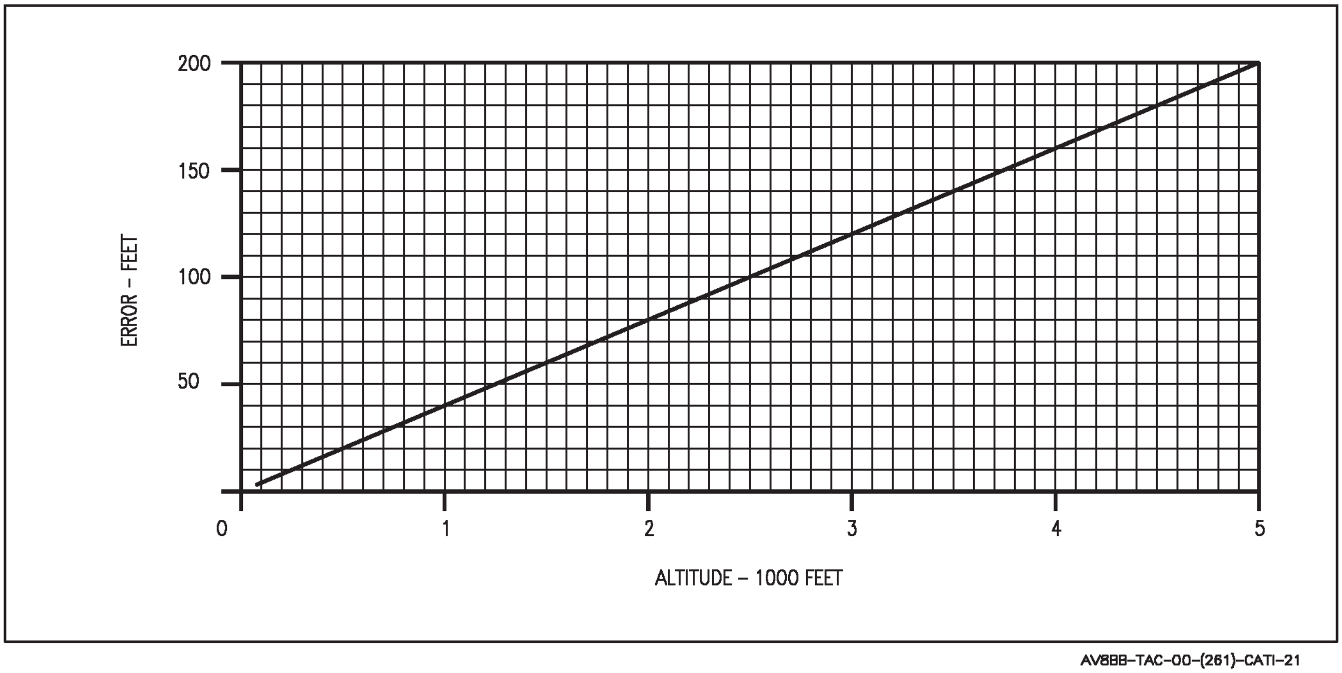


Figure 2-5. Potential Radar Altimeter Error

height-above-target sensor to level laydown and shallow dive deliveries.

2.2.1.3 GPS Altitude. The GPS provides accurate three-dimensional present position, velocity, and time information to the MC. The position and velocity calculations are based on the WGS-84 geodetic datum (earth model). The GPS uses time data in conjunction with almanac and ephemeris data from four satellites to calculate position and velocity. When using GPS altitude in CCIP mode, the waypoint/waypoint offset elevation or the last known target elevation is subtracted from GPS altitude to derive the height above target. When using GPS altitude in AUTO mode to derive height above target, the MC uses a two phased approach. In the first phase, the GPS altitude is used directly; subtracting waypoint/waypoint offset field elevation from GPS altitude. In the second phase that begins at 15,000 feet slant range from the target, the height above target is computed by integrating aircraft vertical velocity.

The GPS calculates three-dimensional position to an accuracy of 16 meters SEP (Spherical Error Probable) and three-dimensional velocity to an accuracy of 0.1 meters per second.

2.2.1.4 Radar Air-To-Ground Ranging (AGR). The AGR function of the radar provides accurate slant range and doppler velocity along the commanded LOS and provides this data to the MC where it is used in the weapons delivery calculations. The AGR acquisition ranges are from 1,000 feet to 10 nm. The MC uses the ranging data to calculate height above target as follows:

h = sin(LOS elevation angle) × (AGR slant range)

In the AUTO mode, AGR ranging is only utilized during initial designation, during slewing, or upon initial selection of AGR (sensor select switch forward). After AGR (slant range) is determined, AUTO will be displayed as an indication that valid AGR was used by the MC to compute height above target.

In the CCIP mode, AGR ranging data is used continuously to compute height above ground at the CCIP point. Refer to paragraph 2.2.3.2.2 for more information.

2.2.1.4.1 Radar Fixed Target Track (FTT). The FTT function of the radar provides accurate slant range and antenna line of sight to the object it is tracking. The MC uses the slant range and antenna line of sight reported by the radar to calculate target range in NORTH/EAST/DOWN (NED) coordinates as follows:

$$Range_N = Direction\ Cosine_N \times Slant\ Range$$

$$Range_E = Direction\ Cosine_E \times Slant\ Range$$

$$Range_D = Direction\ Cosine_D \times Slant\ Range$$

In AUTO mode, the MC is using the radar ranging data to continuously compute target range and time to release. If the radar breaks track, the last valid FTT target range is used by the MC to ground stabilize the designation.

2.2.1.4.2 Radar Ground Moving Target Track (GMTT). The GMTT function of the radar provides accurate slant range, antenna line of sight, and horizontal velocity of the object it is tracking. The MC uses the slant range and antenna line of sight to calculate target range just like FTT. It further compensates for target movement by extrapolating target range as follows:

$$Range_N = Range_N + Target\ Velocity_N \times Bomb\ Fall\ Time$$

$$Range_E = Range_E + Target\ Velocity_E \times Bomb\ Fall\ Time$$

In AUTO mode, the MC is using the radar ranging data to continuously compute target range and time to release. If the radar breaks track, the last valid GMTT target range is used by the MC to ground stabilize the target. The last valid target velocities, however, are not used.

2.2.1.5 Barometric Altitude. BARO bombing can produce excellent hits, but it is very dependent on accurate pilot inputs and management. Height above target in the BARO mode is derived from ADC inputs to the MC. The ADC provides the following critical measurements to the MC for use in weapons delivery calculations:

1. Barometric altitude
2. Pressure altitude
3. Relative air density

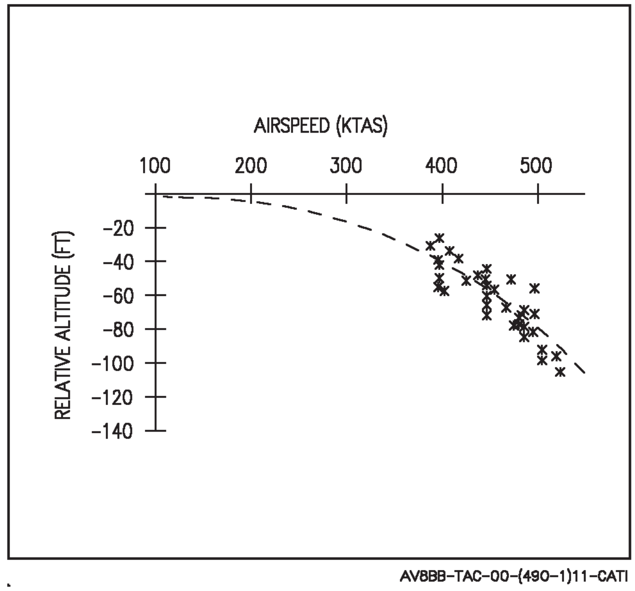


Figure 2-6. Baro Altitude Versus KTAS

4. Total temperature
5. Ambient temperature
6. True airspeed
7. Mach number

The ADC receives information from: the AOA probe, TOT probe, a dual pitot static system, Kohlsman window, magnetic azimuth detector, and the MC. The Kohlsman window setting permits the ADC to convert air pressure into indicated altitude and correct it to match the known field elevation and barometric pressure. Indicated altitude is then corrected for position or systematic errors to derive calibrated altitude. Position Error Correction (PEC) is made necessary by changes in the pressure field surrounding the nose of the aircraft that occur when speed or altitude change. The ADC PEC is based on a nominal test airframe. Test data has shown that fleet airframes show a consistent decrease in indicated altitude as airspeed increases when operating at low altitude (Figure 2-6). This is why overfly updates should always be done at release airspeed. The MC receives calibrated altitude and ambient temperature from the ADC. Calibrated altitude is then adjusted for temperature and air density effects to give corrected altitude. In order to implement this correction, the MC must assume that the air mass

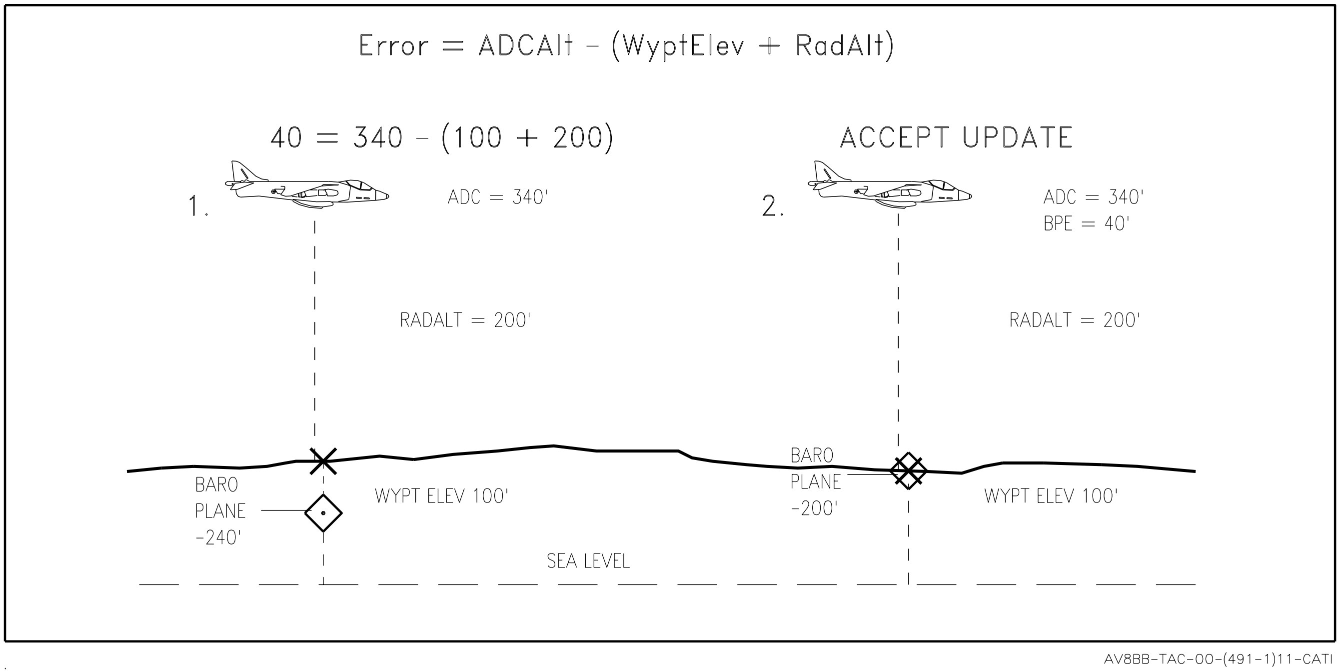


Figure 2-7. Height-Loop Update

exhibits a "standard" adiabatic lapse rate. This is rarely true but the MC has no way of knowing any difference. The effect of the assumption is that on non-standard days, corrected MSL altitude and your *actual* MSL altitude will only coincide at the pressure level of the Kohlsman window.

The MC is capable of making one additional adjustment to correct altitude. This is the height-loop update correction (Figure 2-7). The height-loop update exposes baro system errors by comparing ADC output with the sum of waypoint elevation and radar altimeter height. The scratchpad displays the result of this comparison in accordance with the following formula:

Error = ADCAlt − (WyptElev + RadAlt)

Once accepted by the pilot (by action or no action) this value remains in effect until another height-loop update is accepted or the Kohlsman window is adjusted. Rejecting a subsequent update does not cause the previous update to be deleted. This height-loop update, or baro plane error (BPE), is applied only to weapons delivery calculations inside the MC. It can be verified by comparing the baro altitude, and vertical (Z) range data from the WRD page. It should be noted that the altitude on the HUD will not match the altitude on the WRD page.

The standard adiabatic lapse rate assumption still applies. The height-loop update provides the MC with another place where corrected altitude and actual altitude will be synchronized (at least for weapons system purposes). This occurs at the MSL altitude where the overfly update was performed. This means that overfly updates should be conducted at the MSL release altitude. Since baro releases are not normally conducted at the same altitudes as overfly updates, error in weapon system altitude is induced as the aircraft climbs to delivery altitude. There is no practical way to know or predict the magnitude or direction that errors will take. *Pilots should bomb in baro only if no other option is available.* If you must bomb in baro, use the greatest practical release angle in order to minimize altitude error sensitivity. If possible, avoid release within 2,000 to 3,000 feet of surface. This is the area where non-standard conditions are most likely to exist.

2.2.1.6 Day and Night Attack Aircraft. On these aircraft, height above target determination and the A/G weapon delivery mode altitude source legends in the HUD are, in order of precedence: ARBS, radar altimeter, GPS, and barometric altitude. When tracking is achieved, the ARBS is the primary source for height above target information. The ARBS is primary because it is not subject to barometric inconsistencies, and it is not affected by changing terrain features between the aircraft and the target. Use of the ARBS by the MC in computed weapon delivery modes is denoted on the HUD by the AUTO or CCIP legends.

An option to use GPS altitude to derive height above target is available on the ODU when the ALT option is selected on the UFC. The GPS option is displayed in addition to the BOMB and PUC options on the ODU. The GPS altitude is used as height above target if the GPS option is cued and its outputs are valid and ARBS is not tracking and radar altitude is not valid (BOMB option not cued). If both the BOMB and GPS options are selected, radar altimeter, if valid, is used to determine height above target. The A/G weapon delivery mode legend in the HUD reflects that GPS altitude is being used by displaying GCIP in CCIP mode and GAUT in AUTO mode.

If the GPS vertical error exceeds the threshold limits at any point during the attack or if GPS is deselected, GPS altitude is no longer used. The GCIP or GAUT weapon delivery mode legend changes accordingly to reflect the new source being used to derive the aircraft height above target.

The radar altimeter is used for height above target if the BOMB option is cued and the outputs are valid (i.e., aircraft altitude ≤ 5,000 feet. AGL). Use of radar altimeter altitude by the MC in computed weapon delivery modes is denoted on the HUD by the RAUT or RCIP legends.

If none of the other sources are used, the system uses barometrically derived target altitude (BARO). Use of barometric altitude by the MC in the INS computed bomb delivery modes is denoted on the HUD by the BCIP or BAUT legends.

2.2.1.7 Radar Aircraft. On these aircraft the radar air-to-ground ranging (AGR) mode is the primary source for height above target information. The AGR mode provides accurate slant range along the commanded LOS. The MC uses the radar slant range and LOS angles to compute height above target for the weapon delivery solution. Use of the radar AGR mode by the MC in computed weapon delivery modes is denoted on the HUD by the AUTO or CCIP legends. Also, when AGR is valid, an AGR legend is displayed on the right side of the HUD above the CCIP or AUTO legend.

If AGR acquisition ranges are exceeded, AGR data becomes invalid and is no longer used in the weapon delivery solution. Also, when EMCON is selected, AGR ranging is inhibited. The CCIP or AUTO weapon delivery mode legend changes accordingly to reflect the new source being used, radar altitude, GPS altitude or barometric altitude, to determine height above the target.

2.2.1.7.1 Fixed Target Track (FTT). In the FTT mode the radar is tracking a stationary target and resolves target range from measured slant range and antenna line of sight. The down component of target range is used for height above target information.

2.2.1.7.2 Ground Moving Target Track (GMTT). In the GMTT mode the radar is tracking a ground moving target. The MC computes target range from radar slant range and antenna line of sight. In AUTO mode the target range vector is used to compute time to release. The down component of target range is used for height above target.

2.2.1.8 Summary. In summary, the pilot must understand which altitude source the system is using. This is because ultimately it must be the pilot's decision, based on target conditions and environment, to choose a height above target source for weapon delivery computation.

2.2.2 Weapon Delivery Theory. Bombing is the basic method of delivering conventional weapons with an aircraft against surface targets. The whole thrust of the endeavor is to impart a velocity vector to a piece of ordnance such that it will impact at a desired point. The ability to forecast this impact is dependent upon known ballistics for the weapon and the ability to achieve the planned release conditions.

2.2.2.1 Ballistics Theory. Ballistics is the study of a weapons flightpath through air, and the influence of natural phenomena such as wind, aerodynamics, etc. All bodies act in accordance with Newton's laws of motion: a body at rest tends to remain at rest; a body in motion tends to remain in motion until acted upon by force. Changes in motion obey the law:

$F = ma$

where

F = force
a = acceleration
m = mass

This equation can be written:

$a = dv/dt = F/m$

where:

dv = change in velocity
dt = change in time

m is mass, and is equal to weight divided by the acceleration of gravity (32.2 ft./sec./sec.).

A point to remember is that velocity is a vector quantity, having both a direction and a magnitude. Subjecting the body to an acceleration may leave speed (magnitude) constant while changing the direction of travel. Since all weapons except those that are rocket propelled have a constant mass, the flightpath of the weapon is dependent only on the forces at release. The forces at release can be broken down into three frames: before release, at release, and after release.

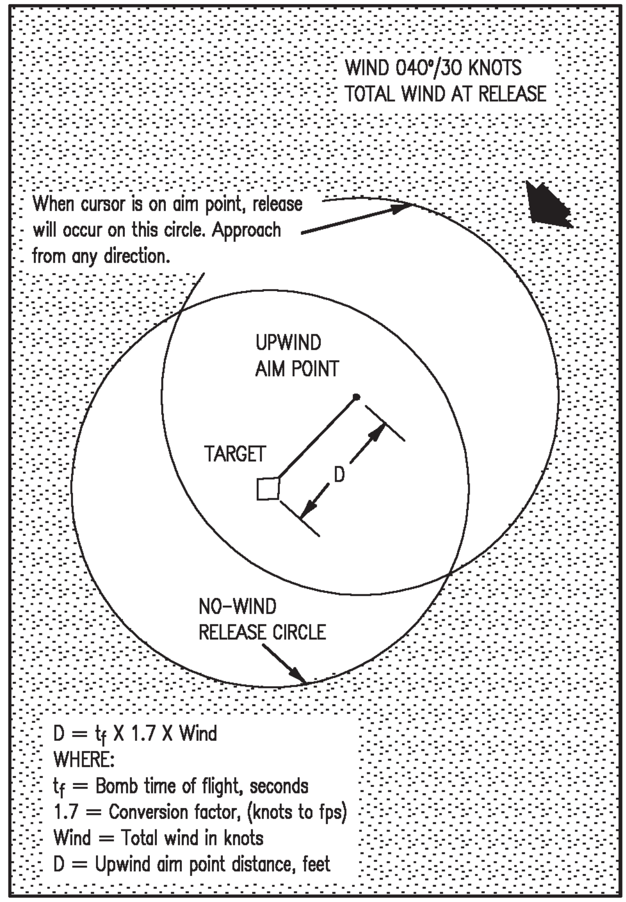
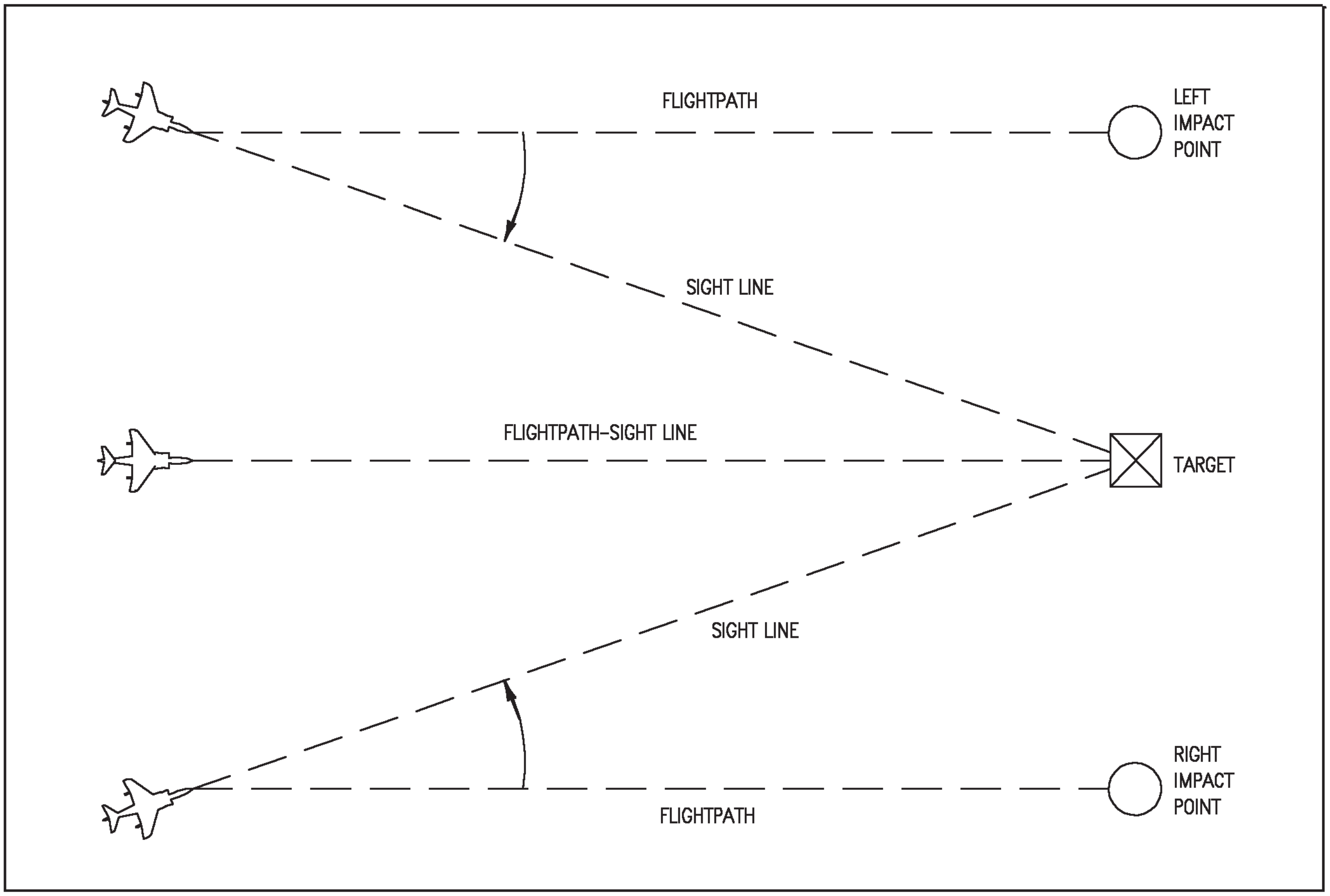


Figure 2-8. Upwind Aim Point

2.2.2.1.1 Before Release. Before release, the flightpath of the aircraft and the weapon are the same. One of the major factors influencing the flightpath of the weapon is the velocity vector imparted to it by the aircraft. This also happens to be the only factor which the pilot can control, so it bears some study. For ease of analysis, the vector is broken into its component parts with respect to the target.

a. Azimuth. This is the aircraft ground track and is equal to heading + sideslip + wind drift. To show the effect of sideslip on bomb vectors, consider the three aircraft in Figure 2-9. Free-fall bombs will follow the aircraft azimuth. If wind drift is zero, then the desired sightline should intersect the target. The addition of sideslip will drive the azimuth in the direction of the slip causing a corresponding impact error. Wind drift must be compensated for by offsetting the aim point because of no means to adjust the sight in azimuth (Figure 2-8). Headwind or tailwind



AV8BB–TAC–00–(107–1)10–CATI

Figure 2-9. Yaw Error

components will change the aircraft vector with respect to the target, and may be compensated for by mil setting adjustments or an upwind aim point.

NOTE

The ballistics computations in the MC adjust for wind. In AUTO or CCIP, the pilot should not make any adjustments for wind. He should follow the ASL (in AUTO) or put the CCIP cross on the target (in CCIP).

b. Dive Angle. Dive angle defines the velocity in the vertical plane, and is equal to attitude + angle of attack + headwind component.

c. Vector Magnitude. This is aircraft speed. The most convenient measure of this is KTAS.

2.2.2.1.2 At Release. At release, only one additional force is exerted on the bomb, that of the ejector foot separating it from the aircraft. For any given bomb weight and dive angle, this will become a constant vertical velocity in feet per second, and is compensated for in manual deliveries by the addition of mils to the sight angle setting.

G loading at release will not affect the trajectory of the ordnance dropped. The only thing imparted to the bomb is the velocity vector at the instant of release; a sudden application of g-force will only change the sight picture and increase angle of attack.

2.2.2.1.3 After Release. After release, the bomb has left the aircraft and is in ballistic flight, subject only to the forces of lift, drag, and gravity.

a. Gravity. The force of gravity, if unopposed by drag or lift, will accelerate the weapon downward at the rate of 32.2 ft./sec./sec.

b. Drag. Drag force is caused by the weapon passage through the air, and is a function of its shape, speed, and density altitude. It is always exerted in the opposite direction to the weapon motion through the air.

The ballistics tables in NWP 3-22.5-AV8B, Vol. II present data based on release altitude AGL, dive angle, and true airspeed. However, drag is a function of calibrated airspeed which is dependent upon density altitude. The tables are therefore accurate for sea level targets, but trajectory drop will decrease as target elevation increases and drag decreases. Normally, these errors are small for low-drag bombs and normal release conditions, but become more significant for high-drag bombs. Remember that release altitude will also affect angle of attack.

The ballistic trajectory drop given in the tables is for an average bomb, and each individual bomb will vary somewhat in weight, skin roughness, etc. These variations will generate ballistic dispersion; for low-drag bombs this dispersion is about 5 mils and for high-drag bombs it is about 8 mils.

c. Lift. Lift will be generated on all bodies passing through a fluid if the angle of attack is something other than zero. Even a bomb can have lift; of course, this doesn't mean it flies well. Lift also generates drag. Fins are put on a bomb to eliminate lift due to tumbling and to make the trajectory predictable. If the fins are bent, however, some lift will be generated. Bomb deviation in azimuth is unpredictable, but it will always cause short impacts due to increased drag.

Lift is also generated if the bomb is dropped in a skid. It will weathercock into the wind along the flightpath vector and continue, but the hit will again be short due to the period of increased drag. The point is, if you are in a skid to get the pipper on the bull, the bomb will still follow the flightpath vector, impacting slightly short.

2.2.2.1.4 Rockets. So far only the flightpaths of freefall weapons have been considered. The basic concepts governing rockets are the same, but the situation is complicated by the fact that the rocket continues to accelerate along its longitudinal axis until motor burnout. The mass of the rocket is also changing throughout this period, but mass is ignored in this discussion. Launcher boresight is the new factor in rocket trajectories.

To illustrate the effect of launcher boresight, assume a rocket is fired out the side of the aircraft. Its initial velocity vector will be 90° to the aircraft velocity vector as it leaves the launcher tube. Once it separates, the fins tend to make it align with the relative wind. At the same time, the rocket is continuing to accelerate, so its relative wind is now no longer the same as the aircraft. This process of accelerating and turning continues until the rocket is stabilized on course; therefore, the pilot cannot simply take the sum of the rocket and aircraft velocity vectors to determine the final vector of the rocket.

The aircraft vector has the most influence on the rocket trajectory. Launcher boresight is only about 25 percent effective in determining rocket flightpath. For example, measure the angle from the launcher boresight to the velocity vector of the aircraft. The final rocket vector will be about 75 percent of the way through the measured angle. This is the launch factor (f). The actual value of (f) is dependent upon release airspeed and rocket type, and is provided in the ballistic tables.

What this means is that, unlike bombs, last ditch changes of attitude will affect the impact point. If the pipper is tracking 5 mils to the right of the target just prior to release, skidding to place it 15 mils to the left should yield an on-target hit.

2.2.2.1.5 Guns. When strafing, the principles discussed for rockets also apply with one difference: the bullet is already at maximum velocity when it leaves the gun barrel. To determine the final vector of the bullet, simple vector addition may be used. The launcher factor becomes:

$f = V_a/(V_a+V_o)$

where:

f = final vector of the bullet
V_a = aircraft velocity
V_o = projectile muzzle velocity

Since bullet velocity is approximately four times greater than aircraft velocity, a 10-mil azimuth error just prior to release can be corrected by a 12.5-mil azimuth correction (or aiming 2.5 mils to the other side of the target) to yield on-target hits.

2.2.2.1.6 Ballistics Theory Summary. A bomb retains its initial vector in azimuth, regardless of heading. A centered ball is required for accurate sight picture. Rudder kicks and last second g-forces do nothing but change the sight picture. The only things that change trajectory are:

1. Ejection velocity.

2. Wind effects.

3. Gravity and predictable drag effects during weapon time of fall.

Rockets follow an intermediate path between the aircraft velocity vector and the launcher boresight; aircraft velocity has the most effect (75 percent).

Bullets also follow an intermediate path; however, gun boresight has most effect (80 percent).

2.2.2.2 Delivery Theory of Air-to-Surface Weapons. The foundation of ordnance delivery is the geometric relationship of the basic bombing triangle of Figure 2-10. The triangle values are based upon ballistics data and defined delivery parameters. Once given these values, the pilot then applies in-flight analysis in an attempt to deliver the weapon on target.

2.2.2.2.1 Bombing Triangle Units of Measure

1. Dive angle. Previously defined: attitude + angle of attack + headwind component.

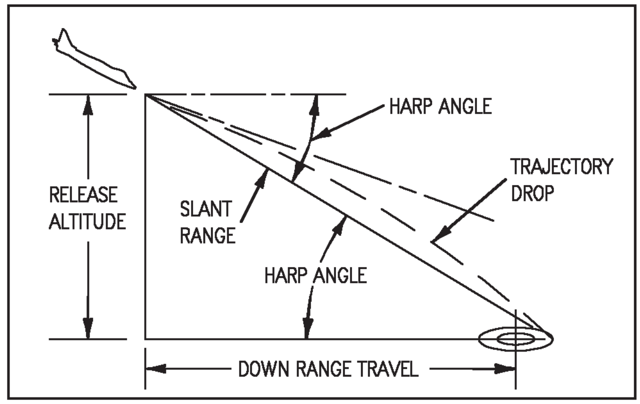


Figure 2-10. Bombing Triangle

2. Release altitude. Vertical weapon to target distance at release.

3. Mils. Mils is a unit of angular measurement. Mils may be used in conjunction with a distance measurement (feet), to provide an analysis of delivery accuracy. 1 mil = 1 foot at 1,000 feet of range. Accordingly, at any given slant range any dispersion can be described in terms of mils. Mils and milliradians (mR) are approximately equal and will be used interchangeably throughout this text (mR = 17.67 per degree, mils = 17.45 per degree).

4. Slant range (SR). Represents the weapon to target distance at release.

5. Harp angle. The angle from the horizontal to the target at release. Simply stated - the dive angle plus the sight angle. Sight angle is obtained by dividing the sight mil setting by 17.5 (17.5 mils per degree of angle).

6. Foot/mil

(a) The ratio of the number of feet to a mil at a given slant range.

(1) Deflection foot/mil. A function of slant range only (3/9 o'clock).

(b) For equal slant ranges with unretarded weapons, steeper dives are best because foot/mil in range is least.

(1) Range foot/mil is a function of slant range and harp angle (6/12 o'clock):

$$(SR/1{,}000) \times (1/\text{sine harp angle}).$$

7. Down range travel (DRT). Distance across the ground from weapon release point to impact point.

8. Time of flight (TOF). Time from release of weapon to impact of weapon.

9. Trajectory drop (TD). Angular measurement of weapon gravity drop expressed in mils.

2.2.2.2.2 Geometry of Bombing Triangle. The objective is to place the aircraft at the proper release "window in the sky" to allow weapon ballistics to achieve the desired results. A mathematical process involving a trigonometric function (right triangle) is utilized to solve the weapon impact problem (Figure 2-10). By knowing one side and one angle or two sides of the triangle, the problem may be solved.

1. Hypotenuse. This is the slant range to the target and can be found in the Tactical Manual Ballistic Tables.

2. Angle. The flightpath angle.

3. Perpendicular. The height above the target at release altitude.

4. Base. The downrange travel of the weapon. The point directly below the aircraft at release, measured to the target.

2.2.3 Computed Weapon Delivery Theory. In computed weapons delivery, the computer faces the same basic problems the pilot does during manual delivery. The difference lies in the speed and accuracy of the computed process. The basic bombing triangle is still the heart of the release solution. The release solution is constantly updated as release parameters change, while the manual release solution is based on one fixed set of parameters. In the AV-8B the primary weapon aiming computations are performed by the mission computer. The data used in these computations is obtained from the various sensors, preprogrammed data, and pilot inputs. The system components listed in Figure 2-11 are involved in the computed process. The interaction, processing, and data exchange within these components is an instantaneous and continuing process. In computed weapons delivery, the problem involves the following four tasks:

1. Defining the velocity vector

2. Determining height above target (solving the bombing triangle)

3. Weapon ballistics

4. Data presentation

COMPONENT	FUNCTION
Mission computer	Provides weapon delivery computations via OFP modules.
Built-in test module	Controls BIT functions, processes failure data, and determines the reversion process.
Sensor control module	Performs sensor management, target and waypoint designation processing, and computes target range for weapon delivery.
Air-to-ground module	Computes the trajectories of air-to-surface weapons and controls their release (working closely with the stores management processor).
Upfront control module	Display data and control input processing for the upfront control set.
Navigation module	Performs coordinate transformations, computes velocities, altitude, and winds along with aircraft accelerations.
Head-up display module	Enables and positions HUD symbology and processes weapon delivery and navigation data.
Multipurpose display module	Enables and positions DDI symbology and processes weapon delivery and navigation data.
Angle rate bombing set 1	Laser spot tracker and TV contrast tracker provide azimuth/elevation angle and rate inputs.
Inertial navigation set	Provides aircraft velocities for flightpath vector computations and wind measurements (with ADC). Measures accelerations, AOA changes, and determines aircraft present position.
Global positioning system	Provides aircraft velocities, present position, and altitude (MSL). Also provides time and stores waypoint data.
Air data computer	Generates TAS, CAS, AOA, and altitude (alone or with INS) to define flightpath vector and determine wind.
Head-up display	Projects pilot steering commands and provides the system with LOS angles.
Digital display indicator 4 Multipurpose Color Display 3	Provides pilot with weapon delivery and stores display information.
Upfront control set	Provides input mechanism for pilot weapons management.
Stores management set	Provides the ballistic data bank and allows pilot selection of weapon type, quantity, fuzing, and delivery mode.
Radar altimeter	Provides altitude input to slant range calculation.
APG-65 radar set 2	Provides slant range, LOS angles, and doppler velocity error.

LEGEND:
1 AV-8B 161573 thru 164547
2 AV-8B 164549 and up
3 AV-8B 163853 and up
4 AV-8B 161573 thru 163852

Figure 2-11. System Components Involved in Computed Weapon Delivery.

2.2.3.1 Defining Velocity Vector. To define the velocity vector, the MC uses data supplied by the INS to determine the aircraft attitude, heading, velocity, and position (Figure 2-12).

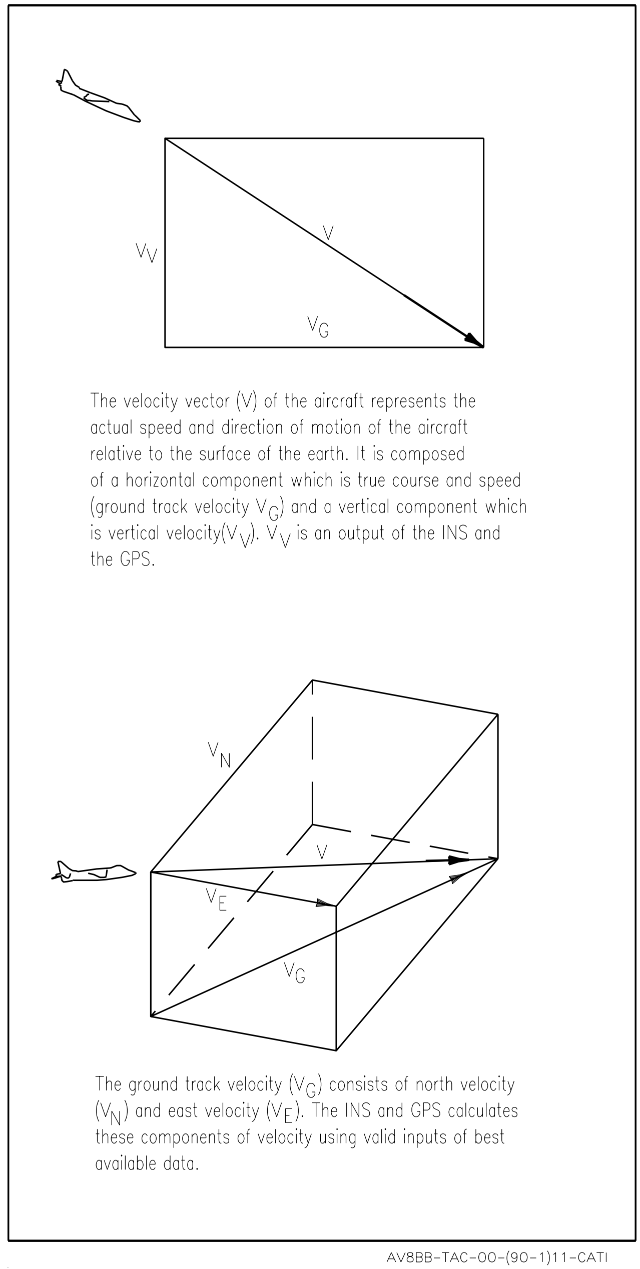


Figure 2-12. Velocity Vector Computation

1. Attitude - uses pitch and roll inputs

2. Heading - uses true heading.

3. Velocity - uses the INS as the primary data source and GPS as a secondary source. Accelerations, as sensed by the INS accelerometers, are integrated based on the time required to compute velocity.

NOTE

Once velocity is computed, additional data is derived and distributed to OFP modules for further computations and to command displays on the HUD and DDI through their respective modules. This additional data includes aircraft ground track, groundspeed, velocity vector movement, waypoint steering, and flightpath angle.

4. Position - uses present position which is computed through the sophisticated dead reckoning process based on initial INS alignment data discussed previously.

2.2.3.2 Solving Bombing Triangle. As the velocity vector is defined, the MC measures the parts of the bombing triangle. Since the triangle is subject to constant change as the aircraft moves toward the target, an on-going computer process is required. The sensor control module is responsible for maintaining this process.

In addition to sensor management and target designation functions, the sensor control module is responsible for providing the key to the bombing triangle solution - target ranging. By definition, ranging is the position of a designated ground point with respect to aircraft position.

The target position problem is depicted at the top of Figure 2-13. To obtain a target position solution, normally two of the quantities listed (altitude above target, LOS angle, slant range, ground range) need to be known to solve the remainder of the bombing triangle problem. In the case of the ARBS, however, the target LOS angle and associated LOS angular rate data can be input to the MC along with air data and attitude information to compute height above target. Thus, two of the triangle quantities are obtained and target ranges are computed.

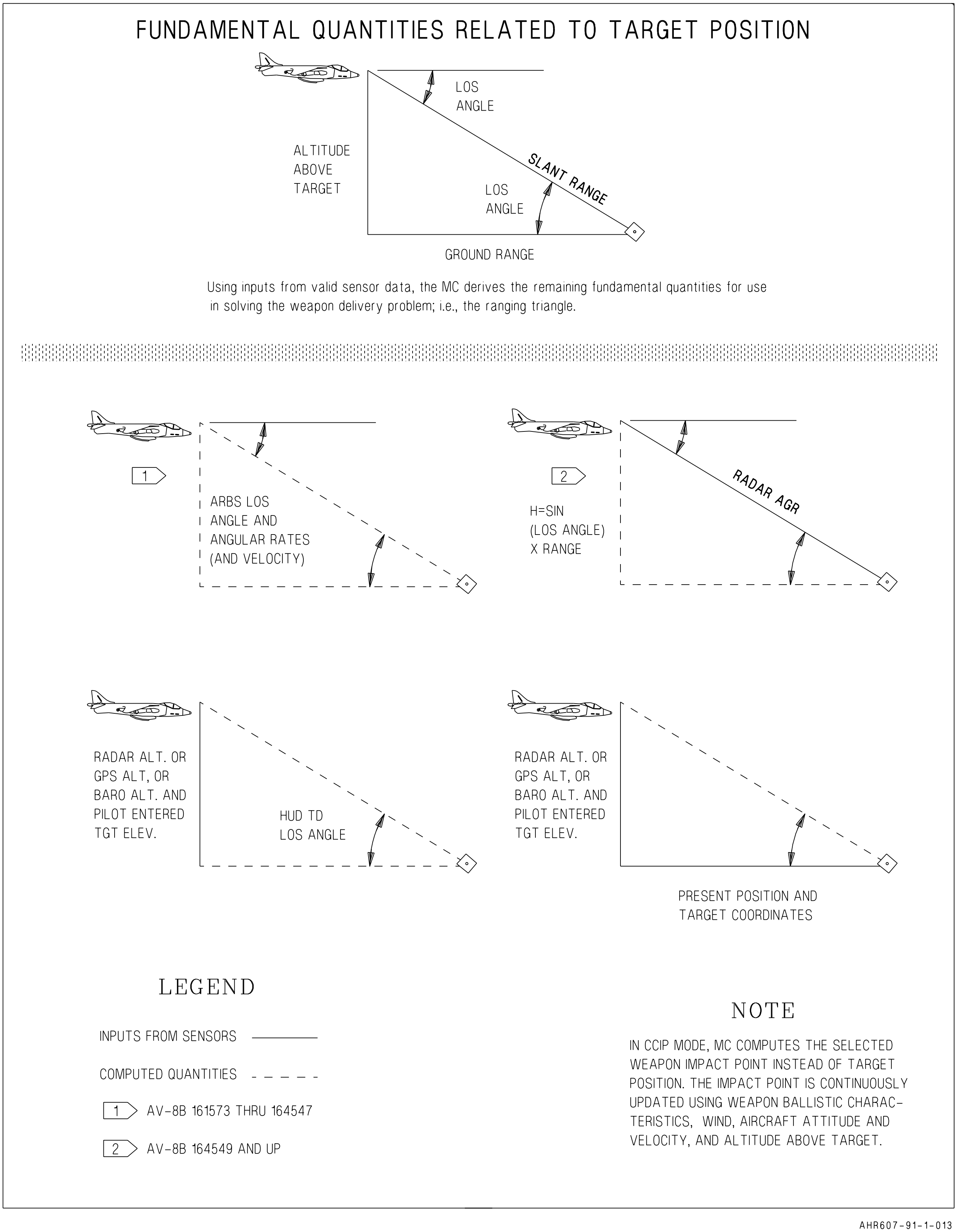


Figure 2-13. Target Position Computation

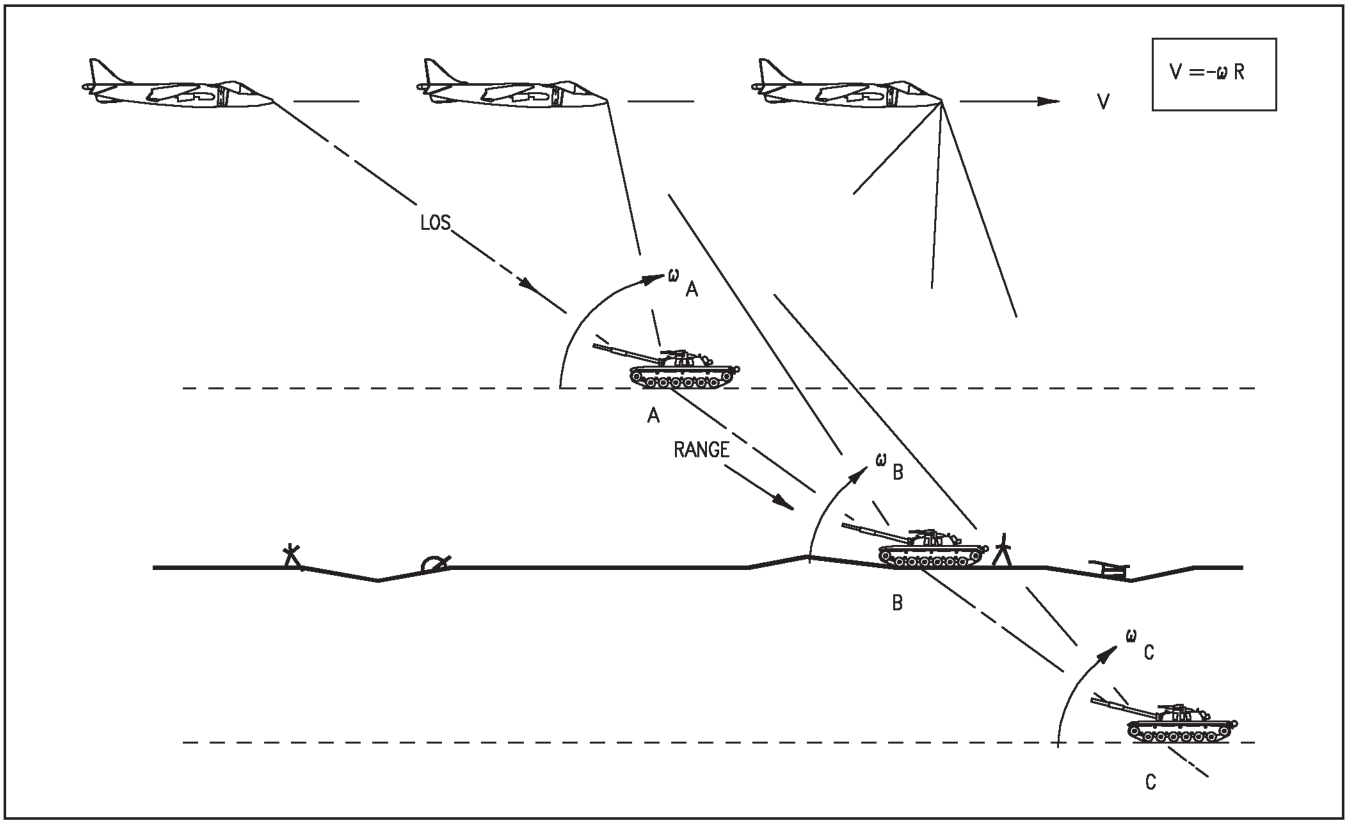


Figure 2-14. Relationship Between Range and Angular Rate

Ranging, as determined by height above target, is the most important factor in solving the triangle because it is the factor most directly affected by pilot selection. With the AV-8B, three types of ranging are available to the MC in decreasing priority as listed below:

1. ARBS LOS angle and angular rates or radar air-to-ground ranging and LOS angles.

2. HUD TD LOS angles and radar, GPS, or barometric altitude.

3. Present position and target coordinates and radar, GPS, or barometric altitude.

2.2.3.2.1 ARBS Tracking. ARBS angle/angle rate processing is a major function of the sensor control module. This ranging process is involved when employing the TV (ARBS) and LST (ARBS) designation modes. Since both modes share the same optics in the DMT, the actual ranging process is identical. Only the designation method and symbology differ.

Using the ARBS/TV sensor mode as an example, when the HUD TV FOV symbol is slewed away from the velocity vector, the ARBS is caged to that angle. When the TDC is pressed, the FOV symbol changes to the track symbol and the ARBS is ground stabilized on the selected target. As the ARBS tracks the target, the sensor control module receives LOS gimbal angles and angle change rates in both azimuth and elevation. This data, along with velocity and attitude information, is used to compute target range and aircraft altitude above target. Figures 2-14 and 2-15 show the relationship of angular rate and height above target. Azimuth and elevation angles (Figure 2-16) are determined. In addition to height above target, when the ARBS is tracking and the flightpath angle is steeper than or equal to 20°, ARBS range winds are utilized for the delivery solution; otherwise inertially derived range winds are used. ARBS cross wind values are always used if available, regardless of dive angle.

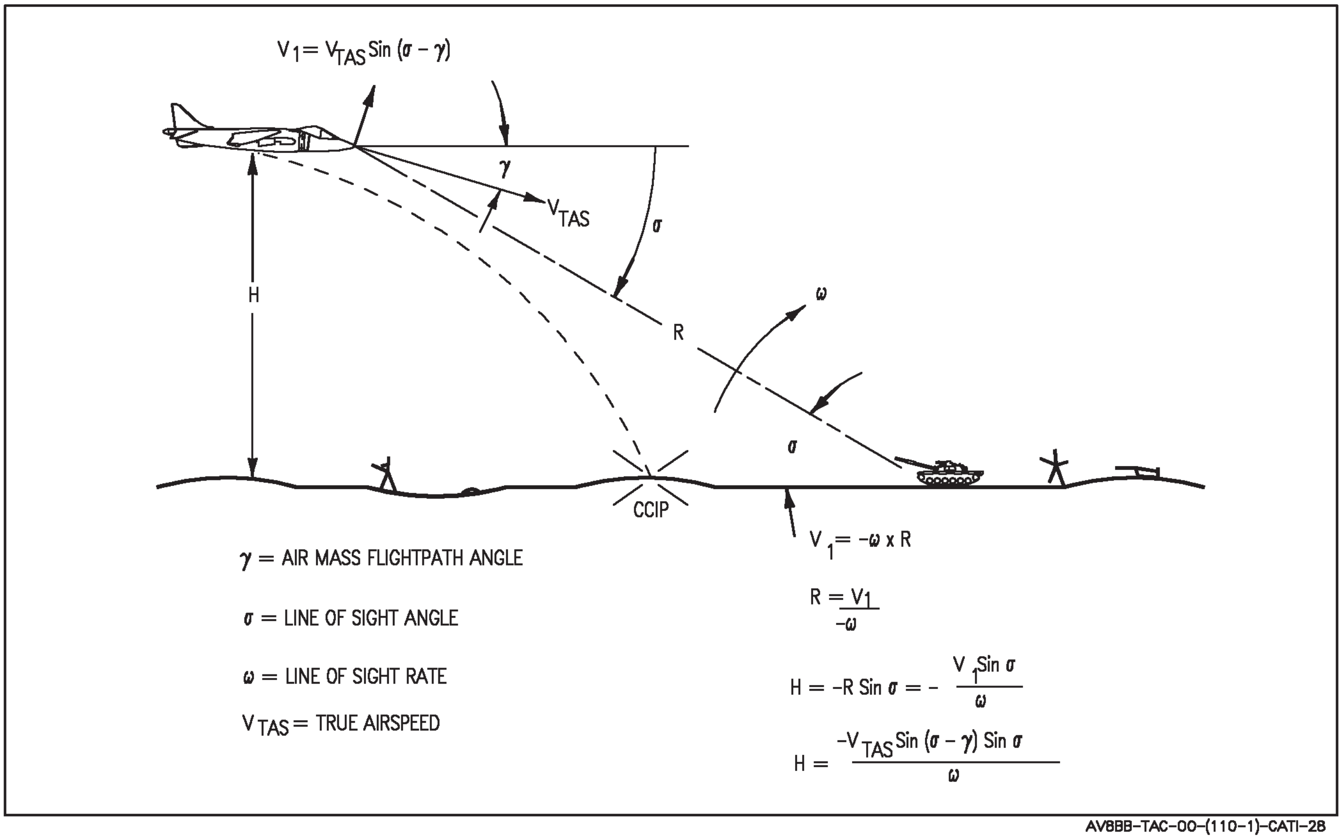


Figure 2-15. Height Above Target

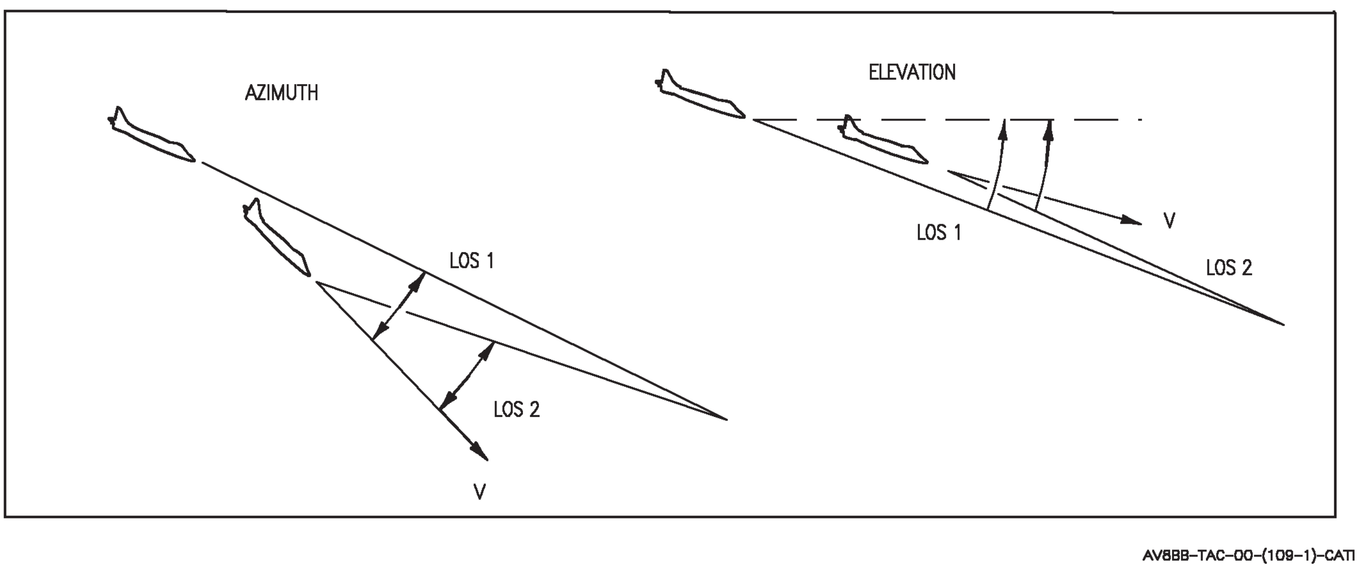


Figure 2-16. Azimuth/Elevation LOS

2.2.3.2.2 Radar Air-to-Ground Ranging. When a target is designated and AUTO mode is selected and the radar is in AGR mode, the radar is continuously ranging to the designation LOS. See Figure 2-17. The radar in turn measures slant range and antenna line-of-sight (direct cosines NED). On first selection of AGR and on subsequent depressions of the TDC, the MC uses the measured slant range and the down direction cosine to derive height above target.

$$\text{HAT} = \text{SR} \times \text{DIR COS DOWN}$$

which is then used to compute target altitude.

$$\text{TGT ALT}(t=0) = \text{ACFT ALT}(t=0) - \text{HAT}(t=0)$$

In between TDC depressions, height above target is maintained using the computed target altitude.

$$\text{HAT}(t=T) = \text{ACFT ALT}(t=T) - \text{TGT ALT}(t=0) \text{ where } T \geqq 0$$

When CCIP mode is selected and the radar is in AGR mode, the radar is continuously ranging to the CCIP LOS. See Figure 2-18. The radar measures slant range and antenna LOS, which is continuously used by the MC to compute height above ground.

$$\text{HAG} = \text{SR} \times \text{DIR COS DOWN}$$

(In this case, ground is the terrain surrounding the CCIP point) The height above ground in turn drives the weapon ballistics and placement of the CCIP point.

When CCIP mode is selected but the CCIP is HUD-limited (as indicated by the dashed cross at the HUD FOV limit and the reflected cue along the bomb fall line) the radar is continuously ranging to the HUD-limited LOS. See Figure 2-19. In this manner, when the pilot depresses the weapon release button and the system designates the target along the HUD-limited LOS, the radar is automatically ranging to the target area.

When AUTO mode is selected and a target is not designated, the radar is continuously ranging along the velocity vector LOS. See Figure 2-20. If the pilot depresses the TDC, the MC designates the target under the velocity vector and the radar is automatically ranging to the designation.

In order of priority, in AGR mode, the radar is continuously ranging to:

1. CCIP point (CCIP, not HUD-limited)

2. Limited CCIP point (CCIP, HUD-limited)

3. Designation (AUTO, designated)

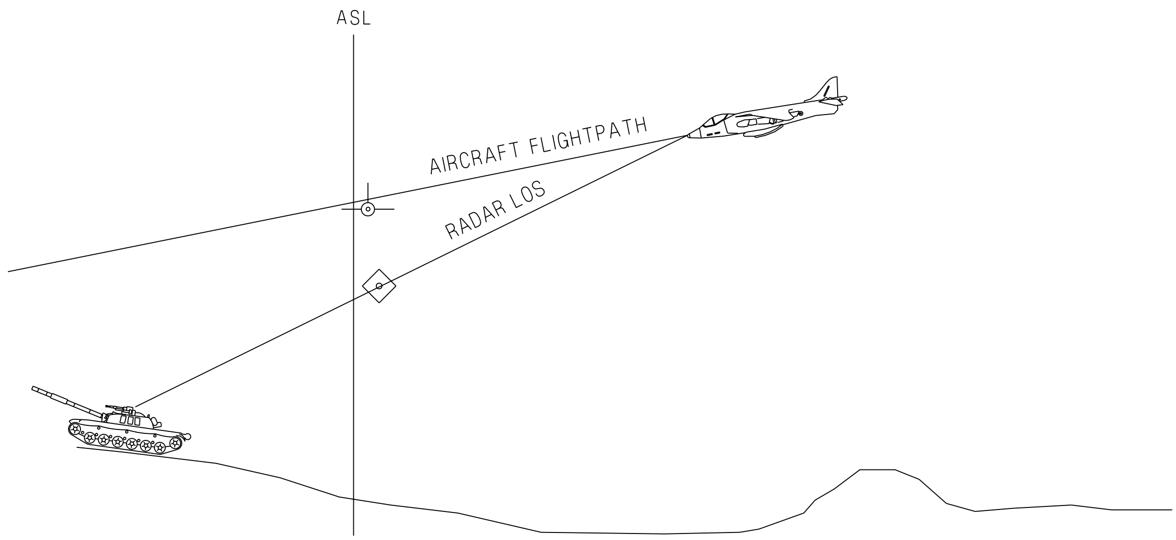
4. Velocity vector (AUTO, undesignated)

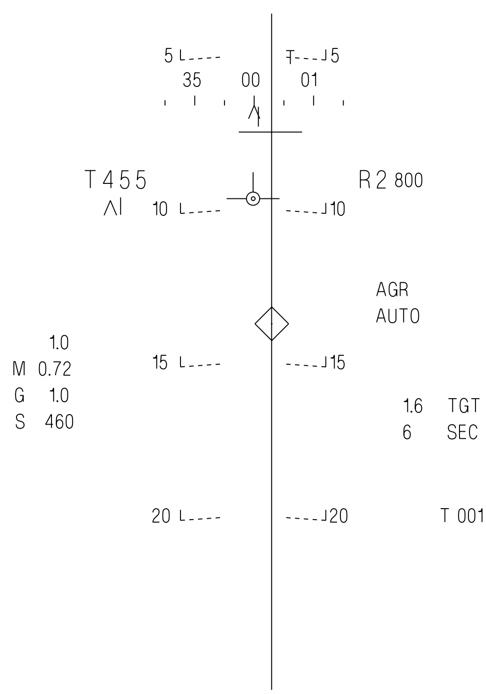
2.2.3.2.3 HUD TD LOS Angle Ranging. HUD TD LOS angle ranging exists when the target is designated using the HUD target designator to establish a LOS input (Figure 2-21).

The altitude is determined from a programmed order of precedence (Figure 2-22). If the BOMB option of the radar altimeter is cued and valid, radar altitude is used for height above target. If the BOMB option is not cued or invalid, height above target is determined using the difference between the selected waypoint elevation and the aircraft's best available altitude. If GPS altitude is cued, GPS vertical position is used for best available altitude. If it is not cued or invalid, ADC derived barometric altitude is used. If a selected offset is designated, height above target is the difference between the designated offset and best available altitude. When AUTO mode is selected with the BOMB option selected, relative altitude is utilized until the TDC is used to sweeten the TD position. At this point, the MC uses altitude provided by the radar altimeter provided it is valid.

An initial range vector (NED) is computed after target elevation is calculated and target position is refined relative to the aircraft using aircraft velocities.

After range initialization, the method of estimating range to target depends on whether or not a GPS receiver is installed. If the GPS is providing a valid aircraft position, the sensor control module continues range estimation by





- HEIGHT ABOVE TARGET DETERMINED BY SLANT RANGE FROM AGR RANGING AND LOS TO TD DIAMOND UPON INITIAL DESIGNATION, SLEW OF TD DIAMOND, OR UPON ENTRY OF AGR WITH TD DIAMOND PRESENT AND AGR VALID.
- AFTER DESIGNATION OR SLEW, HEIGHT ABOVE TARGET DETERMINED BY SUBTRACTING COMPUTED TARGET ELEVATION DERIVED FROM AGR FROM BARO-CORRECTED ALTITUDE.
- AUTO WILL BE DISPLAYED AS AN INDICATION THAT VALID AGR WAS USED BY THE MC TO COMPUTE HEIGHT ABOVE TARGET.

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Figure 2-17. Target Designated, Auto Mode, AGR Ranging

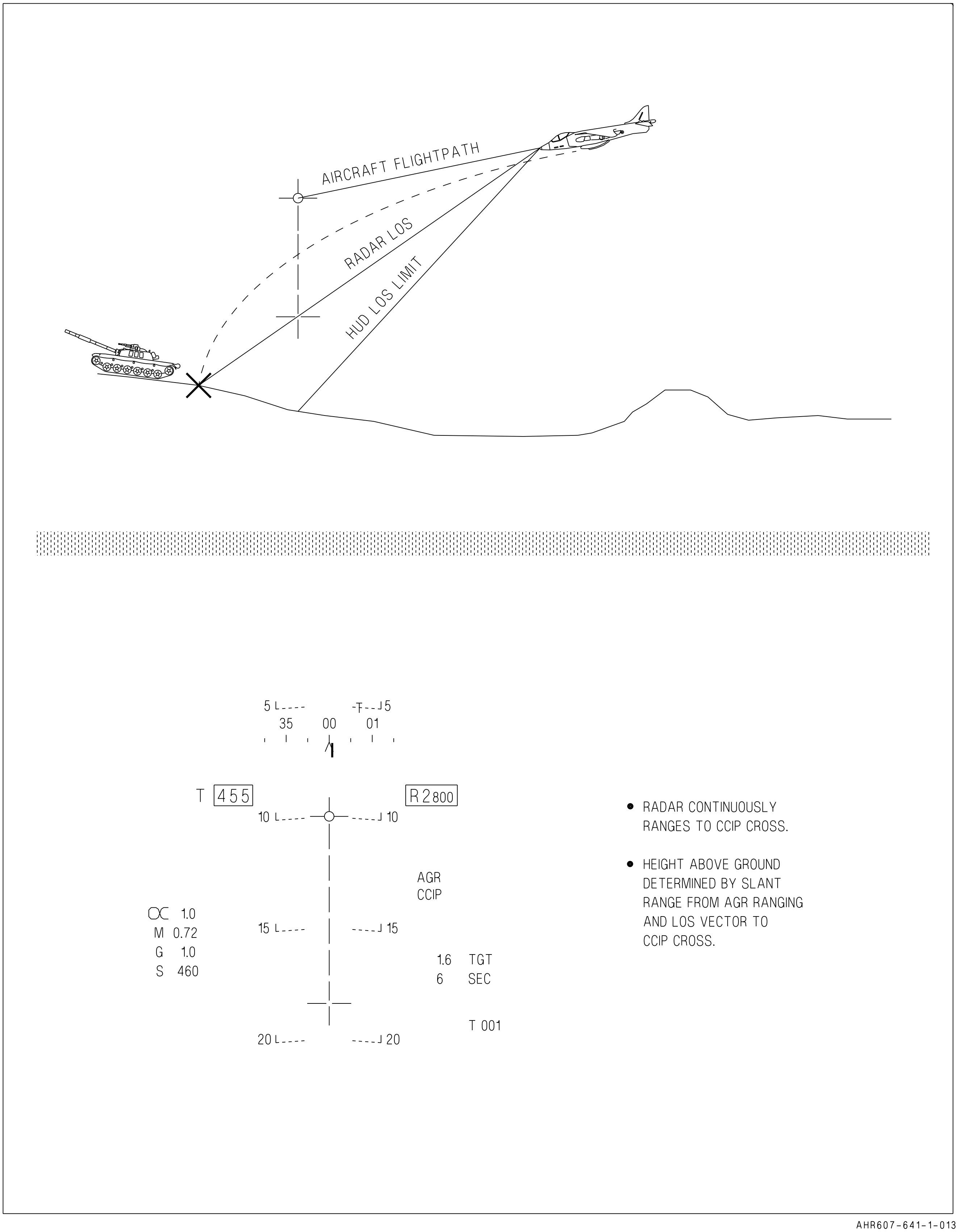


Figure 2-18. CCIP Mode, AGR Ranging

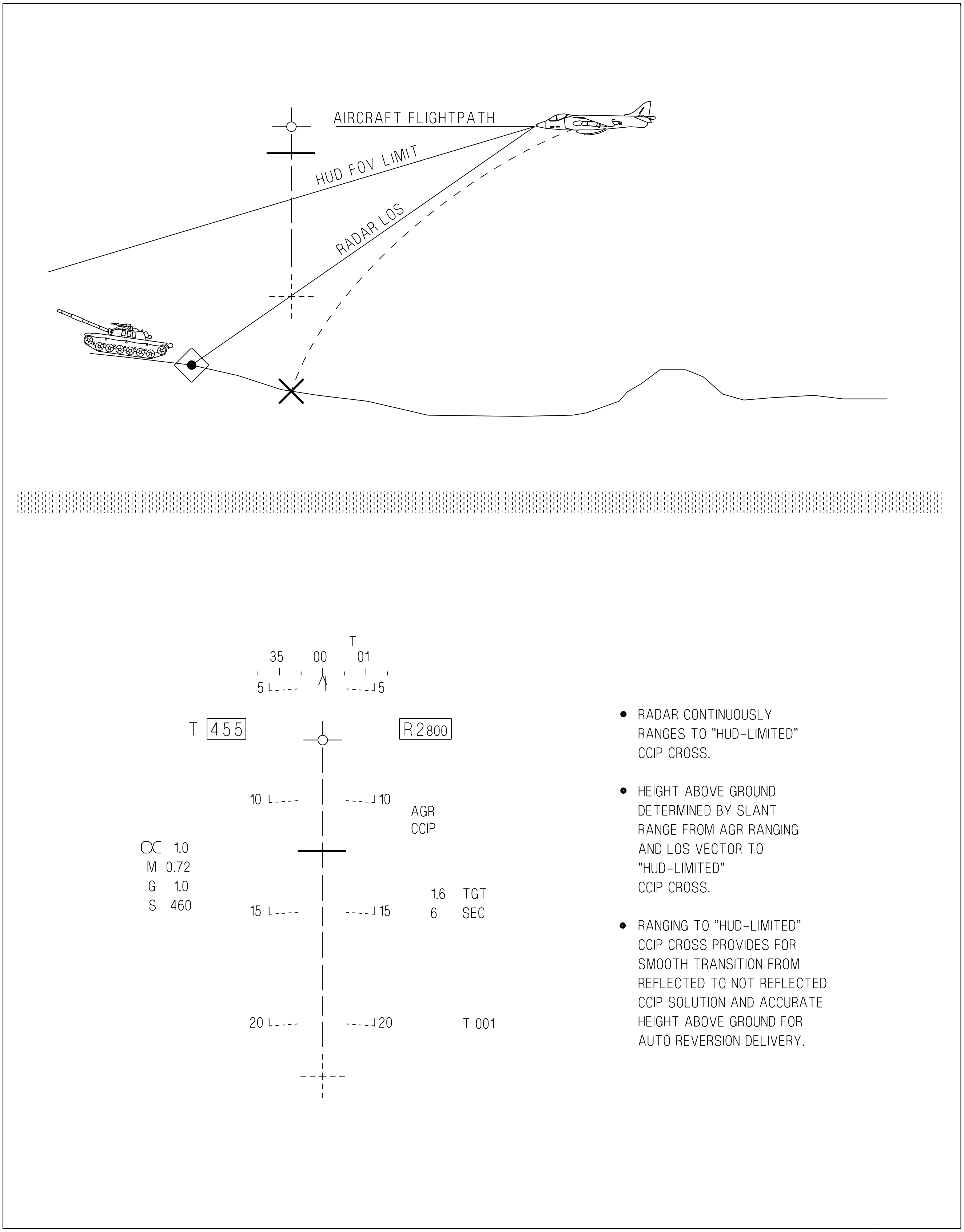
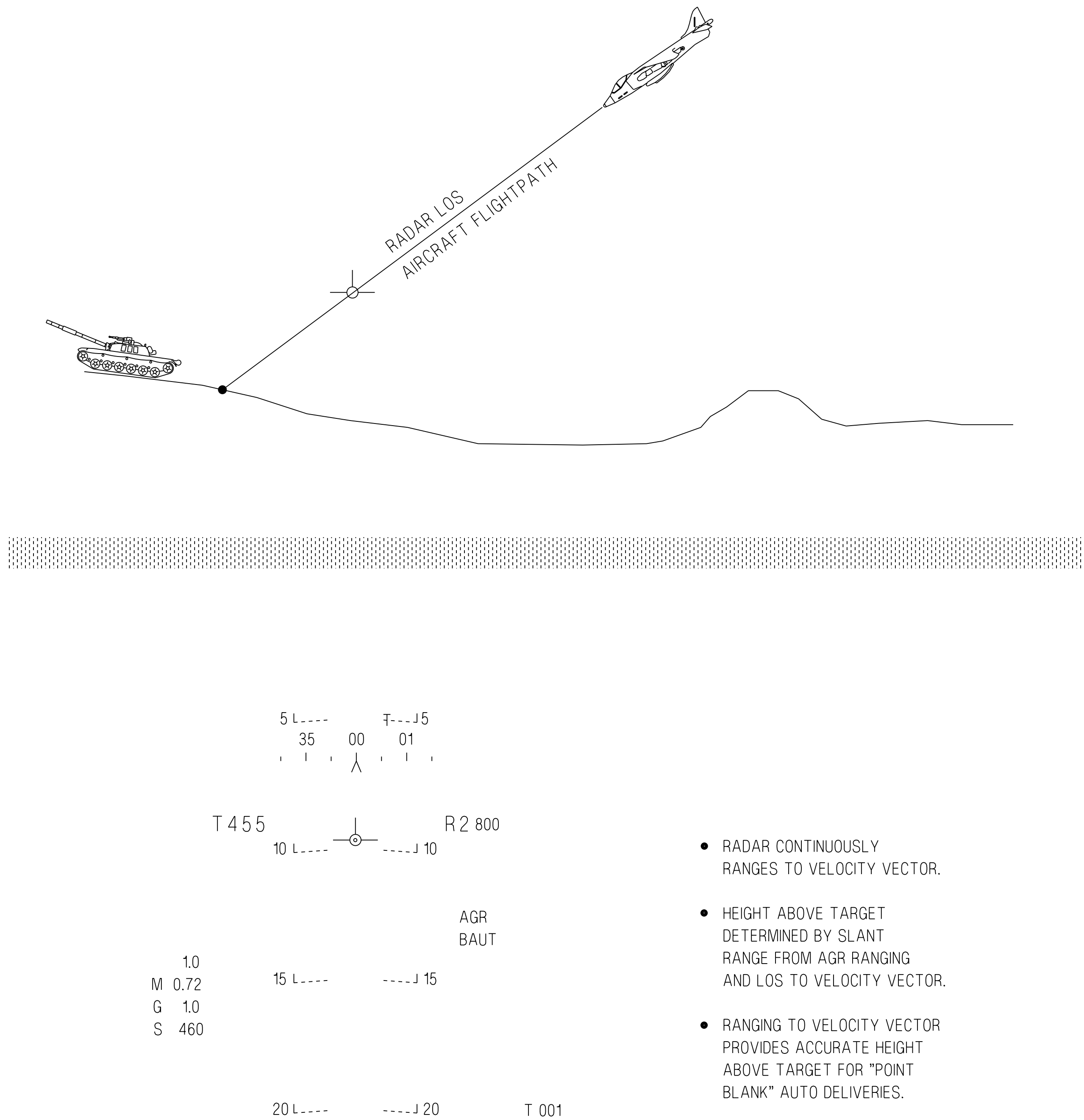


Figure 2-19. CCIP Mode, HUD-Limited, AGR Ranging



- RADAR CONTINUOUSLY RANGES TO VELOCITY VECTOR.
- HEIGHT ABOVE TARGET DETERMINED BY SLANT RANGE FROM AGR RANGING AND LOS TO VELOCITY VECTOR.
- RANGING TO VELOCITY VECTOR PROVIDES ACCURATE HEIGHT ABOVE TARGET FOR "POINT BLANK" AUTO DELIVERIES.

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Figure 2-20. Undesignated, Auto Mode, AGR Ranging

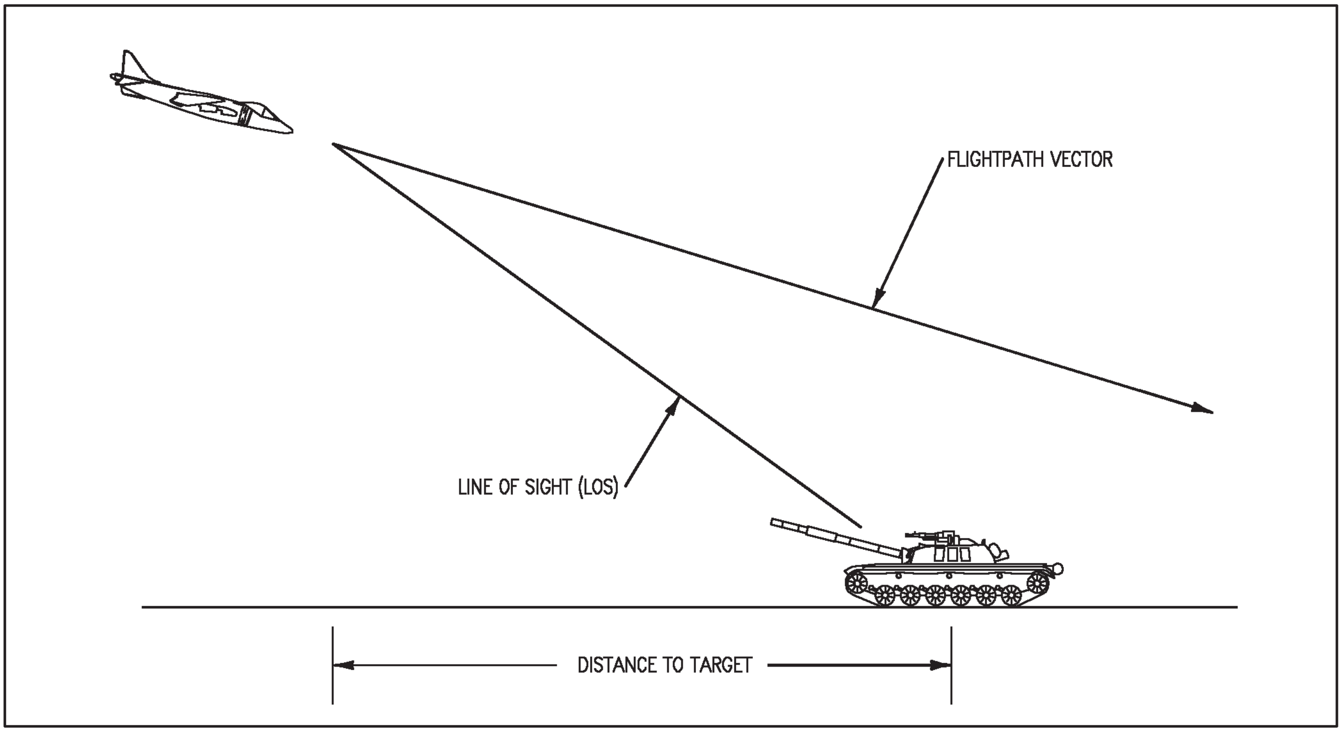

Figure 2-21. HUD TD LOS Ranging

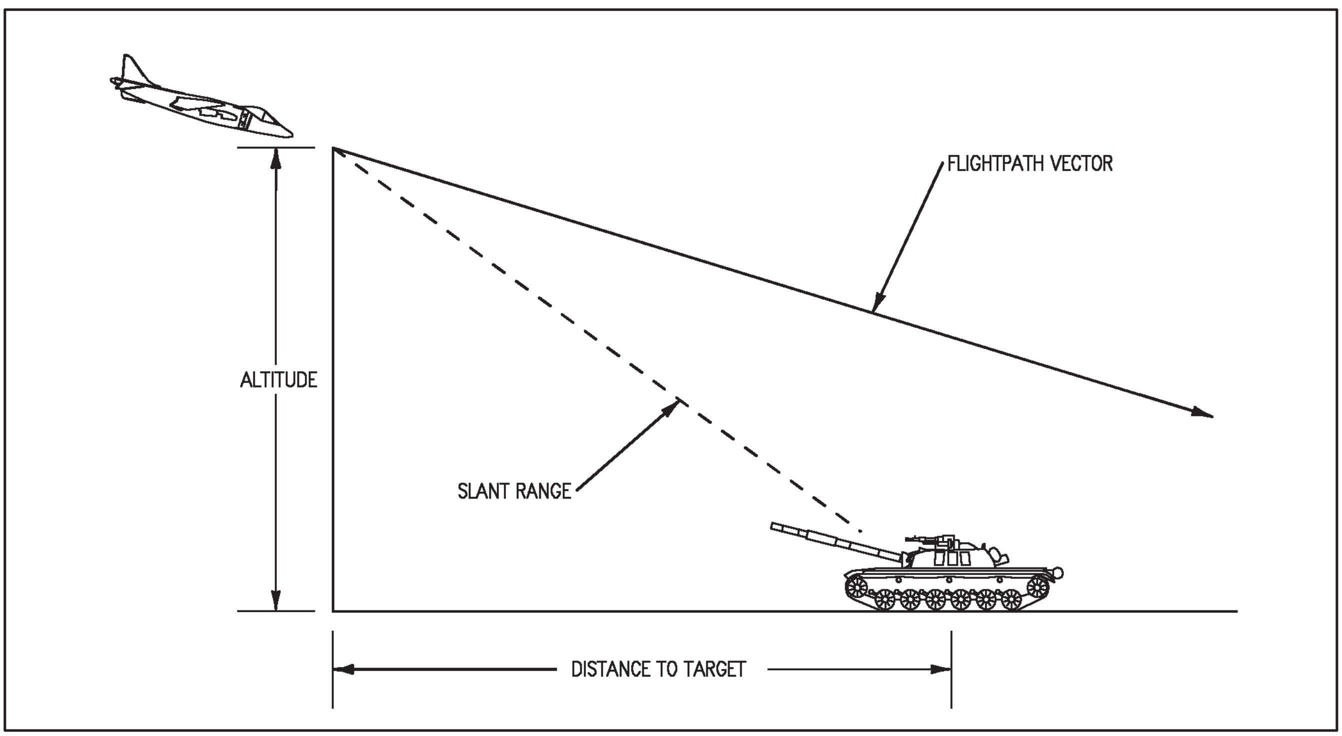

Figure 2-22. Altitude Determination

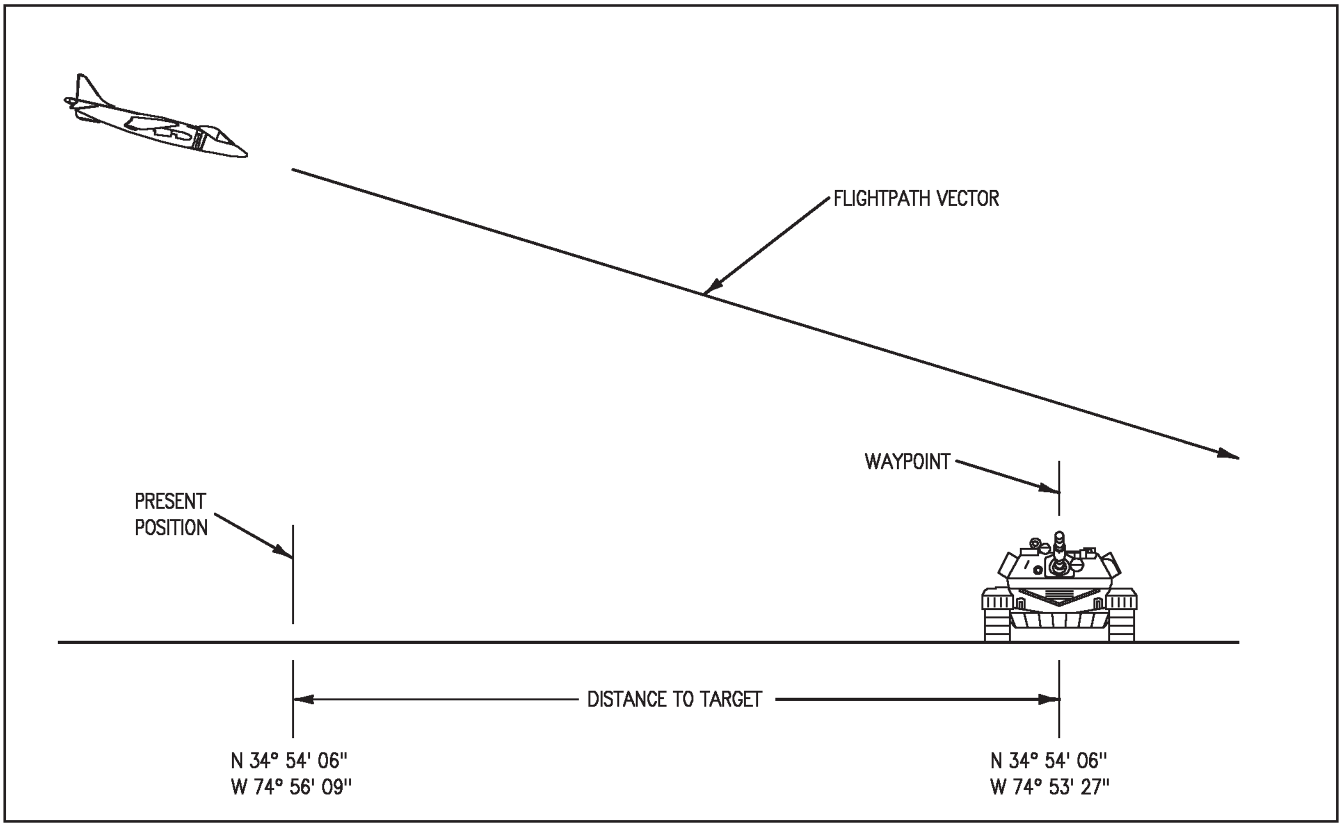

Figure 2-23. Coordinate Ranging

computing range and bearing from current aircraft position to the initial (fixed) target position. When the slant range to the target is less than 15,000 feet (2.5 nm), the sensor control module continues range estimation by computing aircraft movement in the horizontal plane and subtracting these values from the last computed target ranges. This method is also used if GPS position is not valid. The updated range information, along with other flight data, is used to compute ground stabilization rates to keep the designator locked on the target.

2.2.3.2.4 Present Position and Target Coordinate Ranging. Present position and target coordinate ranging exists for all EHSI/EHSD, TOO, and WOF designations. For example, when a waypoint or its offset is designated on the EHSI/EHSD display, the sensor control module compares the designation coordinates to the aircraft present position coordinates. The horizontal distance to the target is computed and one side of the bombing triangle is now known (Figure 2-23). The altitude is determined in the same manner as in the HUD TD LOS angle ranging process. Now two sides of the bombing triangle are known.

Slant range to the target is then computed from the two known sides of the triangle (Figure 2-24) and the data is provided to the air-to-ground module for processing. The triangle is now complete.

The process is the same for TOO and WOF, the only difference being in the methods of designation.

2.2.3.2.5 Wind Calculations During Ranging. Regardless of which ranging method is in use, range wind and crosswind are calculated either by using stored values or by computing relationships of inertial velocity to airmass velocity and ground track to magnetic heading or by the ARBS. The values are provided to the air-to-ground module which requires valid wind data at all times.

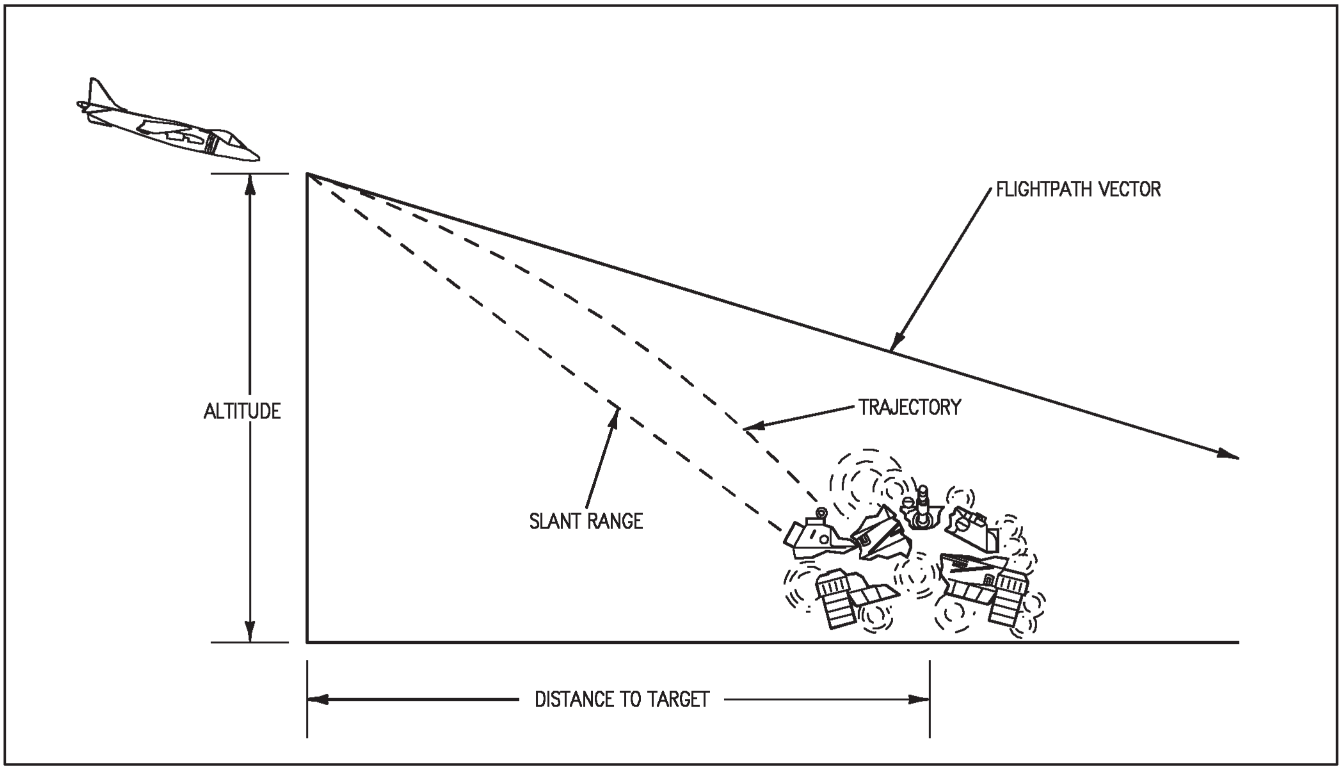

Figure 2-24. Slant Range Computation

2.2.3.3 Weapon Ballistics. Now that the flightpath vector is defined, and the altitude is determined, and the aircraft-to-target range is solved, all that remains to put the weapon on the target is to match the weapon characteristics to these vectors and range parameters. This task is the responsibility of the air-to-ground module. It must provide the system with accurate weapon trajectory, weapon impact point, and weapon release computations.

2.2.3.3.1 Weapon Trajectory Computations. Most of the data used in the trajectory computations is provided by the SMS which, in turn, receives outputs from the air-to-ground module. The trajectory of the selected weapon is computed by using Runge-Kutta ballistics coefficients (digitized ballistics). These ballistics, rack ejection velocities, transmission delays, and weapon release delays have been determined via flight testing and are preprogrammed into the weapon delivery computation store codes. These are set by the load crew and should be verified by the pilot. Weapon selection by the pilot identifies the applicable ballistic data. The MC also receives valid ambient temperature from the ADC, and automatically determines air density to adjust programmed weapon ballistics for variations from standard day temperature. The weapon initial position, airspeed, and drag conditions are analyzed by the A/G module to determine final weapon position, airspeed, and altitude. If the final weapon altitude does not coincide with target altitude, the analysis process is readjusted and another solution is generated.

2.2.3.3.2 Weapons Release Computations. Weapon release processing coincides with the pilot selected weapon delivery program and is provided by the SMS. From the trajectory and impact point computations, weapon release occurs when the wind-corrected weapon fall range equals the designated target range.

In the CCIP delivery mode, weapon release messages are sent to the SMS when the bomb pickle button is pressed.

In the AUTO delivery mode, a miss distance is computed by subtracting the weapon down range travel from the designated target range. This distance minus half the stick length is divided by the miss rate to give instantaneous time-to-go to release. The time-to-go is then put into the air-to-ground module monitor clock and updated in cycles. When the clock times-out, a weapon release message is sent to the SMS if the bomb pickle button has been pressed.

2.2.3.4 Data Presentation. The final task in solving the weapons delivery problem is data presentation. In accomplishing this task, the HUD and Multipurpose Display modules provide situation symbology that assist the pilot in delivering the weapon on target. The steering mode used depends on the delivery mode selected by the pilot.

Figure 2-25 illustrates the specific functions being provided to the MC for use in the computed weapon delivery problem. The external sources (i.e. ADC, INS, SMS, ARBS, etc.) have their outputs individually defined as well as that portion of the weapon delivery problem requiring the input for solution (indented beneath output shown on Figure 2-25). The MC conversely defines the problem segments and has the respective inputs used for their solution (indented and beneath). Figure 2-25 sheet 1 depicts the INS delivery mode; sheet 2 depicts the ARBS mode; sheet 3 the radar AGR sensor mode; and sheet 4 addresses the common MC calculations required for all computed deliveries. It is important for the pilot to understand the solution and its effect on the outcome, especially in the area of height above target and altitude management.

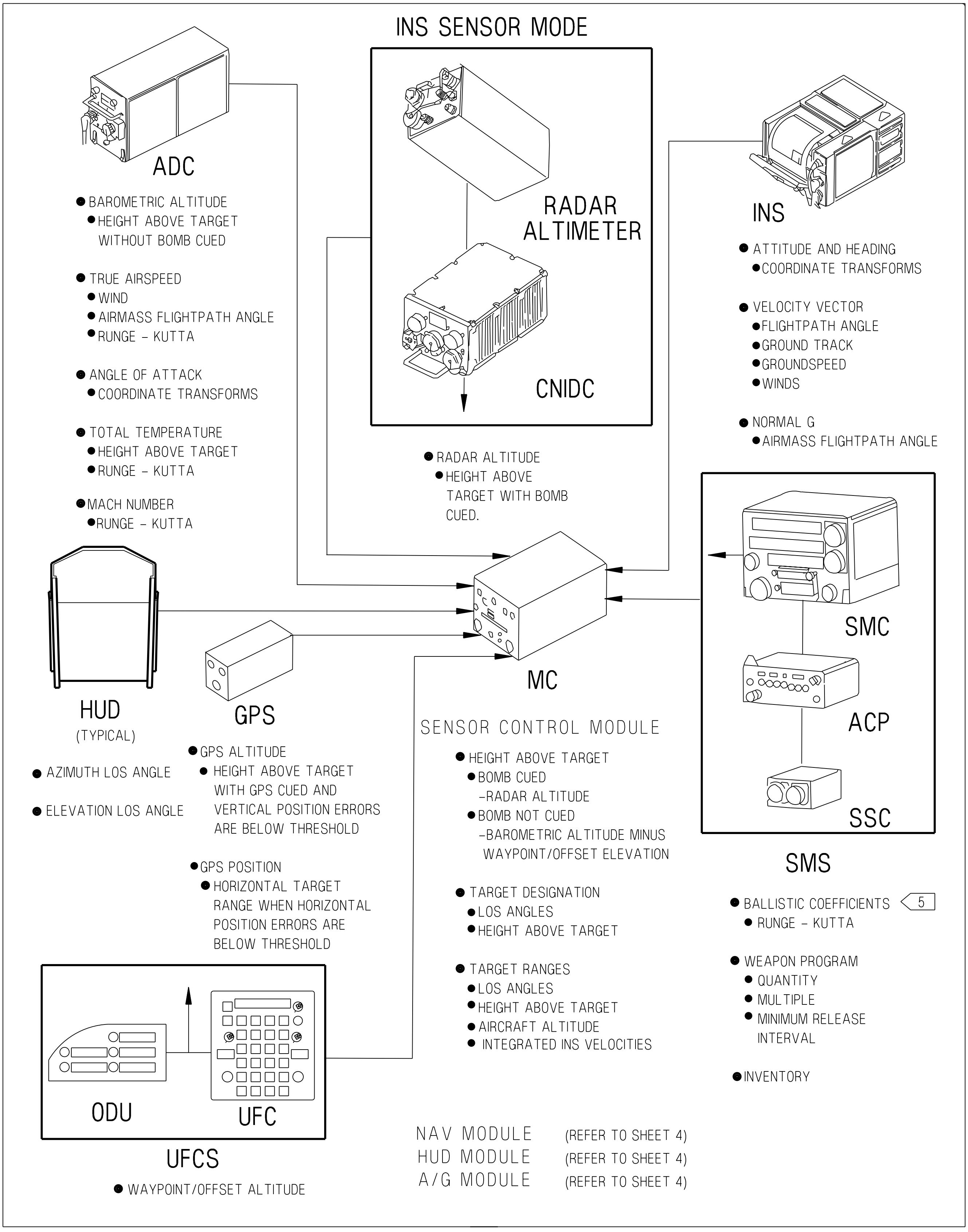

Figure 2-25. Computer Weapon Delivery Block Diagram (Sheet 1 of 4)

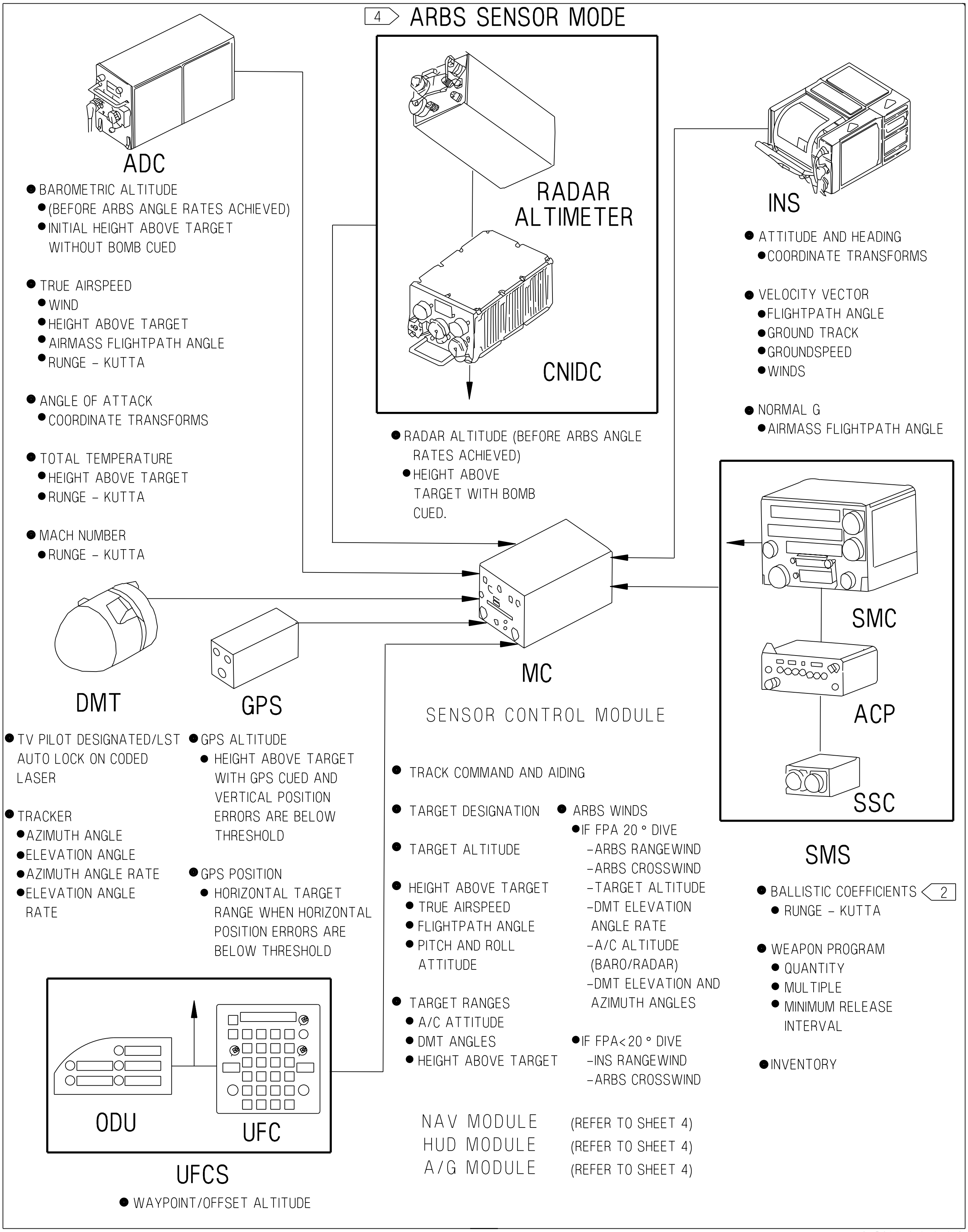

Figure 2-25. Computer Weapon Delivery Block Diagram (Sheet 2 of 4)

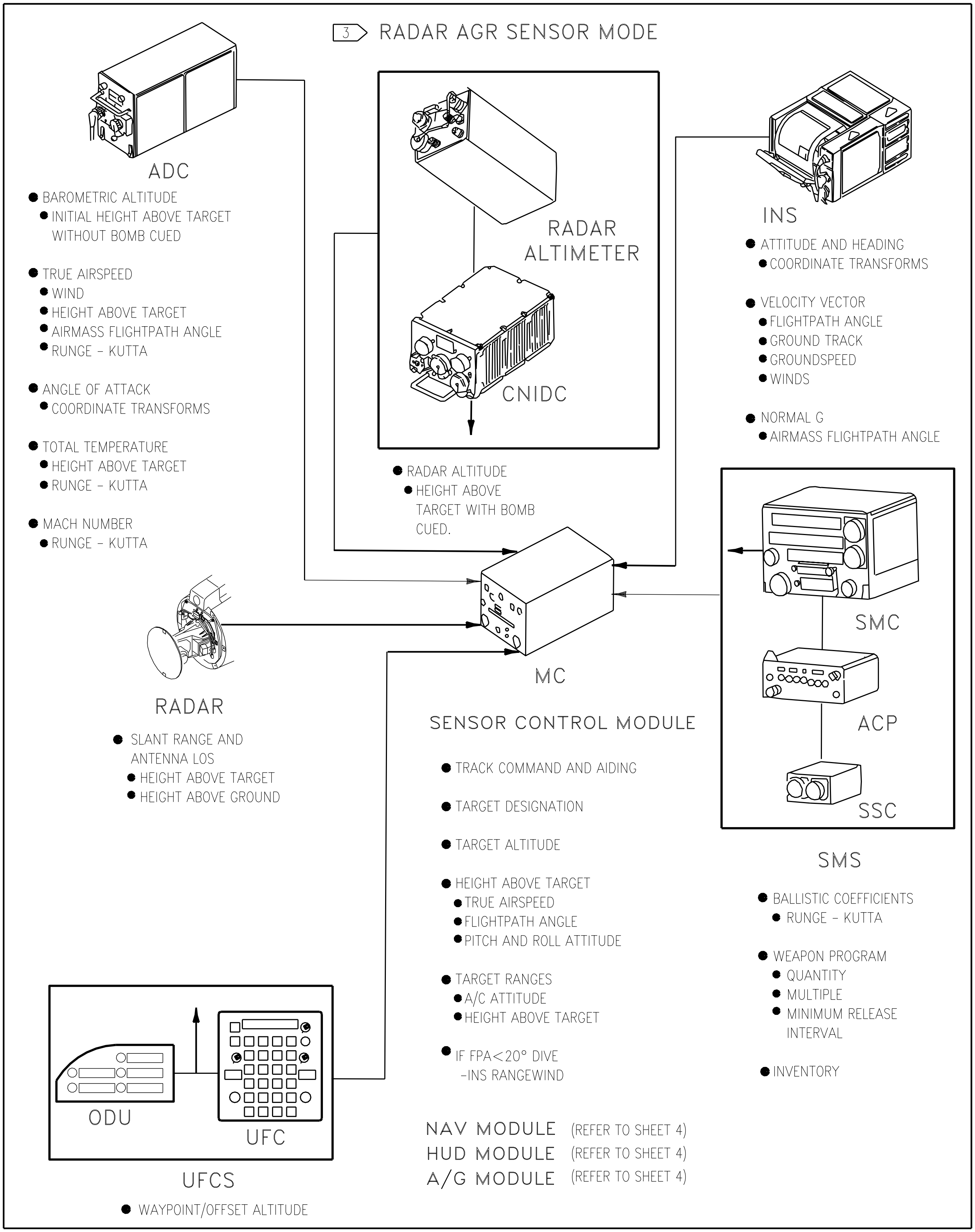

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Figure 2-25. Computer Weapon Delivery Block Diagram (Sheet 3 of 4)

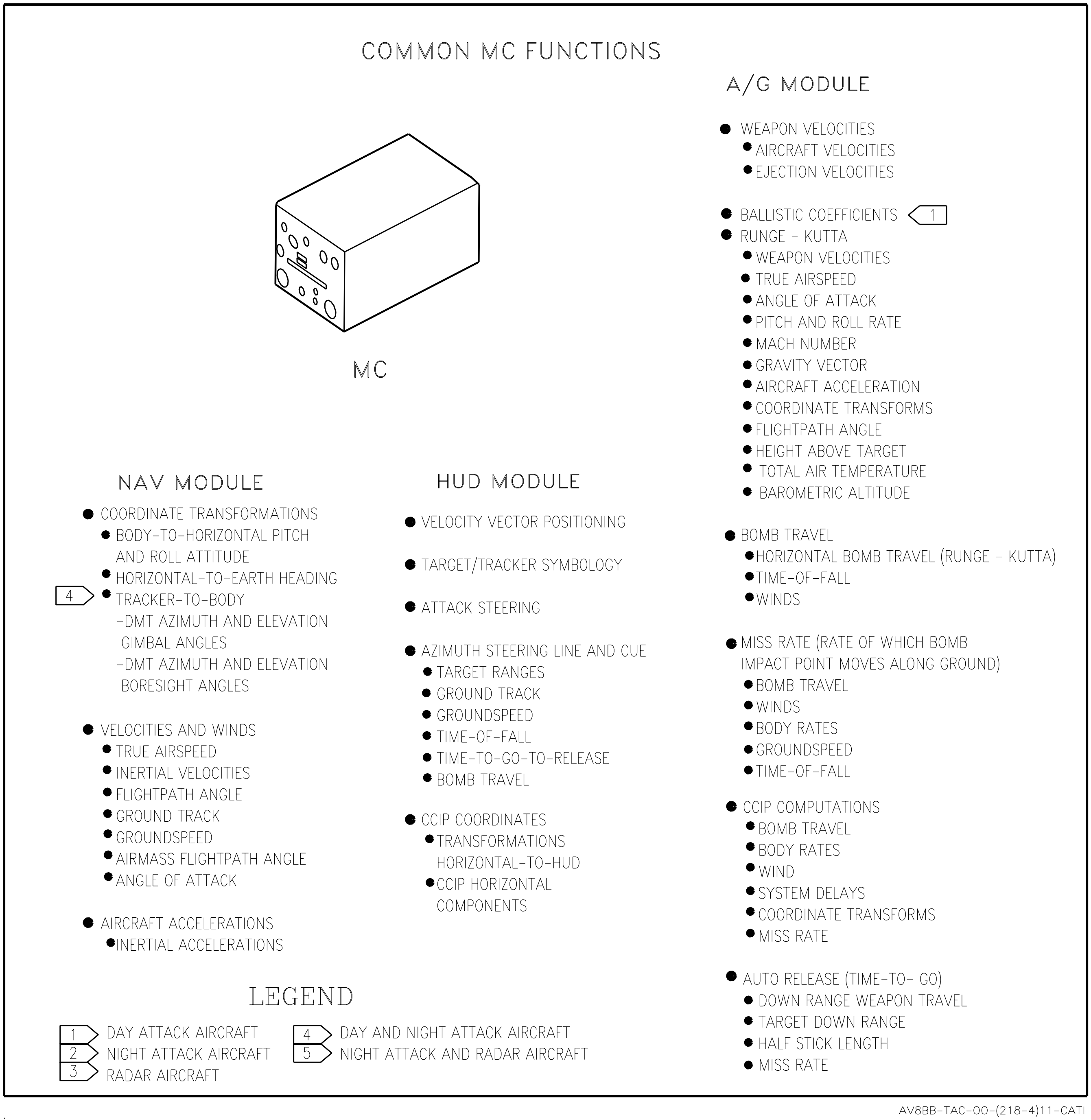

Figure 2-25. Computer Weapon Delivery Block Diagram (Sheet 4 of 4)

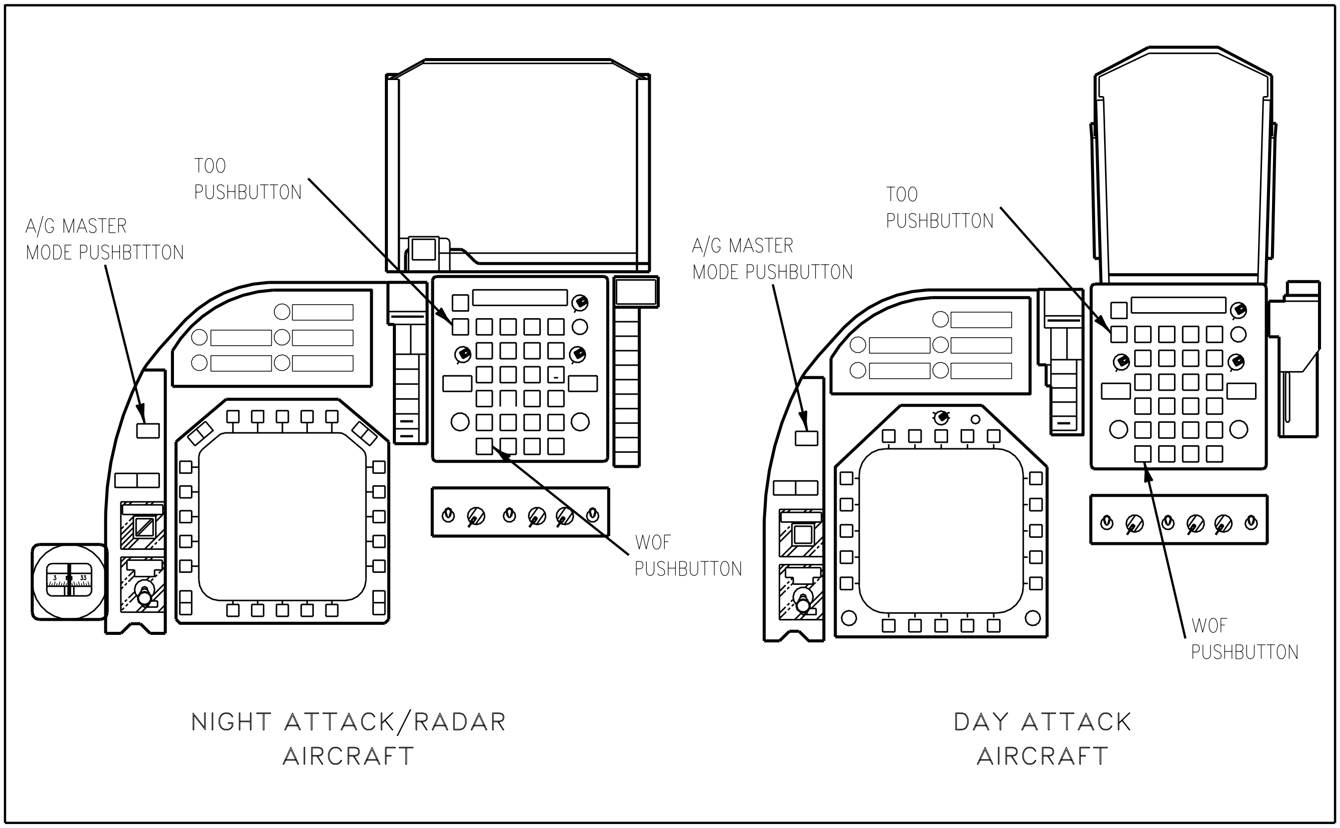

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Figure 2-26. A/G Master Mode Selection

2.3 AIR-TO-SURFACE ATTACK

In the air-to-surface attack phase, the pilot is provided with six A/G delivery modes, a weapon delivery program for each of up to four weapon types loaded on the aircraft, automatic release servicing, and a hot gun capability. Aiming references are provided for bomb delivery, launching rockets, and firing guns. An AGM (Maverick or Sidearm) delivery mode is also provided. On Day and Night Attack aircraft a computed LOFT delivery mode is provided as a submode of the AUTO delivery mode.

2.3.1 A/G Master Mode. The pilot enters the A/G master mode by pressing the A/G master mode pushbutton on the main instrument panel as shown in Figure 2-26. When pressed, this pushbutton is illuminated indicating A/G master mode selection. It is also automatically initiated with either waypoint overfly (WOF) or target-of-opportunity (TOO) pushbutton actuation on the UFC. Activation of the A/G mode initializes the last selected weapon and weapon program for delivery, provides attack symbology on the HUD, and starts the HUD video recorder. Whichever delivery mode is utilized, computed or noncomputed, the A/G master mode must be activated to deliver a weapon.

2.3.2 Weapon Select. Weapons are selected in the A/G master mode via the DDI or ACP. See Figure 2-27. On the DDI, weapon options are displayed next to the five option buttons located on top of the display (i.e., legends 82L, 83, GUN, etc.). The options are available in the A/G master mode when the DDI stores, EHSI/EHSD, ECM, Maverick, DMT, radar terrain avoidance, or a radar track mode display is selected. When selected the option legend is boxed indicating selection. Also, on the ACP the SEL (select) legend appears in the applicable station window. The ACP can be used to select weapons in all master modes. In the A/G master mode, ACP

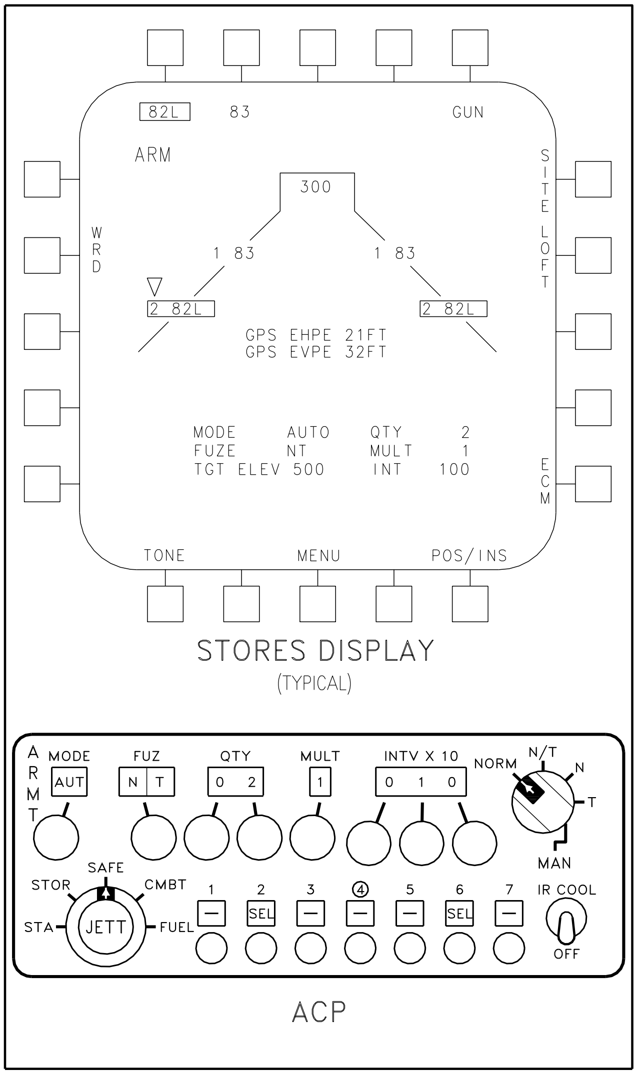
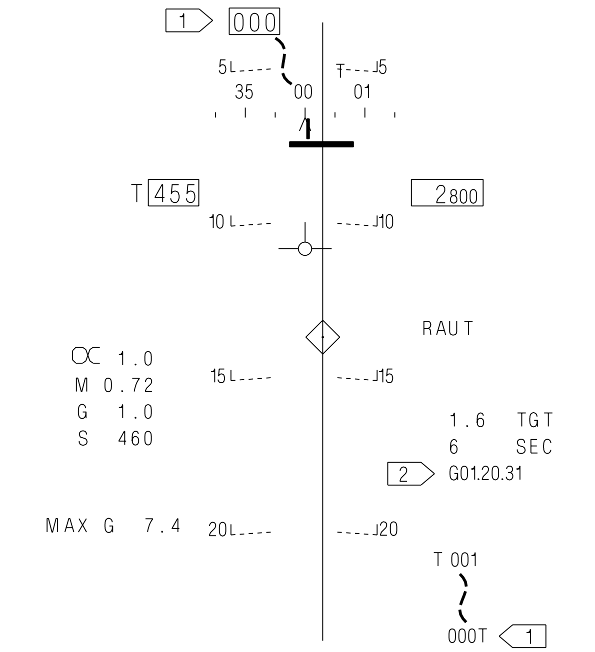


Figure 2-27. Weapon Selection



- WITH MASTER ARM OFF, THE AUTO, LOFT, DSL, CCIP, RKT, GUN, DSP OR AGM LEGEND FLASHES.
- WITH MASTER ARM OFF, THE RAUT, BAUT, GAUT, RCIP, GCIP, OR BCIP LEGEND APPEARS AND FLASHES IF AUTO OR CCIP DELIVERY MODES ARE SELECTED.

LEGEND

1 DAY ATTACK AIRCRAFT

2 DAY/NIGHT ATTACK AIRCRAFT

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Figure 2-28. Weapon Select Cue

selection is indicated on the DDI if one of the above mentioned displays is selected. Selecting a weapon enables attack symbology plus delivery mode or weapon select legends on the HUD (i.e., AUTO, CCIP, RKT, GUN, etc.). See Figure 2-28.

2.3.3 Release Ready. Attack symbology is displayed on the HUD only if an air-to-surface weapon has been selected by the pilot. If weapon selection has not been made during the flight (weapon selections are not stored between flights) or if an SMCS programming fault (fuzing SAFE) is detected, attack symbology is not displayed on the HUD and weapon delivery is inhibited. This is indicated by the weapon inhibit cue, the four slant lines (cross hatch, barber pole) across the center of the HUD FOV. See Figure 2-29.

A flashing weapon inhibit cue denotes a fuselage gun not clear condition if the fuselage gun is the primary weapon or it is in a “hot gun” situation and the primary weapon is not inhibited. Gunfire is not inhibited when the flashing weapon cue is displayed.

A flashing WPN FAIL legend appears above the ARM or SAFE legend on the DDI stores display when an SMS function failure or a fuselage gun function failure is detected. The WPN FAIL legend continues to flash until the pilot selects the SMSFF (SMS function fail) option on the BIT display to determine the exact failure. If the SMSFF display indicates a WEAPON PROGRAM FAIL for all pylon stations this is an

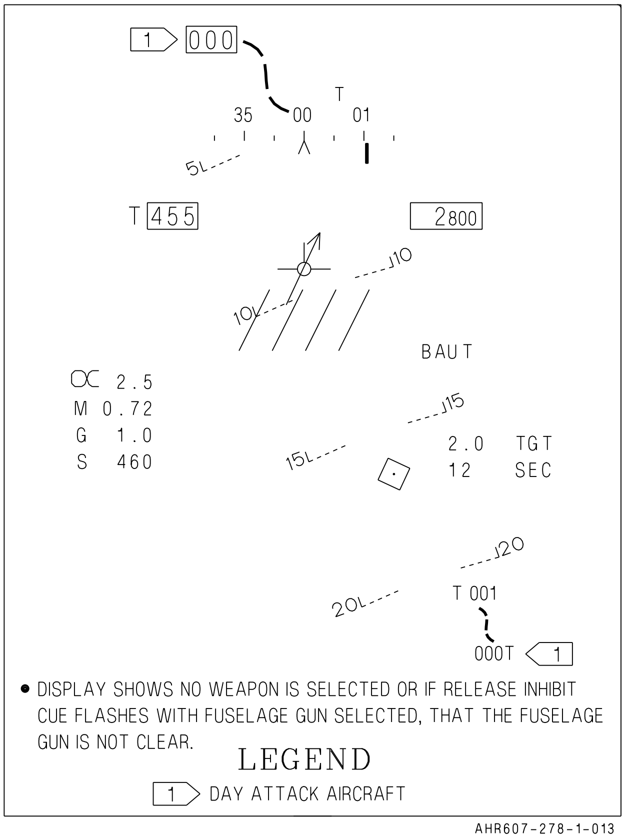


Figure 2-29. Weapon Inhibit Cue

unsafe condition and master ARM should not be selected. The WPN FAIL legend will not be displayed again until another function failure occurs. The WPN FAIL legend appears on any display on which the A/G weapon options are displayed.

If any fuselage gun function failure is detected, the appropriate legend appears under the GUN pushbutton option. On Radar aircraft a NOT CLEAR legend is displayed and on Day and Night Attack aircraft one of three legends can be displayed in the following order of precedence: MISFIRE, LIMITED, and NOT CLEAR. The SMSFF readout confirms the failure.

2.3.4 Master Arm. The presence of attack symbology on the HUD indicates A/G ready status to the pilot. This means that weapon system set-up tasks have been completed for the weapon selected and no failures have been detected. The pilots entire attention can then be directed toward steering and acquiring the target, tracking and releasing the weapon. The pilot is

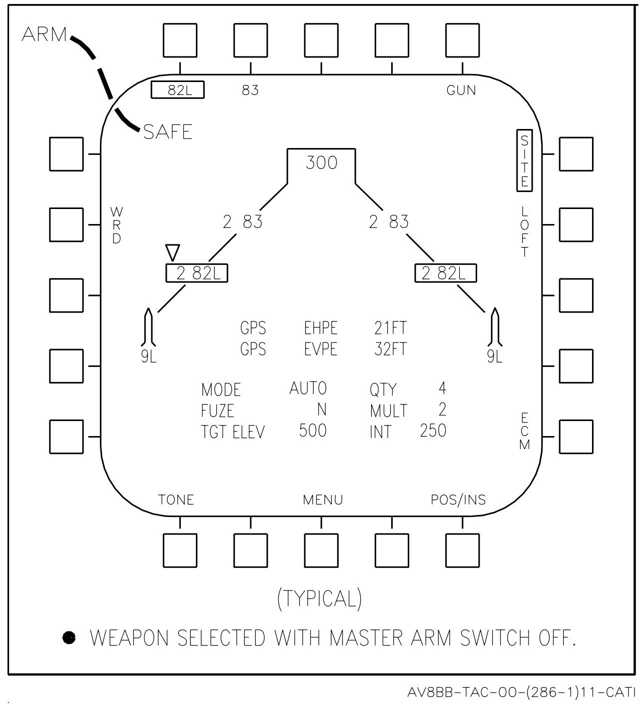


Figure 2-30. ARM/SAFE Cue

required only to select master ARM to enable weapon release. Master arm OFF is indicated by the flashing delivery mode legend (i.e., RAUT) or the weapon selection legend (i.e., LMAV) on the HUD.

A SAFE legend also appears in the upper left corner of the DDI when release is inhibited by the master arm switch as shown in Figure 2-30. Placing the master arm switch to ARM enables weapon release and the SAFE legend on the DDI is replaced by an ARM legend.

CAUTION

When a flashing WPN FAIL legend appears on the DDI, the SMSFF option should be selected. If the SMSFF display indicates WEAPON PROGRAM FAIL for all pylon stations, the master arm switch should remain in the OFF (SAFE) position. With a WPN FAIL indication, selection of master ARM may cause inadvertent release of stores. If any JETTISON FAIL indication is displayed, external stores may be jettisoned with weight-off-wheels (i.e., upon takeoff).

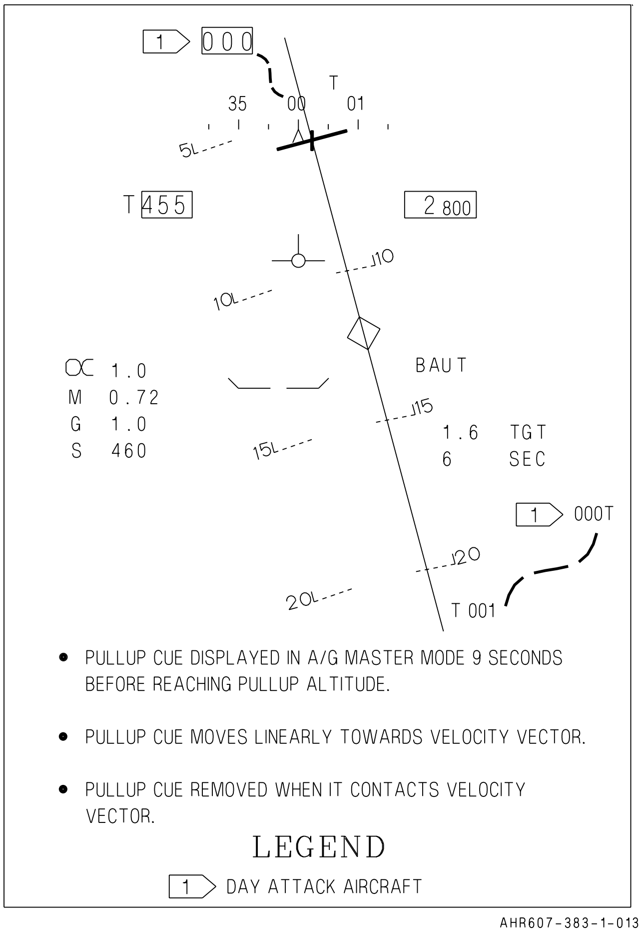


Figure 2-31. Pullup Cue

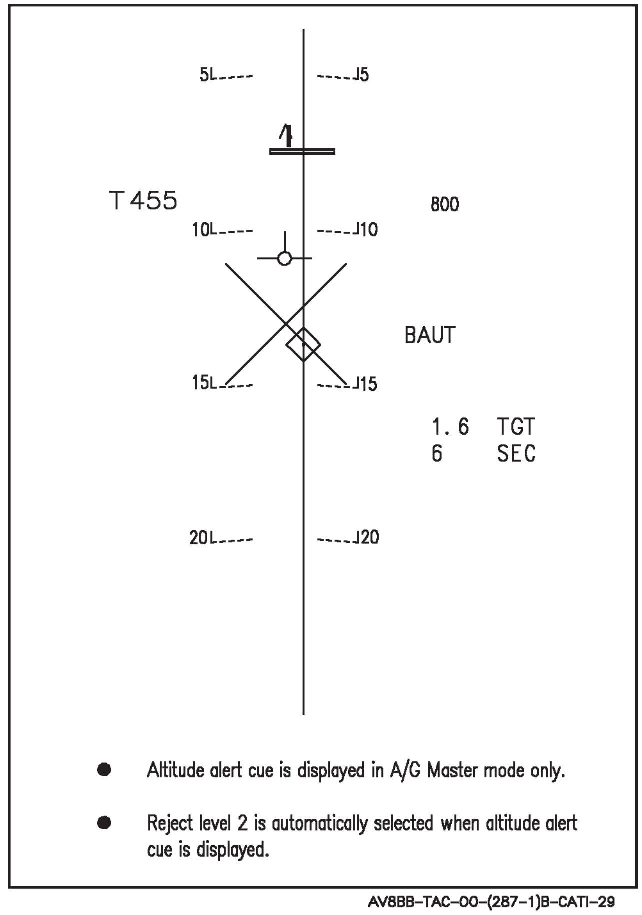


Figure 2-32. Break X Cue

2.3.5 True Airspeed. In the A/G master mode, true airspeed (TAS) is displayed instead of calibrated airspeed on the HUD as in all other master modes. This is indicated by the "T" legend preceding the airspeed box. The system automatically reverts to calibrated airspeed with loss of true airspeed. True airspeed is displayed in A/G since all air-to-ground computations are based on TAS. Also removed from the HUD in A/G is vertical velocity (FPM) data.

2.3.6 Pullup Cue. The pullup cue is enabled in the A/G mode when the PUC option is cued on the ODU, and the conditions for display of the pullup cue have been met. The pullup cue is displayed on the HUD 5° below the velocity vector 9 seconds prior to reaching the pullup altitude previously entered on the UFC (Figure 2-31). The cue starts to move up with 6 seconds to go, and when it approaches the velocity vector the pilot must apply 4g's to be able to bottom out at no lower than the inserted barometric altitude.

2.3.7 Break X. The altitude alert cue (break X) is also enabled in the A/G mode when the flightpath is greater than 5° down, and certain vertical velocity, airspeed, and altitude limits are exceeded (Figure 2-32). The pilot should execute an immediate 4g pullup when the altitude alert cue is displayed. The break X is based on radar altitude, if available. If the radar altitude is not available, the system utilizes the selected waypoint or designated elevation.

WARNING

If a TOO or WOF is performed and the radar altitude is not valid, the break X (then being based on barometric altitude minus pilot entered waypoint or waypoint offset elevation) may be in error.

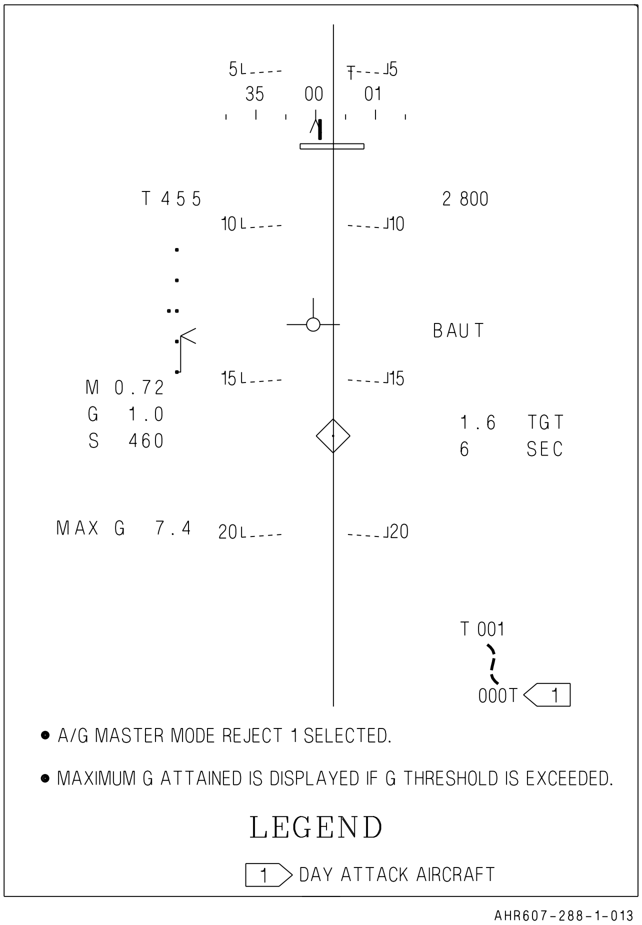


Figure 2-33. A/G HUD Reject 1 Symbology

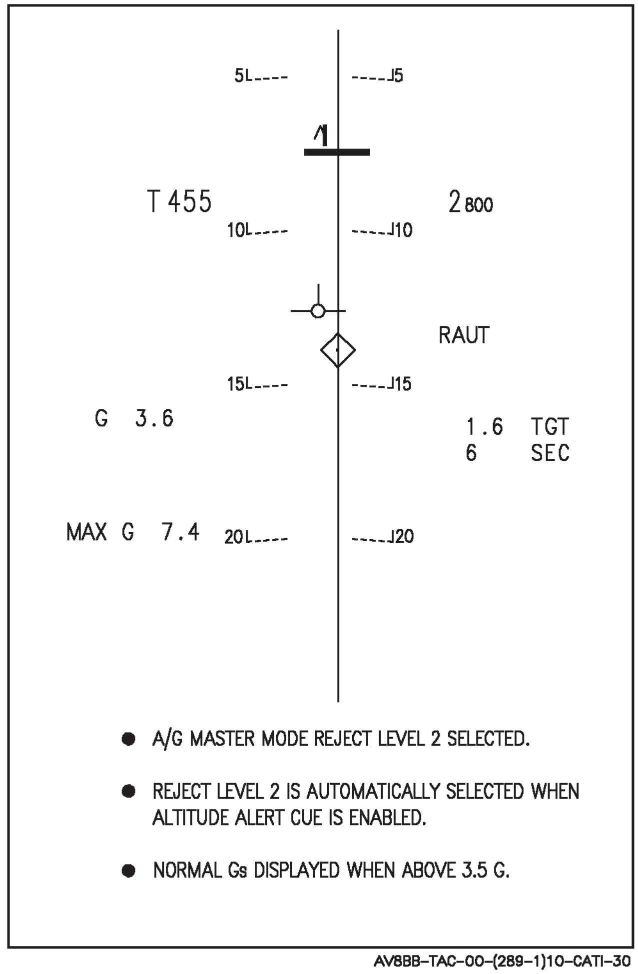


Figure 2-34. A/G HUD Reject 2 Symbology

2.3.8 HUD Reject Levels. Reject level 1 (REJ 1) in A/G removes the airspeed, altitude, and heading boxes (Figure 2-33). The large heading numerics are also removed. Reject 1 also adds the AOA analog scale and removes the digital AOA data.

Selecting reject 2 (REJ 2) removes not only the airspeed, heading, and altitude boxes as in reject 1, but also removes ground speed and Mach. In addition, the heading tape and the auxiliary heading are removed on the Day Attack aircraft. See Figure 2-34. Only the heading caret and bug (with steering or designated point) remain. Digital AOA is again removed but analog AOA is not added. Normal g's are not displayed unless they exceed 3.5g. Reject level 2 is automatically selected when the altitude alert cue is enabled. In both reject levels, maximum g is displayed if the threshold (4.5g) is exceeded.

2.3.9 Release Tone. At weapon release both radios transmit a 1020 Hz tone for 250 milliseconds. This release signal is heard as a sidetone in the pilot's headset. Release tone volume depends on the AUX volume setting on the ACNIP. The pilot can disable tone transmission by deselecting the TONE option on the DDI stores display. Tone selection is indicated by the boxed TONE legend. Tone transmission (if selected) is also disabled if EMCON is selected on the UFC. The TONE legend on the DDI remains boxed and the tone is automatically re-enabled with EMCON deselection.

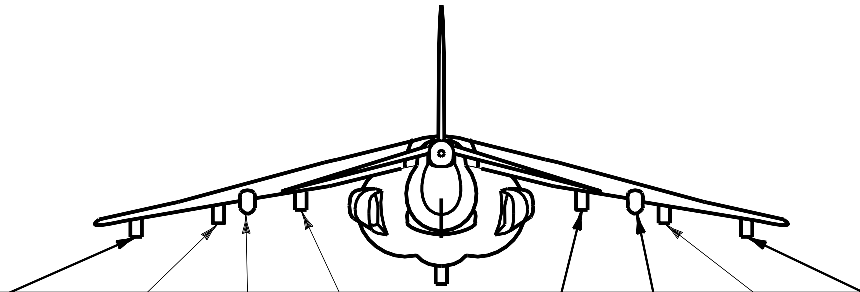
2.3.10 Release Sequence. To avoid excessive asymmetric distribution of wing pylon stores, the SMC automatically selects the priority weapon station for weapon release in the AUTO, CCIP, and DSL mode and identifies it on the stores or Maverick video display. If no ITERs are being used for the selected weapon, the pilot can override the release sequences via the station step option pushbutton on the DDI stores display. The sequences used by the SMC to select weapons for release are shown in Figure 2-35.

NOTE

The charts reflect weapon carriage capability, not authorization for actual loadings.

Outrigger pylons (stations 1A and 7A) are not authorized for carriage.

ARMAMENT STATIONS – AV-8B



WEAPON	NO. ITERS ABOARD	1	2	1A	3	4	5	7A	6	7
Mk76/ITER Mk81/STD Mk81/MAU-94 Mk81/Mk14 LD Mk82/STD Mk82/MAU-93 Mk82/BSU-33 Mk82/Mk15 LD Mk82/BSU-86 LD BDU-33/ITER GBU-12	NONE	1	3	–	5	–	6	–	4	2
	2	1	3	–	7 ●–● 9 5	–	8 ●–● 10 6	–	4	2
	2	1	7 ●–● 9 3	–	5	–	6	–	8 ●–● 10 4	2
WEAPON/STORE CODES 03 14 78 04 15 79 06 16LD 80 07LD 17LD 93 08 18 94 09 25 97LD 10 27 98LD 11 77	4	1	9 ●–● 13 5	–	7 ●–● 11 3	–	10 ●–● 14 4	–	8 ●–● 12 6	2
Mk20 Mk77 MOD4, MOD5	NONE	1	5	–	3	–	4	–	6	2
	2	1	5	–	7 ●–● 9 3	–	8 ●–● 10 4	–	6	2
WEAPON/STORE CODES 37 38 40	2	1	6 ●–● 8	–	3	–	4	–	5 ●–● 7	2
	4	1	4 ●–● 11	–	7 ●–● 9 6	–	5 ●–● 12 3	–	8 ●–● 10	2
Mk83/STD Mk83/BSU-85 LD GBU-16	NONE	–	1	–	3	–	4	–	2	–
WEAPON/STORE CODES 20 23 63 66 21 30 64 67 22 62 65	2	–	1	–	5 ●–● 7 3	–	6 ●–● 8 4	–	2	–

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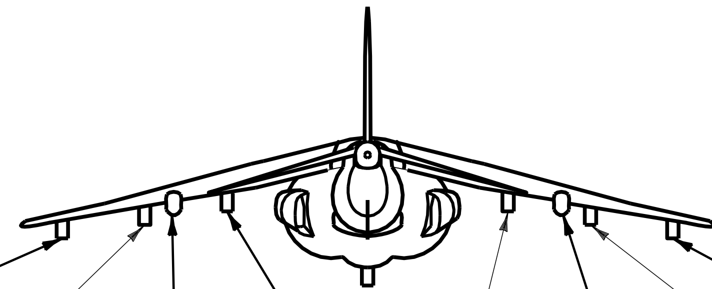
Figure 2-35. Release Sequence (Sheet 1 of 3)

ARMAMENT STATIONS – AV-8B



WEAPON	NO. ITERS ABOARD	1	2	1A	3	4	5	7A	6	7
MAVERICK WEAPON/STORE CODES 54 55	NONE	–	1	–	3	–	4	–	2	–
ROCKETS WEAPON/STORE CODES 41 81 86 42 82 87 43 83 88 44 84 89 45 85 90 46	NONE	–	1	–	3	–	4	–	2	–
	2	–	1	–	5 7 3	–	6 8 4	–	2	–
	2	–	3 5	–	1	–	2	–	4 6	–
	4	–	3 7	–	5 9 1	–	6 10 2	–	4 8	–
DISPENSERS WEAPON/STORE CODES 72	NONE	1	3	–	–	–	–	–	4	2
	2	1	3 5	–	–	–	–	–	4 6	2
Mk40/MAU-91 HD WEAPON/STORE CODES 68 69	4	–	3	–	1	–	4	–	2	–
CBU-78 Mk36/Mk15 HD Mk36/BSU-86 HD Mk81/Mk14 HD Mk82/Mk15 HD Mk82/BSU-86 HD Mk106/ITER BDU-48/ITER WEAPON/STORE CODES 05 17HD 74 07HD 26 75 12 28 95 13 33 96 16HD 60 97HD 61 98HD	NONE	1	5	–	3	–	4	–	6	2
	2	1	5	–	7 3	–	8 4	–	6	2
	2	1	8 10 5	–	3	–	4	–	7 9 6	2
	4	3	7 11 5	–	9 1	–	8 6	–	10 12 2	4

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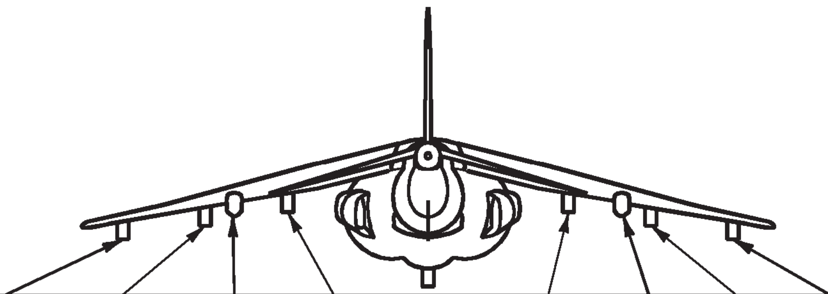
Figure 2-35. Release Sequence (Sheet 2 of 3)

ARMAMENT STATIONS – AV-8B



WEAPON	NO. ITERS ABOARD	1	2	1A	3	4	5	7A	6	7
SIDEWINDER SIDEARM WEAPON/STORE CODES 51 59 53	—	1	3	—	—	—	—	—	4	2

NOTES

1. WEAPONS ARE RELEASED IN THE SEQUENCE BENEATH THE LIST OF ARMAMENT STATIONS. THE NEXT WEAPON LOCATION IN THE SEQUENCE IS SKIPPED IF THERE IS NO SELECTED WEAPON ON THAT STATION.

2. WEAPONS/STORES ABOARD STATIONS 1 AND 7 INHIBIT RELEASE OF WEAPONS/STORES FROM THE OUTBOARD ITER SHOULDER ON STATIONS 2 AND 6.

3. FOR DISPENSERS WHEN MULTIPLE SELECTED IS 2 OR LESS, STATIONS 1 AND 7 WILL BE EMPTIED BEFORE SEQUENCING TO STATIONS 2 AND 6.

4. FOR ROCKETS WHEN THE MULTIPLE SELECTED IS 2 OR LESS, STATIONS 2 AND 6 WILL BE EMPTIED BEFORE SEQUENCING TO STATIONS 3 AND 5.

5. RELEASE PULSES ARE INHIBITED FROM STATION 4 IN AUTO, CCIP, AND DSL RELEASE MODES. ANY STORE OTHER THAN AN/ALQ-164 DEFENSIVE ELECTRONIC COUNTERMEASURES POD WILL CAUSE AN UNRESOLVEABLE LOAD FAULT TO BE DISPLAYED ON THE STORES PLAN FORM.

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Figure 2-35. Release Sequence (Sheet 3 of 3)

2.4 TARGET DESIGNATION

Designation is the action taken to identify the location of the target or offset to the weapon system. The weapon system acquires and maintains the target/offset position for weapon delivery computations. Designation is required in the AUTO delivery mode; it aids in target detection for the other weapon delivery modes. Designation may be performed in either the NAV, V/STOL or A/G master modes. When a designation is performed in the NAV or V/STOL master mode, the designation status is retained when A/G is selected.

There are basically three types of designations available depending on the type aircraft (Day Attack, Night Attack, or Radar) and the source utilized to identify the target to the MC. The sources available are the INS , DMT and radar. Using these sources the system offers five primary methods of designating: (1) waypoint, waypoint offset, mark or mark offset designation on the EHSI/EHSD or DMT display utilizing pure INS data (bomb on coordinates) to designate, (2) visual designation uses INS derived data in conjunction with LOS angles from the HUD aiming symbol, (3) TV designation using the DMT, (4) LST designation using the DMT, and (5) radar designation using the radar set. Supplementing these methods are TOO (target of opportunity), WOF (waypoint overfly), CCIP (at weapon release), and CCIP to AUTO conversion (while cross is limited) designations. Target designation enables the MC to provide steering commands to the target and to compute the automatic release point in the AUTO delivery mode.

2.4.1 Waypoint and Offset Designation on EHSI/EHSD Display. If the coordinates of the target are known, the pilot can enter them as a waypoint or an offset to a waypoint. He can designate this point by calling up the particular waypoint on the EHSI/EHSD or DMT display, selecting waypoint steering, and pressing the DESG pushbutton. The EHSI/EHSD display changes as reflected in Figure 2-36.

It may be desirable to designate the target as an offset to a waypoint. The waypoint may be an easily identified landmark or the point to initiate attack. Waypoint offsets are entered in terms of bearing (degrees TRUE) and range (nm) from the associated waypoint or as UTM coordinates, and are displayed as a dashed circle on the EHSI/EHSD display. Waypoint offsets are designated in the same manner as waypoints. If there is an offset to the waypoint, the designation may be transferred to the associated offset by pressing the WO/S pushbutton. This causes the dashed waypoint offset circle to be replaced by a dashed target diamond as shown in Figure 2-37.

The pilot can also transfer a designation to an offset from a waypoint by overflying the waypoint and pressing the waypoint overfly (WOF) pushbutton on the UFC. If no waypoint offset is available, the waypoint is designated. This action automatically calls up the A/G master mode if not previously selected, displays attack symbology (if weapons selected), and enables both altitude and navigation update on the UFCS.

The designated waypoint or waypoint offset appears on the HUD as the TD diamond symbol. The steering arrow is also displayed if relative bearing exceeds 15°. The WYPT and WO/S legends are used, rather than TGT, to clearly indicate to the pilot what he may be bombing. Figure 2-38 shows offset designation after performing a WOF.

When A/G master mode is selected, the designation is automatically transferred. Time-to-go to weapon release is also displayed below the WYPT number and range legend in the AUTO mode, for the delivery mode and weapon selected. Steering arrow mechanization is the same as in the NAV master mode except it is replaced with the ASL when displayed. A/G master mode selection with a target designated is shown in Figure 2-39.

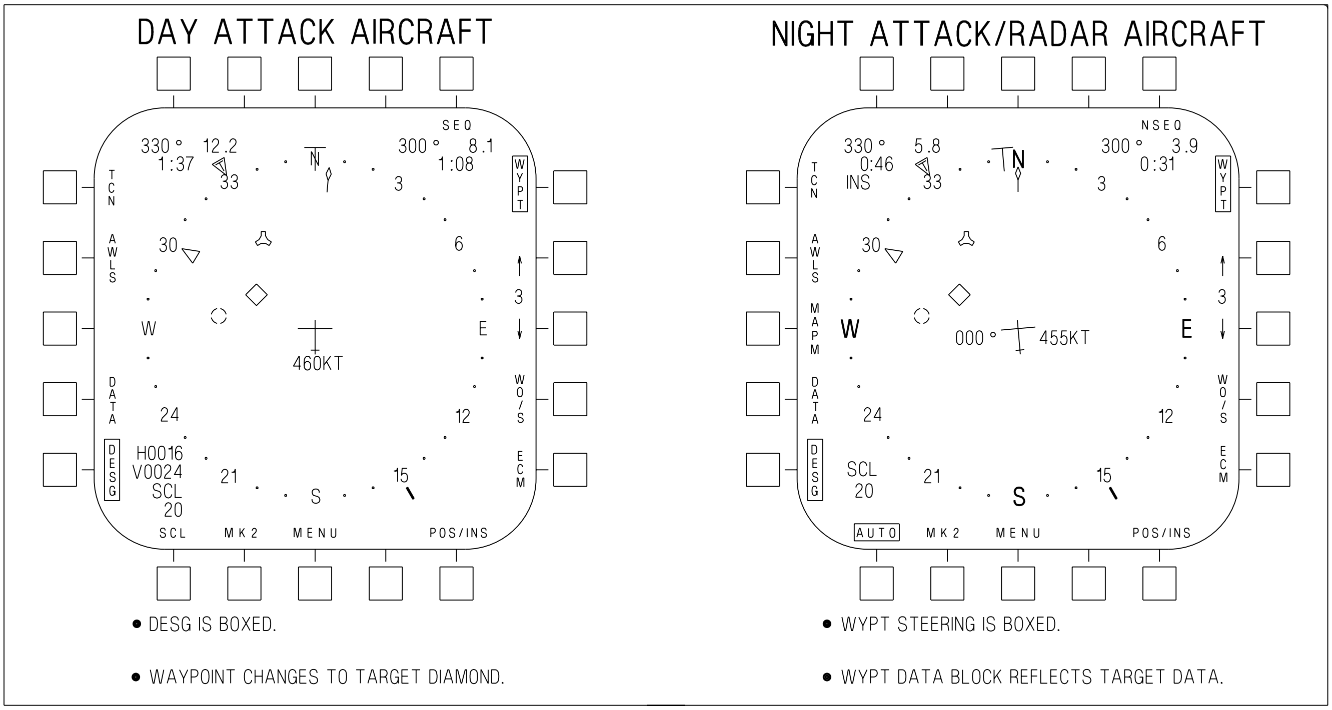

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Figure 2-36. EHSI/EHSD Waypoint Designation

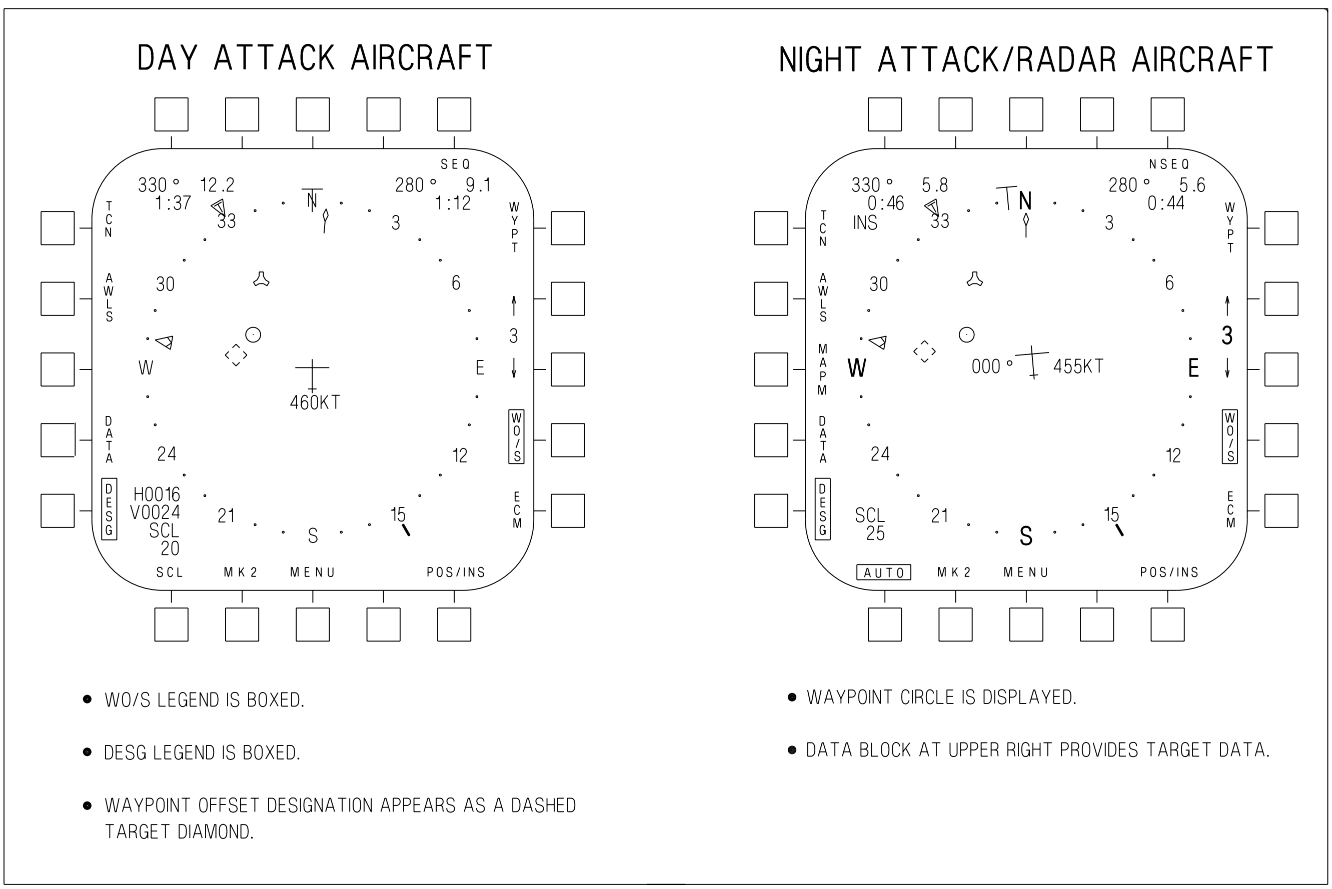

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Figure 2-37. EHSI/EHSD Waypoint Offset (WO/S) Designation

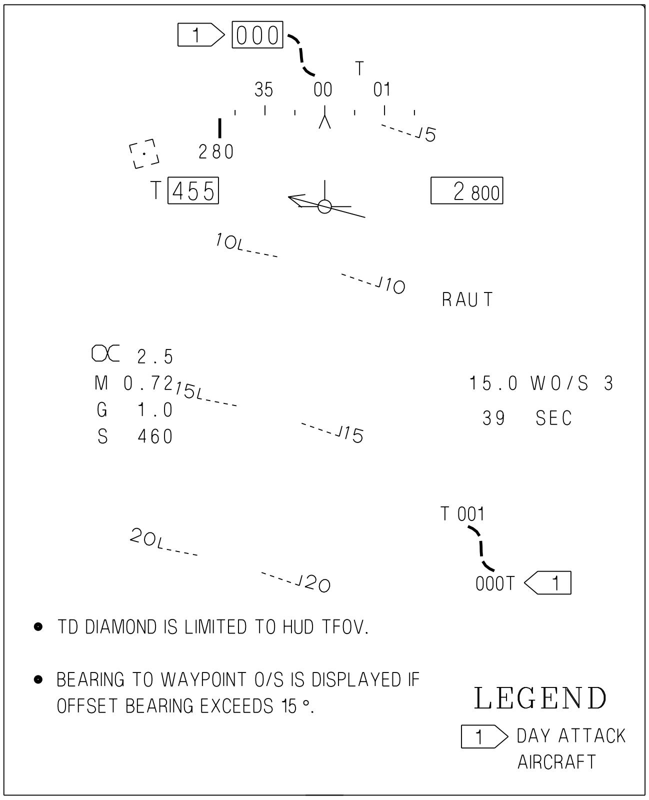


Figure 2-38. HUD Waypoint Offset Designation After a WOF

2.4.2 INS Designation. An INS designation is a visual designation requiring the target to be in the HUD TFOV and the INS sensor mode selected. INS designation can be performed on the HUD in all master modes except A/A. INS designation is a HOTAS function. The INS sensor mode is selected on the control stick by sliding the sensor select switch forward. The TD diamond is then displayed on the HUD by pressing the TDC on the throttle shown in Figure 2-40.

The TDC is an isometric force transducer used for sensor slewing and designation. It is located for thumb operation and incorporates both “action” and “no action” slewing in combination with fast and slow slew rates. Action slewing is used for fast slewing. It requires that the pilot press the TDC while slewing. There is a 0.1 second delay in TD movement after pressing the TDC. This delay allows the pilot to quickly designate a target without introducing inadvertent slew forces. Releasing the TDC designates

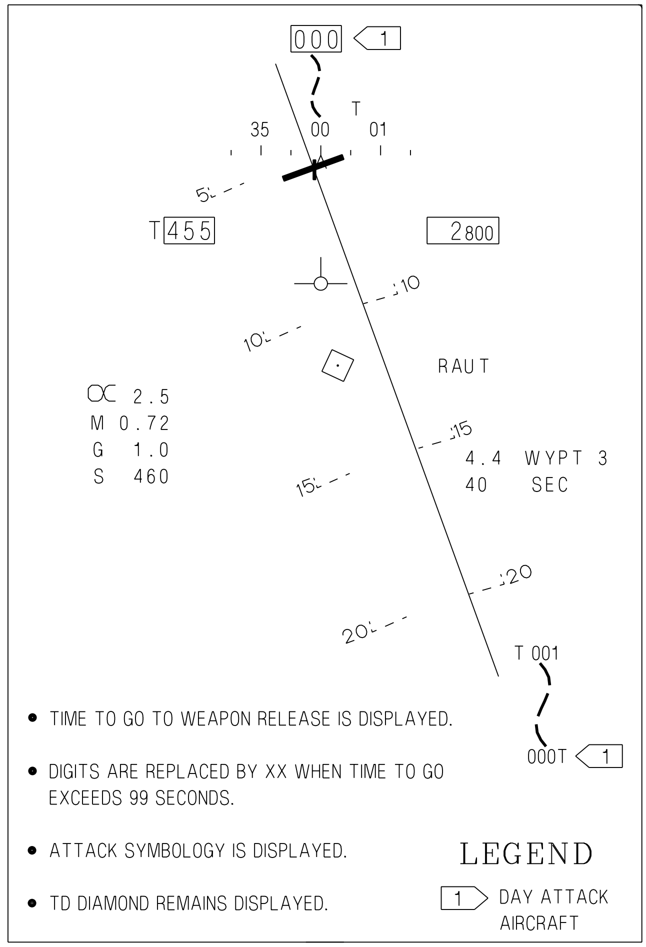


Figure 2-39. A/G Master Mode Selection With Target Designated

the target. It is important for the pilot to designate the intersection of the target and the ground to avoid entering false range information.

When a TDC designation is performed while an offset is selected, offset altitude is displayed on the stores display instead of waypoint altitude.

Once the target is designated, no action slewing can be used to refine target designation and lock on. No action slewing is performed by lateral movement of the TDC without pressing it. The no action slew rate is slower to permit more exact positioning of the TD diamond. There is no TD movement delay as in action slew. When the TDC is pressed the TD diamond appears on the HUD initialized at the velocity vector (Figure 2-41). It is ground stabilized and may be slewed via the TDC. However, the preferred method is

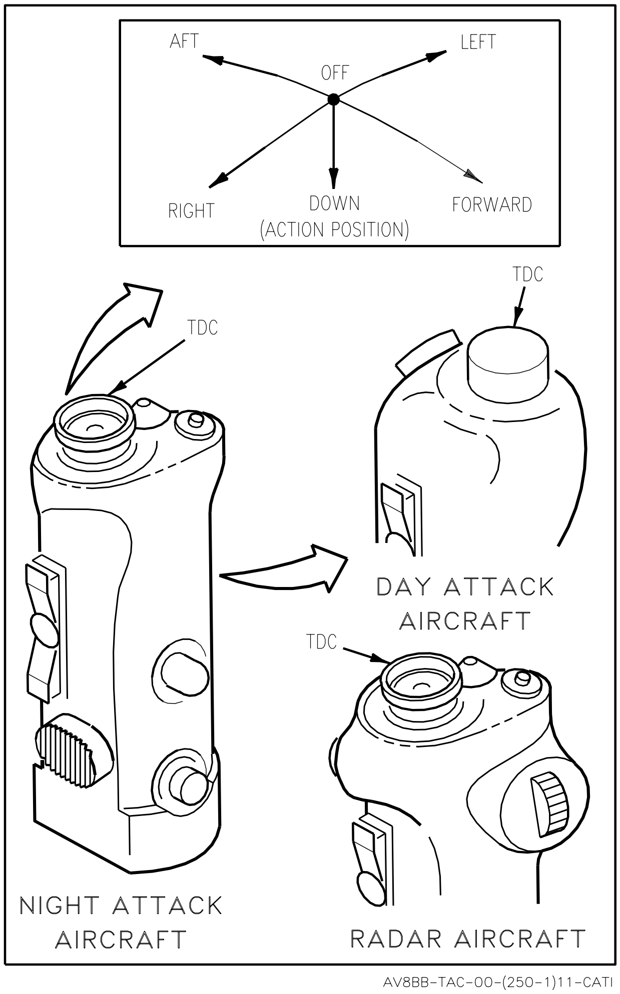


Figure 2-40. Target Designator Control

to steer the aircraft to overlay the velocity vector on the target and when they are coincident, tap the TDC (press/release) to designate. The DMT, if turned on, follows the designated point and provides video on the DDI. If the DMT display is selected, it can then be used for head down sweetening of the designation if desired (required). If the DMT display is not selected, a quick and easy method of selection is to merely slide the sensor select switch forward.

In the INS mode, TD slew is limited to the HUD TFOV. The attack symbology displayed depends on whether AUTO or CCIP delivery modes are selected. An example of an AUTO delivery is shown in Figure 2-41.

2.4.2.1 Point Blank Bomb Pickle Designation. A special case INS designation may be performed in the AUTO mode if a designation has not been accomplished and a weapon has been selected. Place the velocity vector on the target then press and hold the bomb pickle button. This allows for rapid designation of a target without using TDC slewing. Once the bomb pickle button is pressed and the flightpath is greater than 2° dive, AUTO attack symbology appears and the TD diamond overlays the velocity vector. An AUTO delivery may then be performed.

The TD diamond is also displayed on the EHSI/EHSD display when the target is designated and it lies within the selected scale. TD diamond location with respect to the aircraft symbol depends on the scale factor selected. The EHSI/EHSD display changes upon HUD designation are shown in Figure 2-42.

WARNING

An inadvertent weapon release will occur if this method is used while in CCIP delivery mode with the CCIP cross in the HUD FOV.

2.4.3 ARBS/TV Designation. On Day and Night Attack aircraft the TV designation is performed in a similar manner to a INS designation. The DMT must be turned on via the miscellaneous switch panel and the ARBS/TV sensor selected on the control stick. This brings up the ARBS video and TV crosshairs on the DDI, and the TV FOV symbol pipper in the HUD velocity vector (Figure 2-43). The pilot can either fly the velocity vector over the target and press/release the TDC to designate, or action slew the TV FOV box over the target and release the TDC to command target acquisition. Again the preferred (easier) method is to fly the velocity vector to the target to designate.

Once designated, no action slewing may be performed to sweeten the lock on point using 6 to

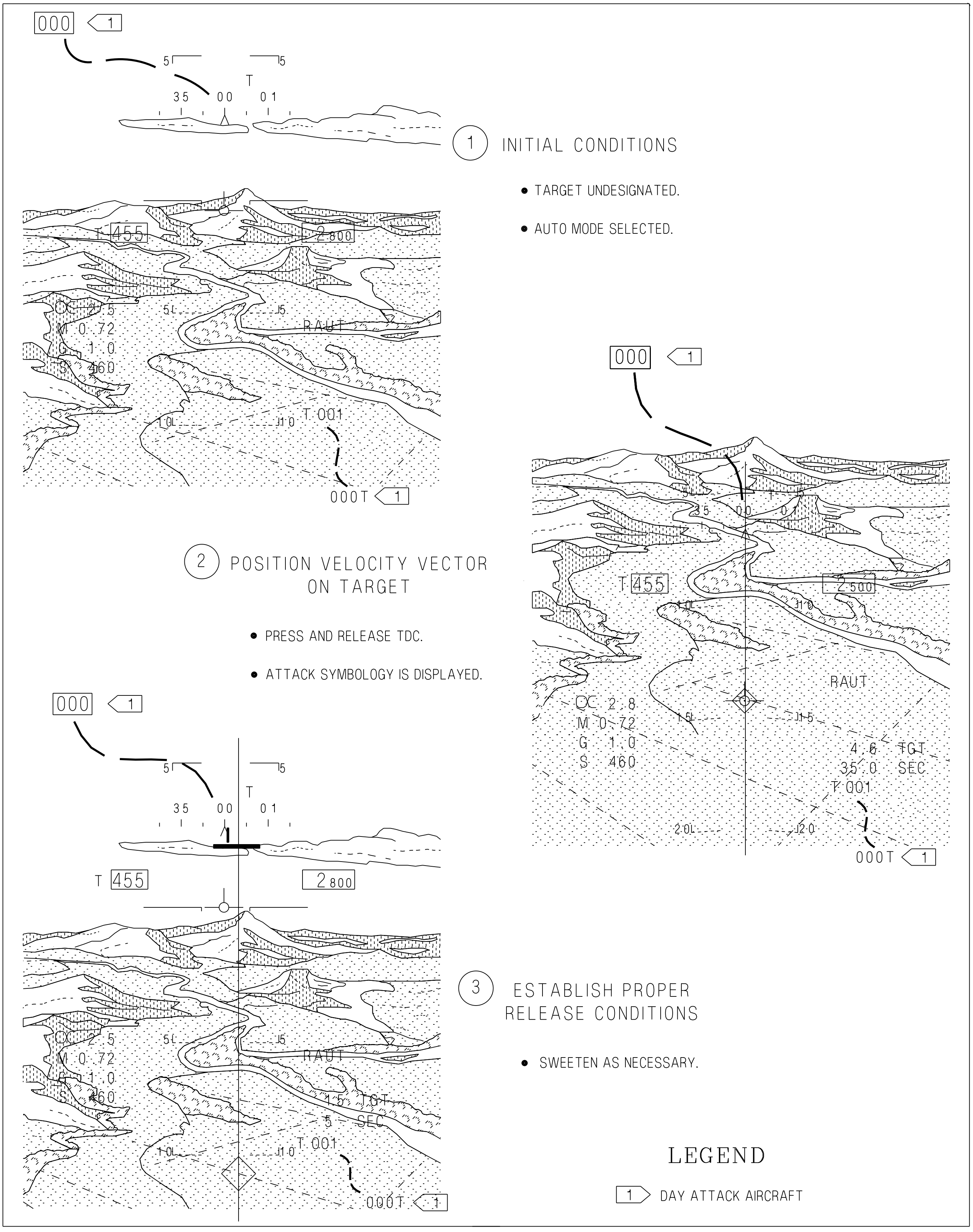


Figure 2-41. INS Designation

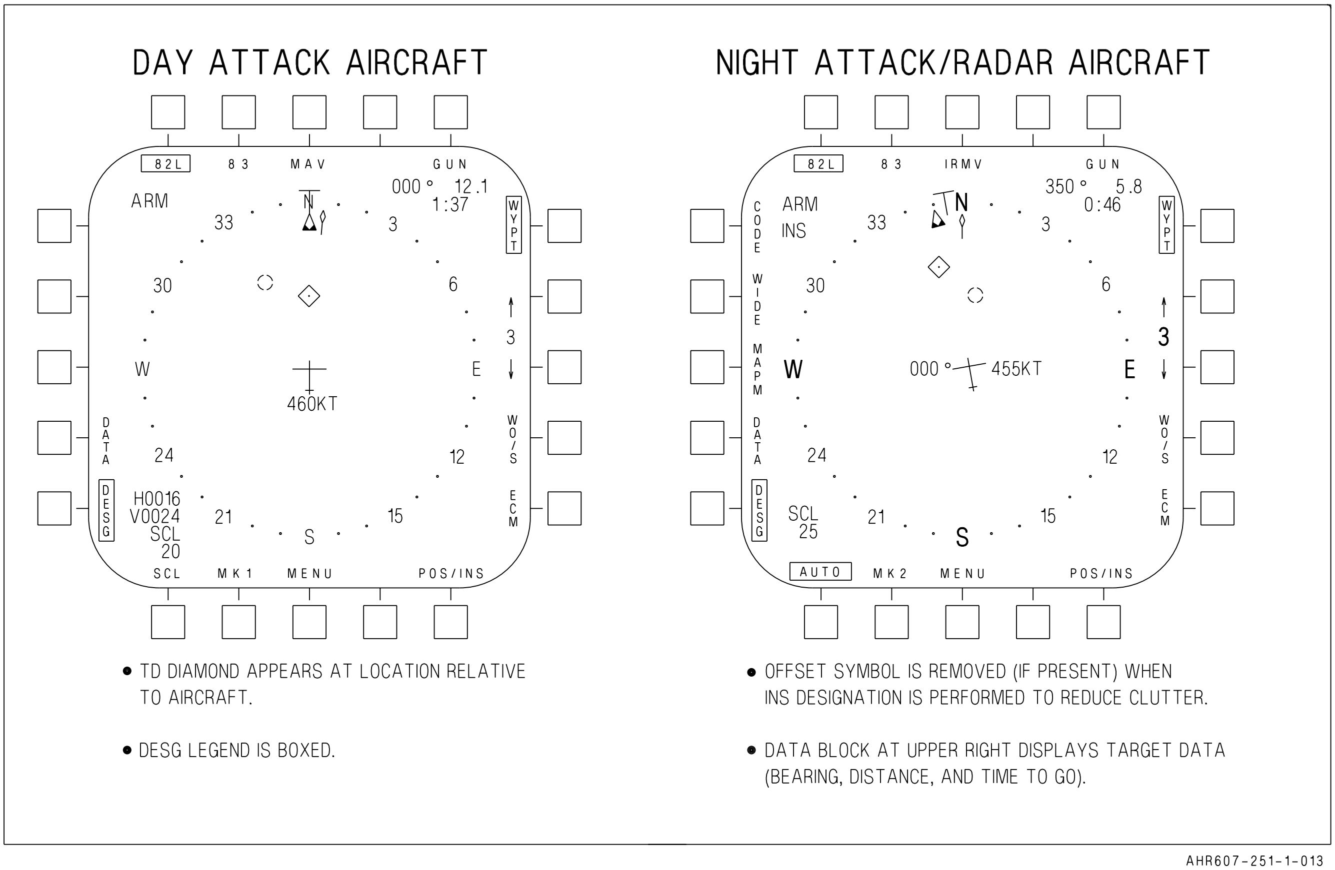


Figure 2-42. EHSI/EHSD With INS Designation

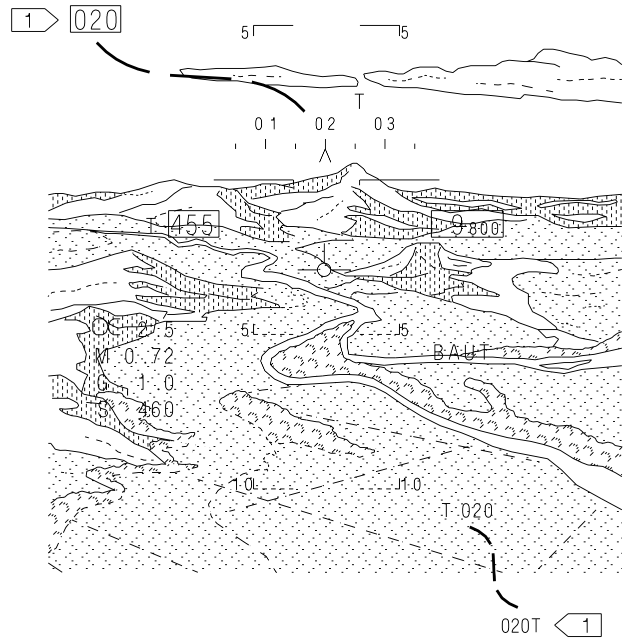
1 magnified video on the DDI. In the A/G master mode, attack symbology is presented on the HUD once target range is established. The MC uses the target LOS rates generated by the ARBS, aircraft altitude, and airspeed to compute target range. After the aircraft overflies the target, the ARBS/TV sensor mode is automatically disabled and the INS sensor enabled. This prevents indiscriminate redesignation by the TV sensor at the gimbal limits during reattack. On the HUD, the TV symbol is replaced by the TD diamond and reattack steering appears. On the DMT display, the TV video is removed and the compass rose appears to aid in reattack.

In the CCIP mode, an ARBS/TV designation is useful to provide accurate target altitude for weapon release calculation. The pilot can lock onto a point near the target and, once TV track is obtained, the CCIP is based on ARBS derived height above target.

2.4.4 ARBS/LST Designation. On Day and Night Attack aircraft this is the only automatic designation. It requires laser illumination of the target by an airborne or ground based forward controller. The laser signal is detected by the LST in the search mode and it automatically acquires and tracks. With the ARBS/LST sensor mode selected and a target designated the NAR and WIDE scan center about the designated point if correct elevation is entered. With no target designated, the NAR/WIDE scan centers about a point centered and 5 nm in front of the aircraft (Figure 2-44). The pilot can relocate the centroid of the scan pattern using no action slewing on the TDC. In the HUD scan mode the ARBS scans in aircraft coordinates and is not slewable by the pilot. Target designation is automatic and is indicated by the HUD LST cross superimposed on the TD symbol (Figure 2-44).

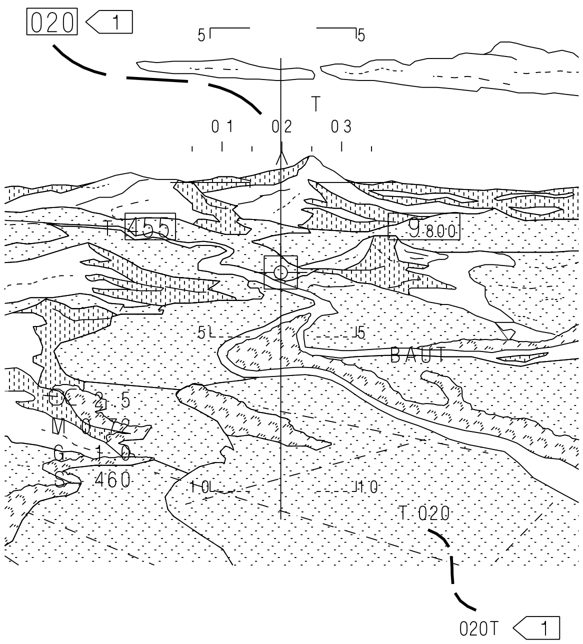
TV video is automatically presented on the DDI at lock on enabling head-down identification of the target. Selecting either the ARBS/TV

PREFERRED METHOD



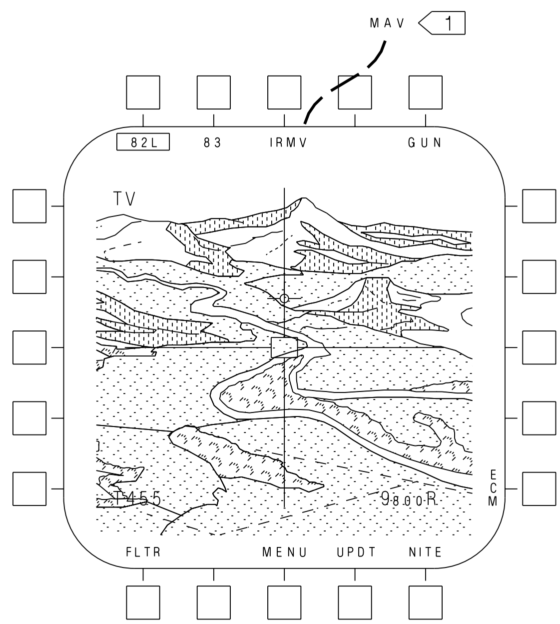
1 SELECT ARBS/TV MODE ON SENSOR SELECT SWITCH

- A DOT IS DISPLAYED AT THE VELOCITY VECTOR TO INDICATE INITIAL POSITION OF TV FOV CENTROID.



2 POSITION VELOCITY VECTOR ON TARGET

- PRESS AND RELEASE TDC.
- ATTACK SYMBOLOGY IS DISPLAYED.



3 TRANSFER HEAD-DOWN

- TV TRACK COMMANDED.
- BOX ENCOMPASSES TRACKED POINT.
- IF SWEETENING IS DESIRED, USE TDC (CAN BE DONE IN EITHER ACTION OR NO ACTION.)
- SLEW CROSSHAIRS OVER TARGET WITH TDC.

LEGEND

1 DAY ATTACK AIRCRAFT.

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Figure 2-43. TV Designation (Sheet 1 of 2)

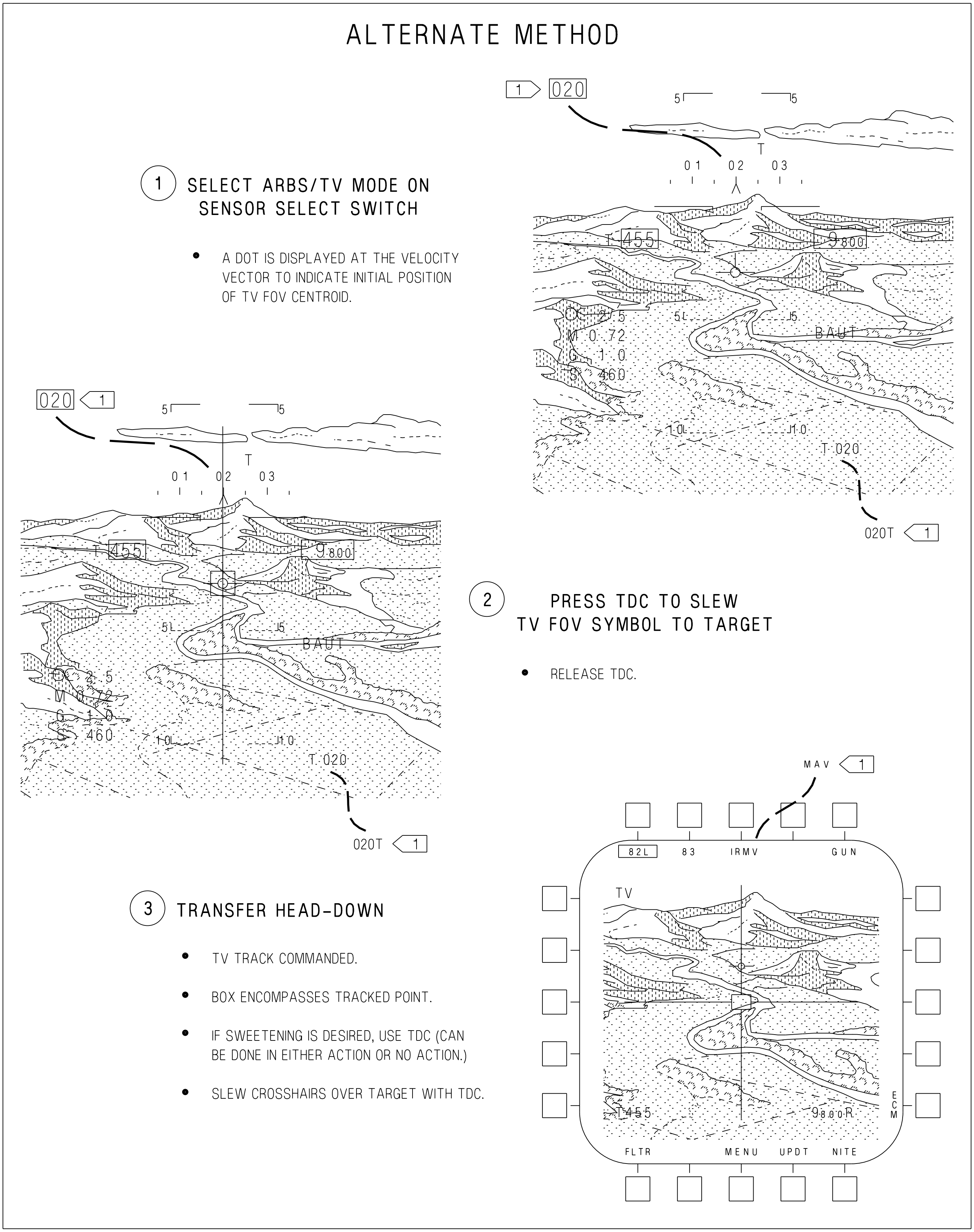

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Figure 2-43. TV Designation (Sheet 2 of 2)

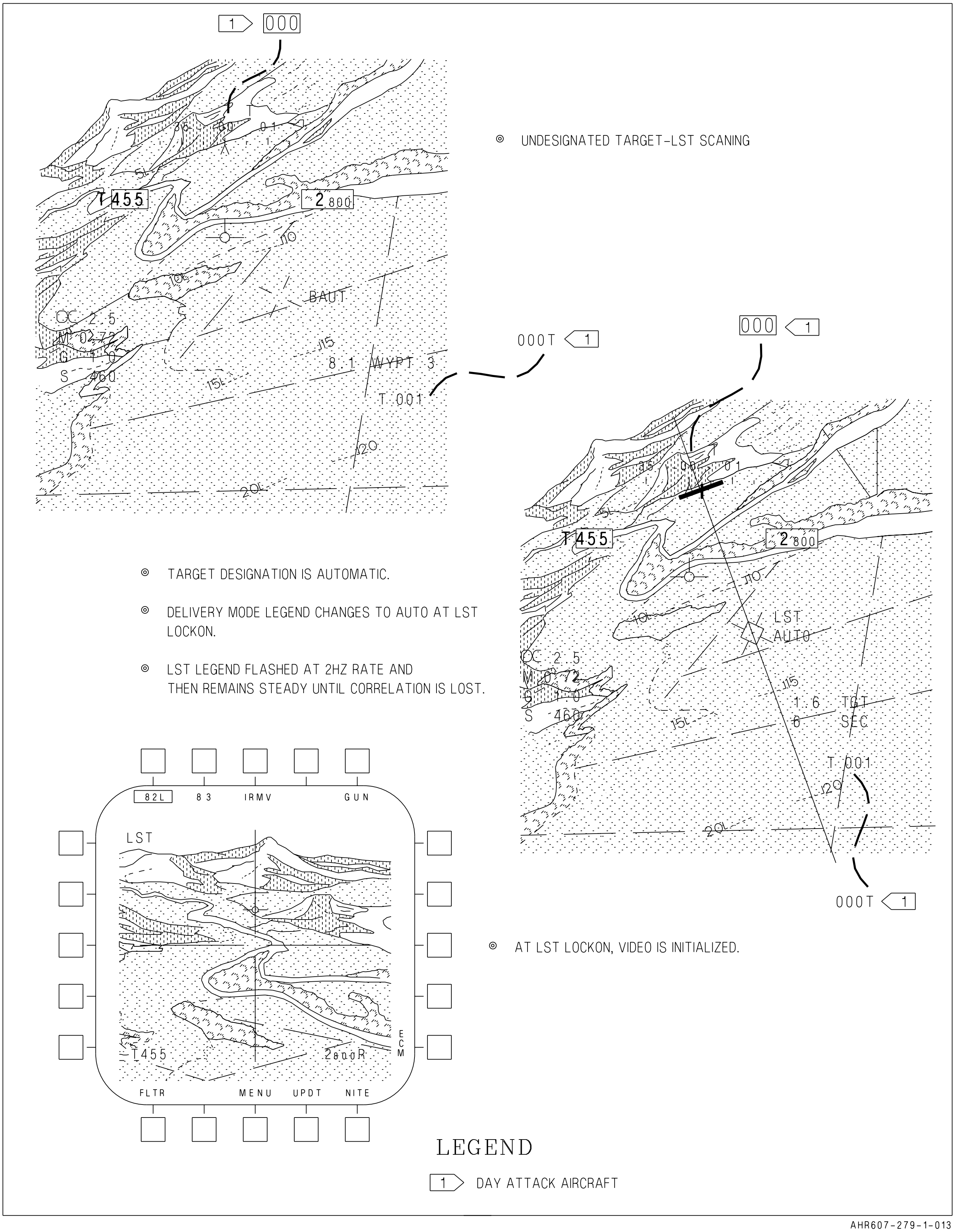

Figure 2-44. LST Designation

or INS sensor mode with the sensor select switch after LST lock on transfers to the respective designation. This may be required if forward controllers are forced to shut down or if other tactics dictate.

2.4.5 Radar Designations. Radar designations function in the same manner as any system designation (HUD, WYPT, WO/S, etc.) and provide accurate aim points for navigation, weapon delivery and update purposes. In addition, radar designations can be used to mark a point (standoff position marking). The pilot simply presses the mark button (MK1/2/3) when designated to store the LAT/LONG of the mark point for later selection or retrieval. After designation, the INS (or best available navigation system) maintains target position.

Efficient use of the expand modes can assist the pilot in achieving the most accurate radar designations. For example, if an aim point is identified in the MAP mode, the pilot should initially designate the aim point (WYPT, WO/S, radar) and then step through the expand modes (i.e., MAP, EXP1, EXP2, EXP3), refining the designation, as required, until a precise radar designation on the highest resolution display available can be performed.

Advantages of radar designations include:

1. Useful at long ranges.

2. Can be accomplished under low visibility conditions (night, weather, haze).

3. Reasonably accurate when using the expand modes (within 500 feet of radar significant targets).

Disadvantages of radar designations include:

1. Target must be radar significant.

2. Must be accomplished heads down.

3. Not very practical at very low altitudes (pilot work load, radar shadowing, radar LOS).

4. Not available under EMCON conditions.

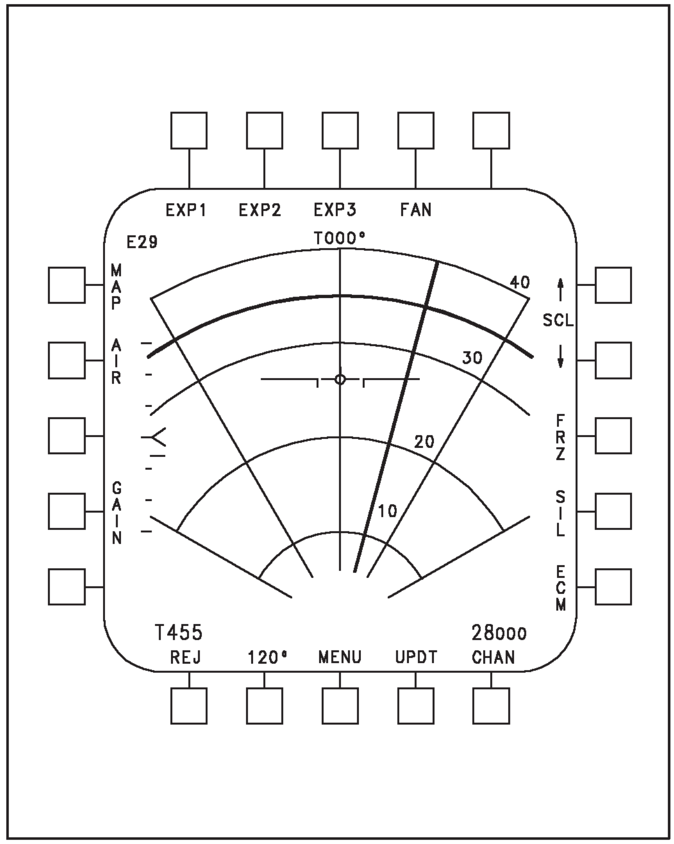

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Figure 2-45. Air-to-Surface In-video Cursor

2.4.5.1 Radar Designation Procedures. When the pilot detects a video return on the radar display he wishes to designate, the first step is to assign the TDC to the radar. The pilot then slews the acquisition cursor over the desired aim point and depresses the TDC. When the TDC is depressed to the action position, the ″in-video cursor″ appears in place of the acquisition cursor. See Figure 2-45. The in-video cursor is made up of a range arc and a bearing line. While holding the TDC depressed, the pilot adjusts the in-video cursor precisely over the aim point, and then releases the TDC to complete the designation (The TDC must be depressed in order to slew the in-video cursor.) At this point, the in-video cursor is replaced by a smaller stabilized cue (stab cue) and the acquisition cursor reappears in the stowed position. In addition, if a limited azimuth scan is selected the scan centers about the stab cue within the gimbal limits of the radar.

The stab cue and the associated radar designation are ground stabilized. The MC maintains the position of the stab cue by using the best available navigation data and provides the aim point range and bearing to the radar to update the stab cue position. If the stab cue drifts off the aim point because of a navigation error buildup (INS drift), the pilot may refine the designation to update its position. The pilot must ensure that the acquisition cursor is slewed within the tactical display region before depressing the TDC to the action position.

NOTE

The pilot does not have to place the acquisition cursor directly over the aim point because the in-video cursor is initialized by the radar at the stab cue position.

After repositioning the in-video cursor over the aim point, the pilot releases the TDC to complete the redesignation. In the expand modes, update of the video is inhibited while designating.

Once a target is designated, the range increment and decrement arrows are no longer displayed since the MC automatically commands range scale changes to maintain the stab cue between 45 % and 93 % of the display. In addition, when a designation exists, selection of the RSET option does not affect the antenna position. Steering is provided on the HUD and EHSD to the designated point and time-to-go to weapon release (99 seconds maximum) is displayed (for applicable weapon modes).

2.4.6 Other Designation Methods. In addition to the major designation methods previously described, several other designation methods are provided for the pilot to take advantage of specific situations or as a backup when the selected planned delivery may not be accomplished.

2.4.6.1 WOF Designation. Pressing the WOF (waypoint overfly) pushbutton on the UFC executes an overfly update using the waypoint selected on the EHSI/EHSD or DMT display. The procedure bypasses the update steps previously described and simply requires that the pilot overfly the stored waypoint and press WOF. In addition to enabling altitude and present position updates, the WOF function automatically selects the A/G master mode if not previously selected. The offset to the selected waypoint is designated as a target, and steering and range information to the WO/S is displayed on the HUD and DDI. Target position is automatically updated and there is no need to accept or reject the position update until after the ensuing attack when more time will be available. The ALT (altitude) update option is presented first during the WOF update since height above target is more critical to weapon delivery. The overall procedure consists of the following:

1. Call up the EHSI/EHSD or DMT display on the DDI to enable waypoint selection.

2. Select desired waypoint by pressing increment/decrement pushbuttons on the display.

3. Overfly the waypoint and press the WOF pushbutton.

4. Accept/reject the ALT update shown in Figure 2-46 by actuating the appropriate option select pushbutton on the ODU. This brings up the OVFY (overfly) update option on the ODU.

5. Accept/reject the present position errors shown in Figure 2-47 by actuating the appropriate option select pushbutton on the ODU as time permits.

If radar altitude is invalid, the ALT option is blanked after approximately 1 second, and the OVFY update option is displayed. If the position update is accepted, the waypoint symbology on the DDI shifts accordingly and the offset designation and steering to the target reflect the update.

If the reject option is not pressed within 15 seconds the ALT update is be automatically accepted and the OVFY update is

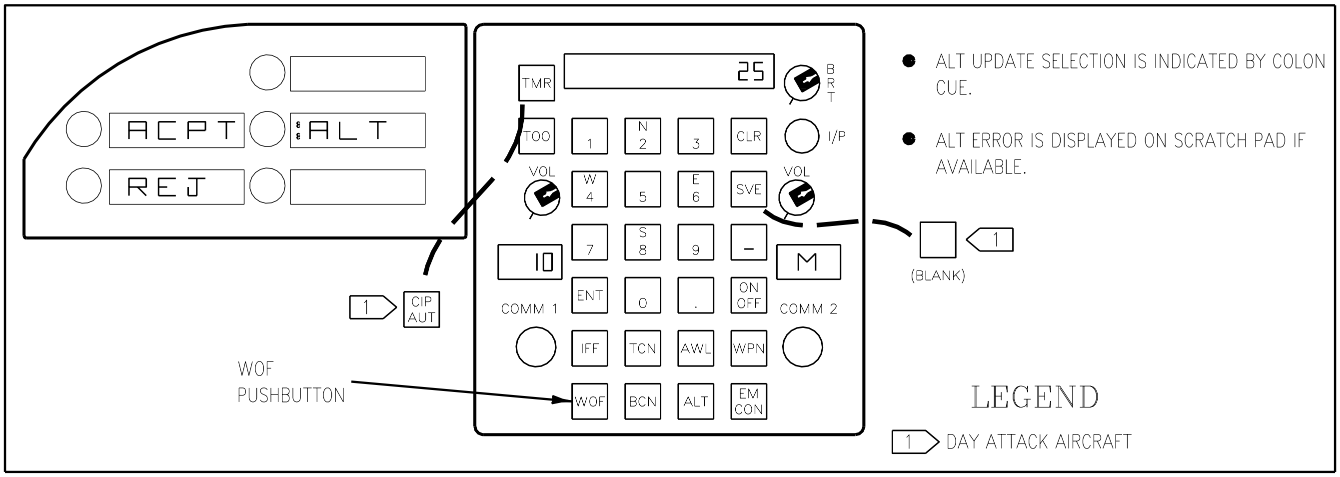

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Figure 2-46. Waypoint Overfly (WOF) Selection

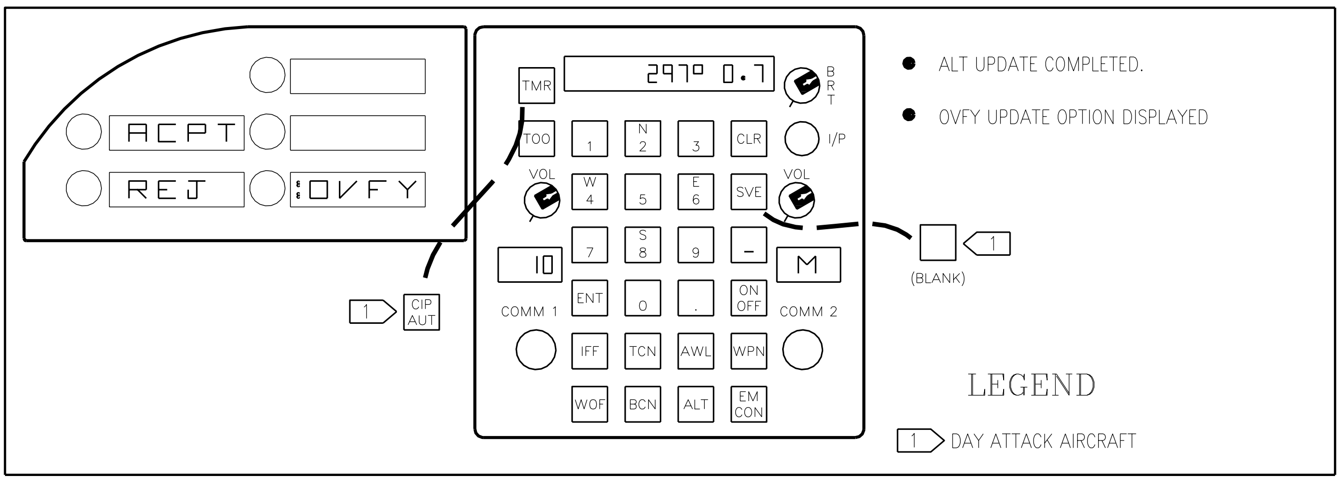

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Figure 2-47. Altitude (ALT) Update Accepted/Rejected

displayed. If an ALT update cannot be performed (e.g., radar altimeter inoperative), the ALT update display will quickly blank and the OVFY update will be displayed. If REJ is not pressed within 15 seconds, the OVFY update is displayed, the OVFY update will be automatically accepted and the ODU will be blanked. Rejection of the OVFY update associated with a WOF within the 15 seconds will result in the waypoint/waypoint offset symbols automatically returning to their original positions while remaining designated.

2.4.6.2 TOO Designation. A TOO designation is provided to allow low level head-up designation of unplanned targets of opportunity. The pilot presses the TOO pushbutton on the UFC shown in Figure 2-48 to designate the point directly below the aircraft as the target. This action automatically turns on the radar altimeter (if not operating) to supply target elevation to the system and commands the A/G master mode for immediate attack.

If a weapon was previously selected, the last selected weapon and delivery program are called up. In the AUTO mode, attack symbology will be presented when target bearing decreases to 11° (TFOV). If in the CCIP mode, CCIP symbology will be presented throughout reattack. The steering arrow will be removed when relative bearing decreases to less than 1°. Reattack steering is also automatically available for display on the EHSI/EHSD display.

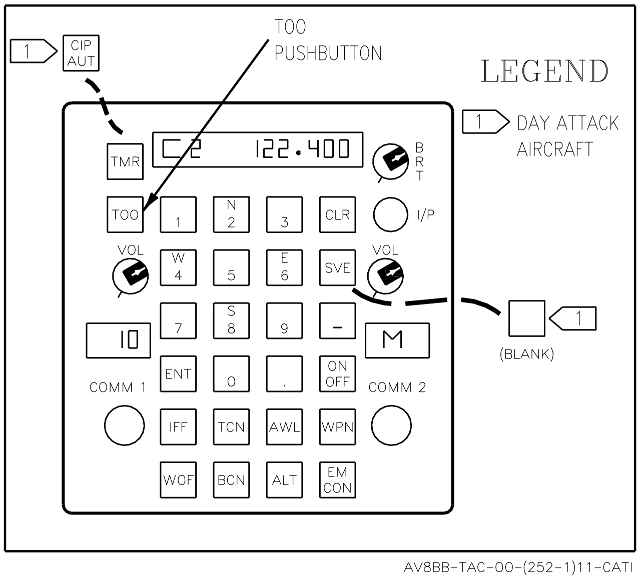

Figure 2-48. Target of Opportunity (TOO) Pushbutton

If a weapon was not previously selected, the TD diamond and reattack steering are displayed. Attack symbology is not presented since a weapon has not been selected for delivery. This condition is cued by the four slant lines across the center of the HUD.

Pressing the TOO pushbutton adds a TOO message to the DSU consisting of the latitude, longitude, elevation and the MC real time. Adding TOO data to the DSU allows for the storage of unlimited TOO messages. TOO data is only temporarily stored and must be retrieved immediately following a flight by downloading the DSU.

2.4.6.3 CCIP to AUTO Conversion Designation. In the CCIP delivery mode, the pilot can designate on the limited CCIP symbol (dashed cross) by pressing and holding the bomb pickle button. This capability is provided to allow the pilot to drop weapons while performing a CCIP delivery when he feels the CCIP symbol may not enter the HUD FOV in time to get a weapon release (since weapon release is inhibited in CCIP mode when the CCIP symbol is outside the HUD TFOV). By pressing the bomb pickle button in this situation, the ground point below the limited CCIP symbol is designated and the AUTO delivery mode activated. The azimuth steering line (ASL) appears and an AUTO delivery may be performed. Once the bomb pickle button is released, CCIP attack symbology reappears and the designation is retained.

2.4.6.4 CCIP Target Designation with Weapon Release. At weapon release in the CCIP mode, the computed impact point is automatically designated. The TD diamond appears at the designated target location. Reattack steering is then provided on the HUD and EHSI/EHSD display.

2.4.7 Undesignation. The pilot can undesignate a target by pressing the undesignate button on the control stick or pressing the DESG pushbutton on the EHSI/EHSD display. This removes the TD diamond from the HUD and EHSI/EHSD. Steering symbology and data reverts to the previous selection. In the AUTO mode, attack symbology is removed. Selection of the A/A master mode also undesignates.

2.5 DELIVERY MODES

The A/G delivery modes are: automatic (AUTO), Loft (LOFT), continuously computed impact point (CCIP), air-to-ground missile (AGM), depressed sight line (DSL), direct (DIR), and DSL(1) a manual mode. Loft is a submode of the automatic delivery mode, DSL, DIR, and DSL(1) are backup delivery modes. Primary A/G weapon delivery mode options are listed in Figure 2-49.

STORE	DELIVERY MODE				
	AUTO	1 LOFT	CCIP	DSL	AGM
Bombs	X	X	X	X	
Rockets			X	X	
Gun(s)			X	X	
Dispensers (Flares/ Sonobuoys)	X			X	
Air-to-Ground Missiles					X
NOTE: 1 The LOFT delivery mode is a submode of the AUTO delivery mode.					

Figure 2-49. Delivery Mode Options

Selecting a weapon automatically recalls the primary delivery mode last entered for that selected weapon. The selected mode along with current weapon programming is displayed on the DDI stores display. See Figure 2-50. Mode selection is displayed on the ACP in the MODE window for all master modes. It is displayed on the HUD in the A/G master mode.

An indication of which master mode and the altitude source used by the MC to perform weapon delivery calculations is presented on the HUD for the computed delivery modes. The AUTO and CCIP legends are only displayed if the ARBS or radar AGR is the altitude source used for the delivery. The legends change to RAUT or RCIP if radar altitude is the altitude source (BOMB option selected and not in EMCON), to GAUT or GCIP if GPS is the altitude source (GPS option selected and BOMB option not selected or radar altitude not valid) and to BAUT or BCIP if barometric altitude is the altitude source used. The MC determines the altitude source based on pilot selections and data validity. The AUTO and CCIP HUD delivery mode/altitude source displays are listed in Figure 2-51.

Delivery mode selection may be changed with the mode control switch on the ACP or the cage/uncage button on the throttle. See Figure 2-50.

Delivery modes are selected on the ACP via the mode switch in the upper left corner for AUT, CIP, DSL, and DIR delivery modes. The LOFT delivery mode is a submode of the AUTO delivery mode and is selectable from the DDI when AUTO mode is enabled. The manual mode (DSL1) is a backup mode using relay operation

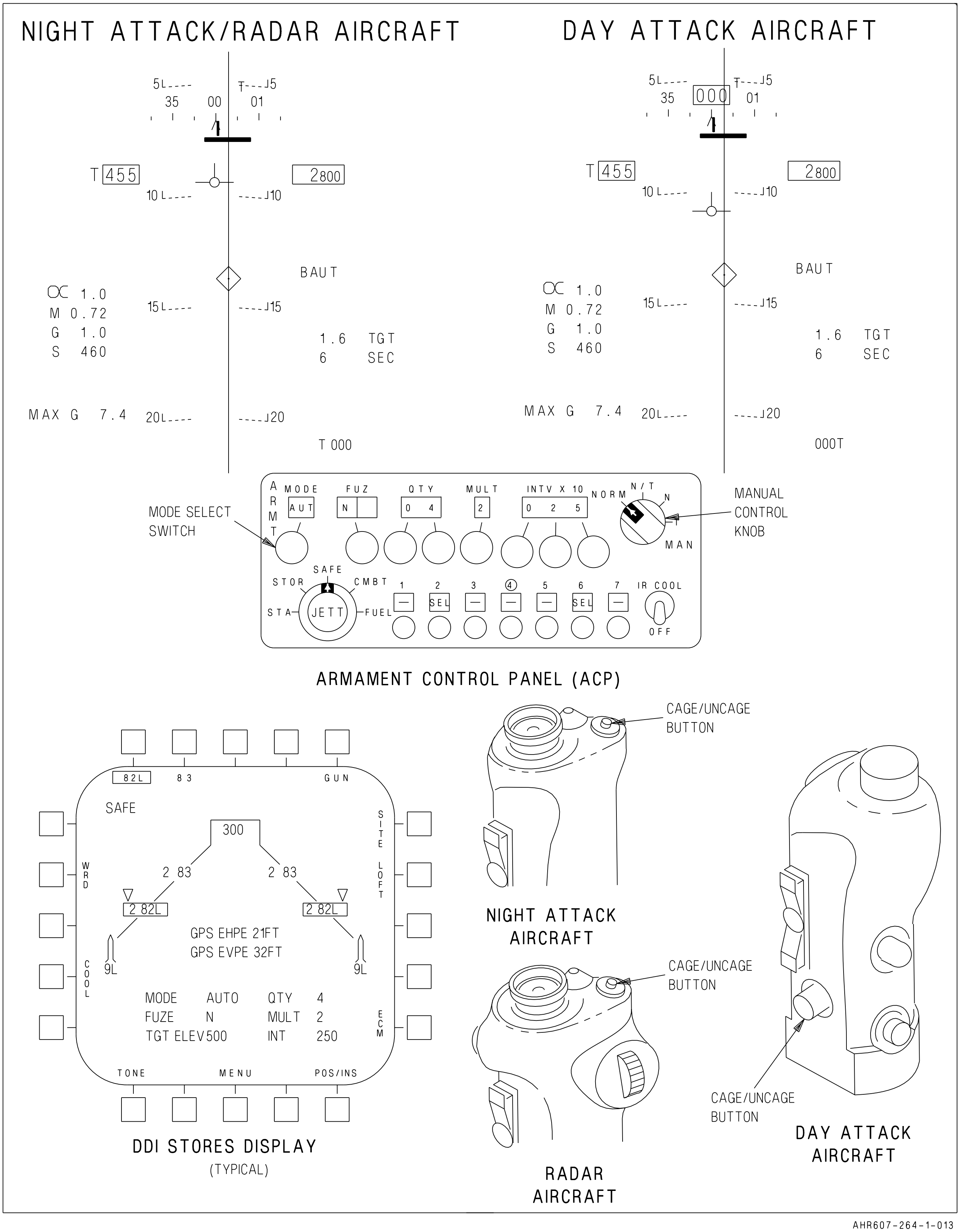

Figure 2-50. Delivery Mode Selection

DELIVERY MODE	ALTITUDE SOURCE				
	2 ARBS	1 AGR	RALT	GPS	BARO
CCIP Mode	CCIP	CCIP	RCIP	GCIP	BCIP
AUTO Mode	AUTO	AUTO	RAUT	GAUT	BAUT

LEGEND:
1 Radar aircraft
2 Day and Night Attack aircraft

Figure 2-51. Delivery Mode/Altitude Source Display

rather than the microprocessor in the stores management computer (SMC) or ACP. It may be employed with manual fuze arming to arm the weapon. It is selected by placing the manual (MAN) control knob on the ACP in any position other than NORM.

The pilot has the option of using HOTAS to change delivery mode selection between CCIP and AUTO using the cage/uncage button on the throttle. Successive actuations of the cage/uncage button alternates the mode selection for bombs between CCIP and AUTO in the A/G, NAV, and V/STOL master modes.

NOTE

On Day Attack aircraft the CIP/AUT button on the UFC is the timer function.

2.5.1 AUTO Delivery Mode. The AUTO mode provides fully computed automatic release of bombs, flares, or sonobuoys. It requires that the target be designated by any method described previously, by the pilot, in order to provide command steering to an appropriate release point. It provides flexibility in delivery since it does not restrict the pilot to a specific set of release conditions. AUTO delivery is summarized in Figure 2-52.

Once designated, the azimuth steering line (ASL), time-to-go, and release cue (if in range) are displayed if the target is in the TFOV of the HUD as shown in Figure 2-53, detail A. If the target is outside the TFOV, the ASL is replaced by a steering arrow.

During AUTO delivery a quasi ASL is presented on the HUD when the apex of the computed bomb trajectory is below the elevation of the designated target. In this situation the ASL is provided to the target (not the release point) based on inertial data (or best available data). Refer to Figure 2-53 detail B. The ASL disappears if the pilot initiates slewing with the TDC.

During an AUTO delivery, when the relative bearing to the target exceeds 90° (normally on target overfly), the ASL, time-to-go, release cue, and TD diamond are removed from the HUD, and the steering arrow is displayed as shown in Figure 2-53, detail C.

The ASL is limited in the lateral direction to the HUD total field of view (TFOV) and is always oriented perpendicular to the horizon (roll stabilized). A weapon release cue appears at 6 seconds time-to-go for high drag bombs. For low drag bombs, it appears when the time-to-go to release is such that a bomb toss release would occur prior to reaching a 45° pullup. This cues the pilot that a dive-toss or loft delivery is possible. The release cue initializes at 3° above the velocity vector on the ASL as shown in Figure 2-53, detail D. However, the weapon release cue does not appear as long as the aircraft is below the target elevation. If uphill bombing is required, LOFT is the preferred mode.

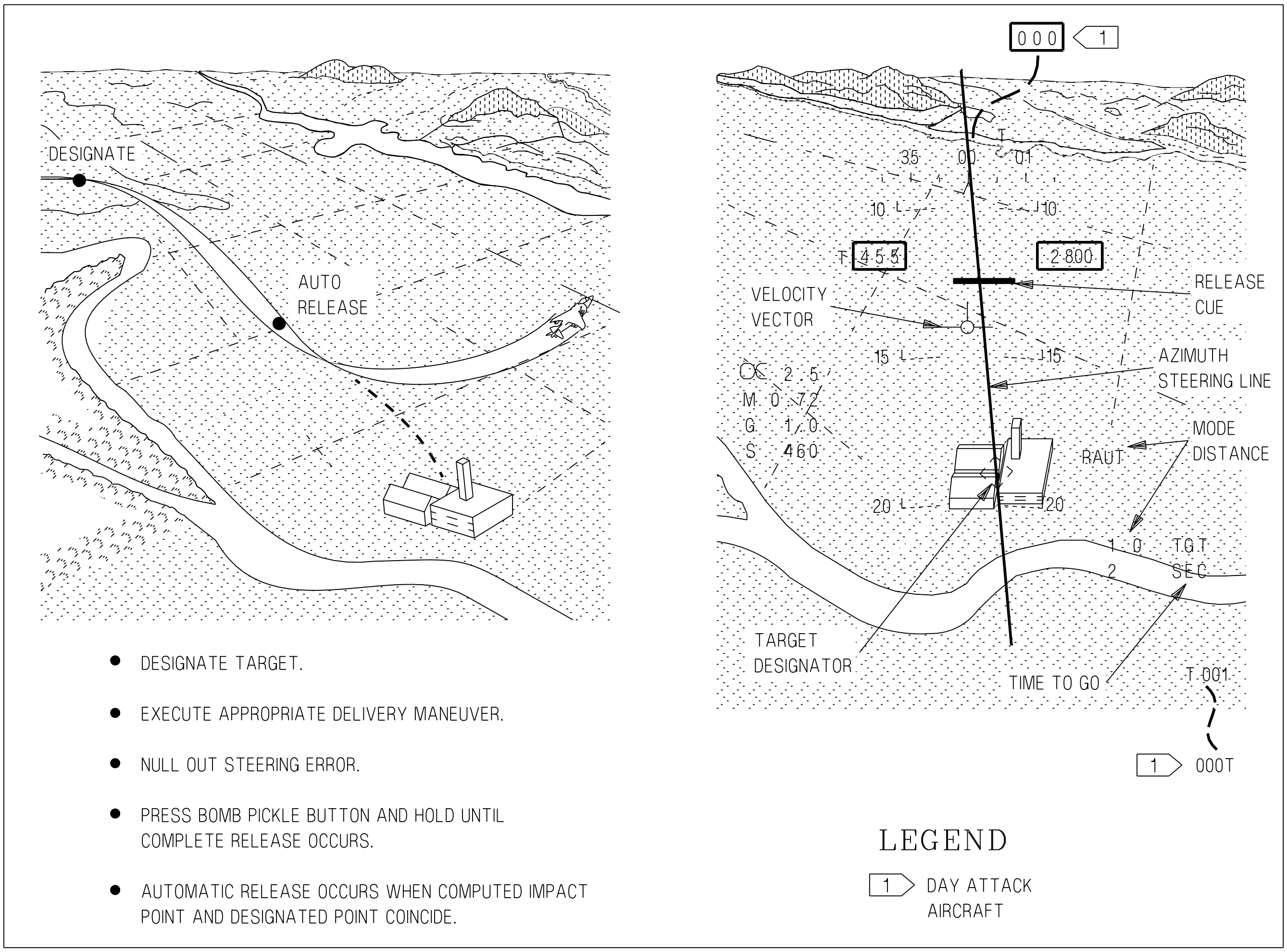

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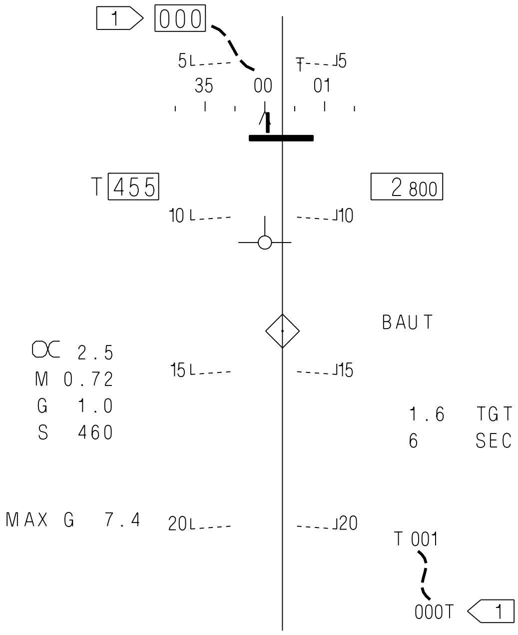
Figure 2-52. AUTO Delivery Mode

The pilot steers to null out the azimuth error and then enables weapon release by pressing the A/G release (bomb pickle) button. At 3 seconds to release, the release cue moves down the ASL and intercepts the velocity vector at release. The bomb(s) are automatically released when weapon range equals target range. If the pilot fails to press the bomb pickle button prior to the first computed release point (for multiple bomb deliveries), but presses it before the computed end of the bombing pattern, the remaining bombs will still be released. If the bomb pickle button is released by the pilot prior to the end of the bombing pattern, the remaining bombs in the pattern will not be released. When the release sequence is completed, the ASL is replaced by the crosshatch symbol until the pilot releases the bomb pickle button. After bomb release and target overfly, HUD attack symbology is removed.

The pilot can then reattack using the HUD steering arrow and the attack line on the EHSI/EHSD or DMT display (Figure 2-53, detail E). When target bearing decreases below 90° the diamond and time-to-go symbology reappear on the HUD. When the relative bearing to the target decreases to less than 11° for the reattack, the ASL and release cue (if within range) reappear.

The attack line is displayed on the EHSI/EHSD display through the TD diamond at the ground track heading held at weapon release. The attack line can be changed by changing the setting with the standby HSI course knob (Day



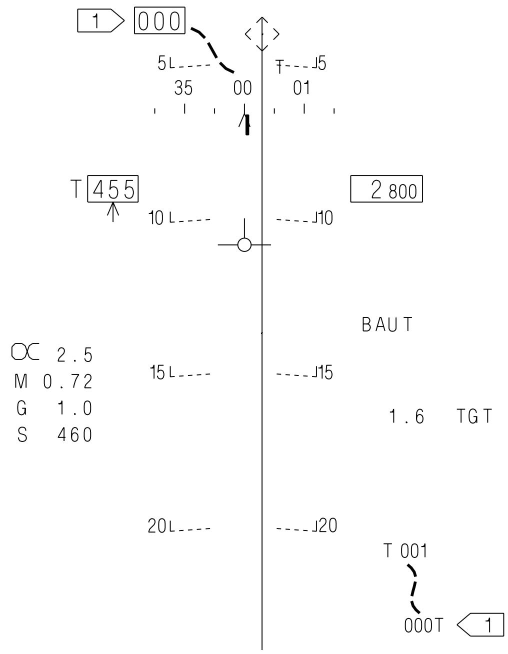
DETAIL A

LEGEND

1 DAY ATTACK AIRCRAFT

- ASL IS DISPLAYED WHEN IN A/G MASTER MODE, AUTO MODE, AND A TARGET IS DESIGNATED IN TFOV (RELATIVE BEARING TO TARGET MUST BE LESS THAN 90 °).
- TIME TO GO TO WEAPON RELEASE IS DISPLAYED IN SECONDS.
- DISTANCE TO TARGET IS DISPLAYED IN NM.
- TD IS LIMITED TO 10.6 ° FROM HUD CENTER.
- BAUT INDICATES THE MC IS USING BAROMETRIC ALTITUDE TO DETERMINE HEIGHT ABOVE TARGET.

INS SENSOR MODE



- ASL DENOTES STEERING TO TARGET INSTEAD OF STEERING TO RELEASE POINT IN ALL SENSOR MODES

DETAIL B

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Figure 2-53. AUTO Mode Symbology (Sheet 1 of 2)

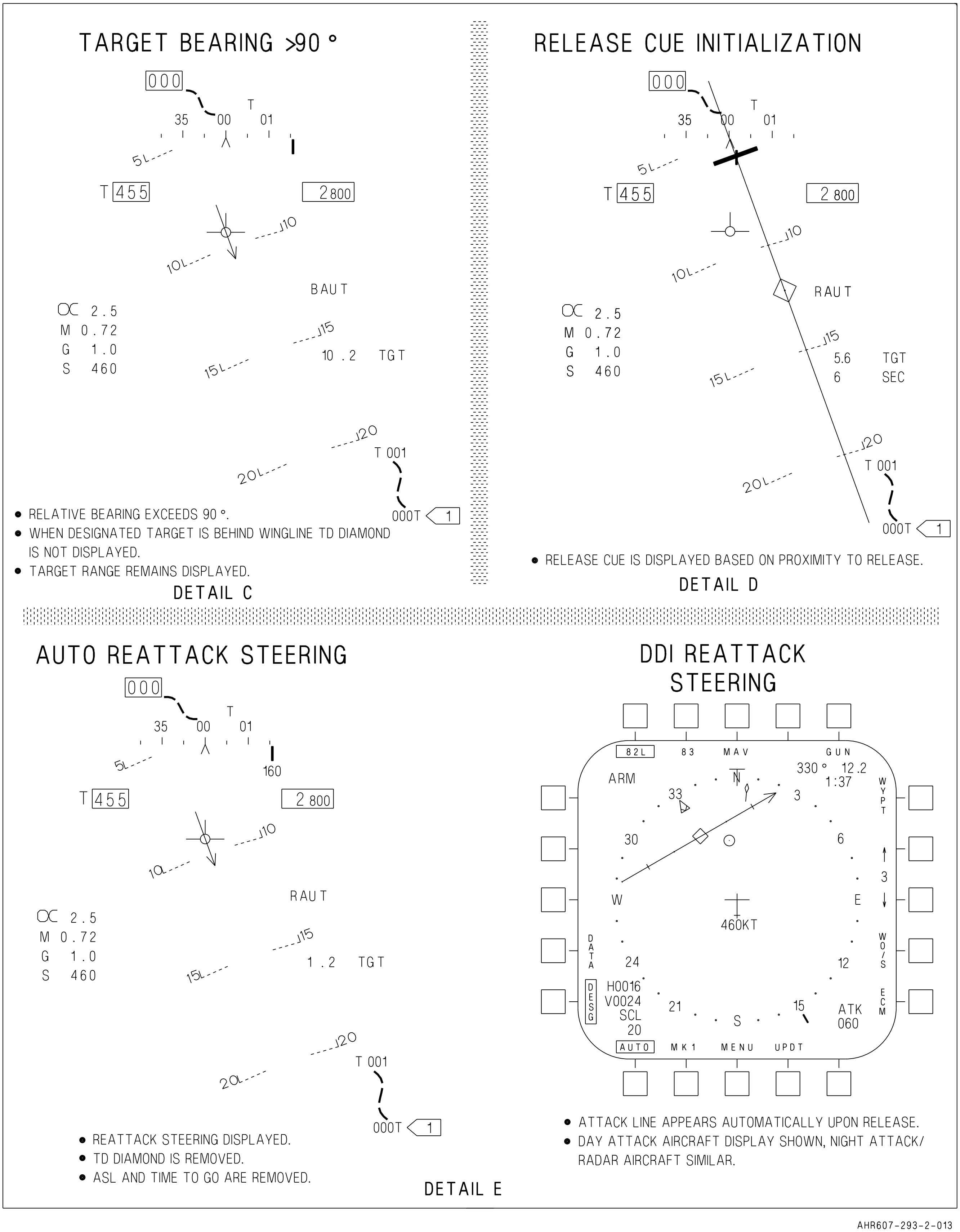

Figure 2-53. AUTO Mode Symbology (Sheet 2 of 2)

Attack aircraft) or the course set switch (Night Attack and Radar aircraft).

2.5.1.1 Point Blank Bomb Pickle Delivery. If the AUTO mode has been selected and no target designated, the pilot can perform a very rapid AUTO release in A/G using a point blank delivery. In this method, the velocity vector is used to designate the target by maneuvering the aircraft to place it on the target and pressing the bomb pickle button. This designates the target and calls up AUTO attack symbology. During pullup the weapon is automatically released as described earlier.

WARNING

An inadvertent weapon release will occur if this method is used while in CCIP delivery mode with the CCIP cross in the HUD FOV.

2.5.2 LOFT Delivery Mode. The LOFT delivery mode is provided to enhance attack capability by providing increased standoff ranges to minimize the aircraft's exposure to enemy air defenses thereby contributing to aircraft survivability.

The LOFT delivery mode is a submode of the AUTO delivery mode. LOFT is a valid delivery mode for most weapon types (singles and ripples). Exceptions include forward firing ordnance, AGM-65s, AGM-122, etc.

The LOFT delivery mode software determines a continuously computed release point (CCRP) which provides pullup and release cues (using a standard 4g pullup profile) to cause weapon release to occur at the optimum release angle (either pilot entered or MC determined). LOFT provides pullup and release cueing for a standard 4g aircraft flight profile to a specific release angle between 4° and 38° for Day Attack aircraft or 9° and 38° for Night Attack and Radar aircraft. The CCRP compensates for pilot deviations from the 4g profile to ensure optimum release angle. See paragraph 2.5.2.5, Loft Computations and Limitations.

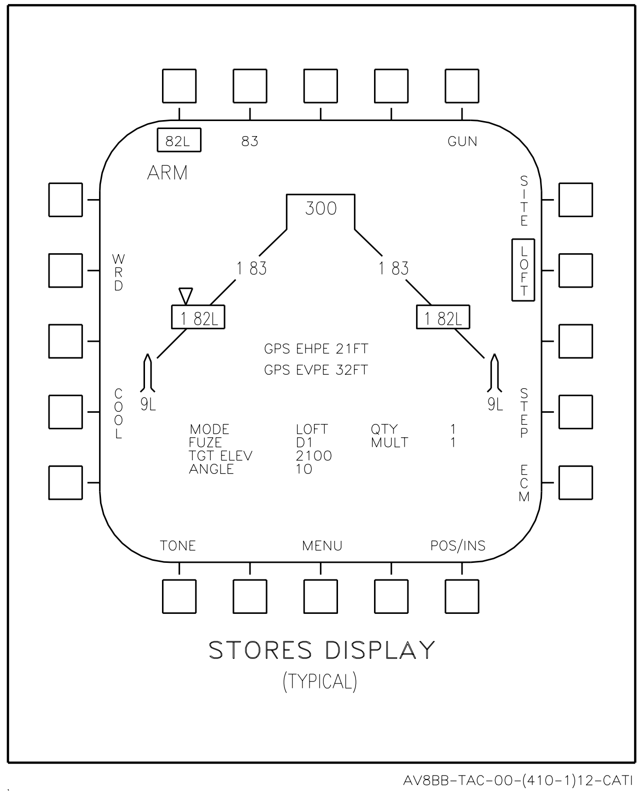

Figure 2-54. LOFT Selection.

The LOFT delivery option is available for selection only if an A/G weapon is selected and the current mode is AUTO. Loft is implemented as a submode of AUTO, therefore, the AUTO delivery mode must be selected to enable the LOFT mode legend on the DDI stores display (Figure 2-54). Boxing the LOFT option initiates the LOFT delivery mode displays and logic. The LOFT option will not appear if the selected weapon is in the CCIP mode. Selecting another A/G weapon *will not* force the system out of LOFT.

The pilot will be forced out of LOFT and into AUTO by any of the following:

1. Pitching or rolling the aircraft beyond 45° when in range for pullup. In-range occurs when the pullup cue intersects the velocity

vector, which is also when the solid ramp up tone begins. This also coincides with the appearance of the release cue.

2. Overflying the selected target.

3. Performing a TOO.

4. Weapon release complete.

In addition to these methods the pilot can deselect the LOFT mode by unboxing the LOFT option or deselecting the weapon. If the pilot selects a different weapon while LOFT is selected, LOFT remains selected if the new weapon was previously programmed for AUTO. However, if the new weapon selection is programmed for CCIP, the LOFT mode is deselected. Another quick method of deselecting the LOFT mode is to press the cage/uncage button or toggle the ACP mode switch which switches the delivery mode to CCIP. Once the LOFT mode is deselected, it can only be reselected by boxing the LOFT option on the STRS display. The loft mode is designed to require a positive pilot action for each release.

2.5.2.1 LOFT Angle Data Entry. The LOFT angle is defaulted by the MC to 38°, although any angle between 4° (Day) or 9° (Night andRadar) and the maximum angle allowed can be used. Loft angles can be manually changed by selecting WPN on the UFC, cuing the ANGL option on the ODU, and entering the appropriate angle using the UFC during weapons programming. The entered LOFT angle is displayed on the scratch pad and on the DDI as part of the stores program.

NOTE

Maximum range angle varies between weapons. It is the pilot's responsibility to determine the desired LOFT angle using Figure 2-55 and enter the appropriate angle.

Once the LOFT angle has been entered, it remains unchanged during the remainder of the flight unless the pilot enters a new loft angle. Also, changing weapon type does not change the entered loft mode.

2.5.2.2 Typical LOFT Delivery. See Figure 2-56. If the LOFT option is preselected in flight, the LOFT mode and associated weapons are called up when the pilot performs a WOF. The pilot then flies the aircraft to the azimuth steering line. At a point 6000 feet from the pullup point (approximately 8 seconds, based on range and airspeed), a pullup cue is displayed in the HUD. The pullup cue initialized 3° below the velocity vector and moves up to the velocity vector as the pullup point is approached. A series of tones are sounded in the pilot's headset indicating anticipation of a 4g pull to weapon release.

The first short tone comes on at 2 seconds to pullup indicating to the pilot to prepare for the pull. The second short tone is a preparatory tone that begins at 1 second to pullup. The third and final tone (ramp up tone) occurs as the pullup cue intersects the velocity vector and it indicates that the pilot should begin the ramp up to the release cue. This ramp up tone lasts for a duration of 1.5 seconds.

When the ramp up tone begins, the pilot initiates a 4g profile pullup (ramp up) and attempts to maintain a 4g pull. Once the ramp up begins, if the pilot pitches or rolls the aircraft greater than 45°, the MC assumes the LOFT was aborted and cause an automatic reversion to the AUTO delivery mode.

After the 4g ramp up ends, the pullup cue becomes a 4g programmer. The 4g programmer uses the position of the pullup cue in relation to the velocity vector to indicate what actions are needed to maintain 4g's. If the pullup cue is above the velocity vector, more g's are needed. If the pullup cue is below the velocity vector, less g's are required. When the cue and the velocity vector overlay each other, 4g's are being pulled.

NOTE

In Day Attack aircraft, the LOFT tones are sounded and broadcast over comm 1. In Night Attack and Radar aircraft the LOFT tones are sounded, but are not broadcast.

2.5.2.3 Checklist for LOFT Delivery

1. Select STRS display.

2. Select the appropriate weapon to be delivered.

3. Select proper fuzing options for store.

4. Select AUTO delivery mode using either cage/uncage button or ACP MODE switch.

5. Select the LOFT option on the DDI stores display.

6. Select WPN on UFC and cue ANGL if a different loft angle is desired (4° to 38°, Day Attack) (9° to 38°, Night Attack and Radar).

NOTE

- In Night Attack and Radar aircraft, the pilot entered loft angle is read by the system only at transition into LOFT mode or when target becomes designated. In Day Attack aircraft, the pilot entered loft angle is read by the system immediately upon data entry.

- In Night Attack and Radar aircraft, if a new loft angle is entered after LOFT has been selected and after the target has been designated, the system will use the previously entered angle. The pilot must undesignate/re-designate or deselect LOFT/ select LOFT to allow the system to use the new loft angle. If none exist the system will use the default.

7. Master Arm - ARM.

8. Continue run-in with no restrictions on maneuvering until the ramp up tone begins (coincides with the release cue appearing). Once the pullup begins, any maneuvering that causes the aircraft to exceed 45° pitch or roll will cause the delivery mode to revert to AUTO.

9. With pullup cue displayed, depress bomb pickle button.

10. At the first and second short tones, prepare to begin 4g pullup.

11. At the third tone begin the ramp up and fly a smooth 4g wings level pull to the cue for weapons release.

NOTE

The bomb pickle button must be released after the delivery is completed. Keeping the bomb pickle button depressed may result in an inadvertent secondary release.

2.5.2.4 LOFT Delivery Notes

1. The LOFT delivery mode is designed to bomb specific INS/GPS coordinates (i.e., EHSI designation). Due to the long ranges and low grazing angles associated with LOFT, do not use the TDC to "sweeten" the TD diamond.

2. The DMT (TV) can be used to look at the designation; however, do not attempt a TV lock on. Although a TV lock on can occur, there are insufficient angular rates for an ARBS height above target. During the pullup, sufficient angular rates are generated and the system switches from BARO or RALT to ARBS height above target, thereby causing the TD diamond to shift. This adversely affects the LOFT delivery solution.

3. Do not attempt to chase the pullup cue (4g programmer) after the ramp up tone, this can result in poor accuracy caused by the MC attempting to compensate for quick pitch changes. Instead, make smooth corrections

WEAPON CODE	DESCRIPTION	MAXIMUM LOFT ANGLE
1	(Spare)	N/A
2	(Spare)	N/A
3	Mk-81 (STD)/Mk-81 conical fin with blunt nose	38°
4	Mk-81 (STD)/Mk-81 conical fin with pointed nose	38°
5	Mk-81 (STD)/Mk-14 HD	30°
6	Mk-81 (STD)/Mk-14 LD	38°
7	Mk-81 (STD)/Mk-14 HD/LD	30°/38°
8	Mk-82 (STD)/Mk-82 conical fin with blunt nose	38°
9	Mk-82 (TP)/Mk-82 conical fin with blunt nose	38°
10	Mk-82 (STD)/Mk-82 conical fin with pointed nose	38°
11	Mk-82 (TP)/Mk-82 conical fin with pointed nose	38°
12	Mk-82 (STD)/Mk-15 HD	30°
13	Mk-82 (TP)/Mk-15 HD	30°
14	Mk-82 (STD)/Mk-15 LD	38°
15	Mk-82 (TP)/Mk-15 LD	38°
16	Mk-82 (STD)/Mk-15 HD/LD	30°/38°
17	Mk-82 (TP)/Mk-15 HD/LD	30°/38°
18	GBU-12B/B Laser Guided Bomb	38°
19	(Spare)	N/A
20	Mk-83 (STD)/Mk-83 conical fin with blunt nose	38°
21	Mk-83 (TP)/Mk-83 conical fin with blunt nose	38°
22	Mk-83 (STD)/Mk-83 conical fin with pointed nose	38°
23	Mk-83 (TP)/Mk-83 conical fin with pointed nose	38°
24	Test Set	N/A
25	Mk-76 on ITER	38°
26	Mk-106 on ITER	30°
27	BDU-33 on ITER	38°
28	BDU-48 on ITER	30°
29	(Spare)	N/A
30	GBU-16/B Laser Guided Bomb	38°
31	(Spare)	N/A
32	(Spare)	N/A
33	CBU-78/B GATOR	25°
34	(Spare)	N/A
35	(Spare)	N/A
36	(Spare)	N/A
37	CBU-100, Mk-20 Mod 10/12 (STD)	25°
38	CBU-99, Mk-20 Mod 9/11 (TP)	25°
39	ADSID III (Day Attack), ADSID V (Night Attack)	N/A
40	Mk-77 Fire Bomb	30°
41	5 inch ZUNI Single (Mk-71 Mod 1, Mk-63, Mk-93)	N/A
42	5 inch ZUNI Ripple (Mk-71 Mod 1, Mk-63, Mk-93)	N/A
43	2.75 inch FFAR Single (Mk-4, Mk-151) LAU-61	N/A
44	2.75 inch FFAR Ripple (Mk-4, Mk-151) LAU-61	N/A
45	2.75 inch FFAR Single (Mk-4, Mk-151) LAU-68	N/A
46	2.75 inch FFAR Ripple (Mk-4, Mk-151) LAU-68	N/A
47	Mk-24, Mk-45 Flares	N/A
48	SSQ-23/A Sonobuoy	N/A

Figure 2-55. Maximum Loft Angle for AV-8B Weapons (Sheet 1 of 2)

WEAPON CODE	DESCRIPTION	MAXIMUM LOFT ANGLE
49	SSQ-50/A Sonobuoy	N/A
50	MXU-648	N/A
51	AIM-9M	N/A
52	(Spare)	N/A
53	AIM-9L	N/A
54	AGM-65E Laser Maverick	N/A
55	AGM-65F IR Maverick	N/A
56	300 Gallon Fuel Tank	N/A
57	ALQ-164 DECM Pod	N/A
58	(Spare)	N/A
59	AGM-122A Sidearm	N/A
60	Mk-36 Destructor, Mk-62 Quickstrike (STD)/Mk-15 HD	30°
61	Mk-36 Destructor, Mk-62 Quickstrike (TP)/Mk-15 HD	30°
62	Mk-83 (STD)/BSU-85 LD	38°
63	Mk-83 (TP)/BSU-85 LD	38°
64	Mk-83 (STD)/BSU-85 HD	30°
65	Mk-83 (TP)/BSU-85 HD	30°
66	Mk-83 (STD)/BSU-85 HD/LD	30°/38°
67	Mk-83 (TP)/BSU-85 HD/LD	30°/38°
68	Mk-40 (Mk-83 STD)/MAU-91 HD	30°
69	Mk-40 (Mk-83 TP)/MAU-91 HD	30°
70, 71	(Spare)	N/A
72	LUU-2 Flare/SUU-25	N/A
73	LUU-2 Flare on ITER	N/A
74	Mk-36 Destructor, Mk-62 Quickstrike (STD)/BSU-86 HD	30°
75	Mk-36 Destructor, Mk-62 Quickstrike (TP)/BSU-86 HD	30°
76	TACTS	N/A
77	Mk-82 (STD)/BSU-33 with blunt nose	38°
78	Mk-82 (TP)/BSU-33 with blunt nose	38°
79	Mk-82 (STD)/BSU-33 with pointed nose	38°
80	Mk-82 (TP)/BSU-33 with pointed nose	38°
81	5 inch ZUNI Single (Mk-71 Mod 1, Mk-24, Mk-188)	N/A
82	5 inch ZUNI Ripple (Mk-71 Mod 1, Mk-24, Mk-188)	N/A
83	2.75 inch FFAR Single (Mk-4, Mk-1) LAU-61	N/A
84	2.75 inch FFAR Ripple (Mk-4, Mk-1) LAU-61	N/A
85	2.75 inch FFAR Single (Mk-4, Mk-1) LAU-68	N/A
86	2.75 inch FFAR Ripple (Mk-4, Mk-1) LAU-68	N/A
87	2.75 inch FFAR Single (Mk-66, Mk-151) LAU-61	N/A
88	2.75 inch FFAR Ripple (Mk-66, Mk-151) LAU-61	N/A
89	2.75 inch FFAR Single (Mk-66, Mk-151) LAU-68	N/A
90	2.75 inch FFAR Ripple (Mk-66, Mk-151) LAU-68	N/A
91, 92	(Spare)	N/A
93	Mk-82 (STD)/BSU-86 LD	38°
94	Mk-82 (TP)/BSU-86 LD	38°
95	Mk-82 (STD)/BSU-86 HD	30°
96	Mk-82 (TP)/BSU-86 HD	30°
97	Mk-82 (STD)/BSU-86 HD/LD	30°/38°
98	Mk-82 (TP)/BSU-86 HD/LD	30°/38°
99	No SCU	N/A

Figure 2-55. Maximum Loft Angle for AV-8B Weapons (Sheet 2 of 2)

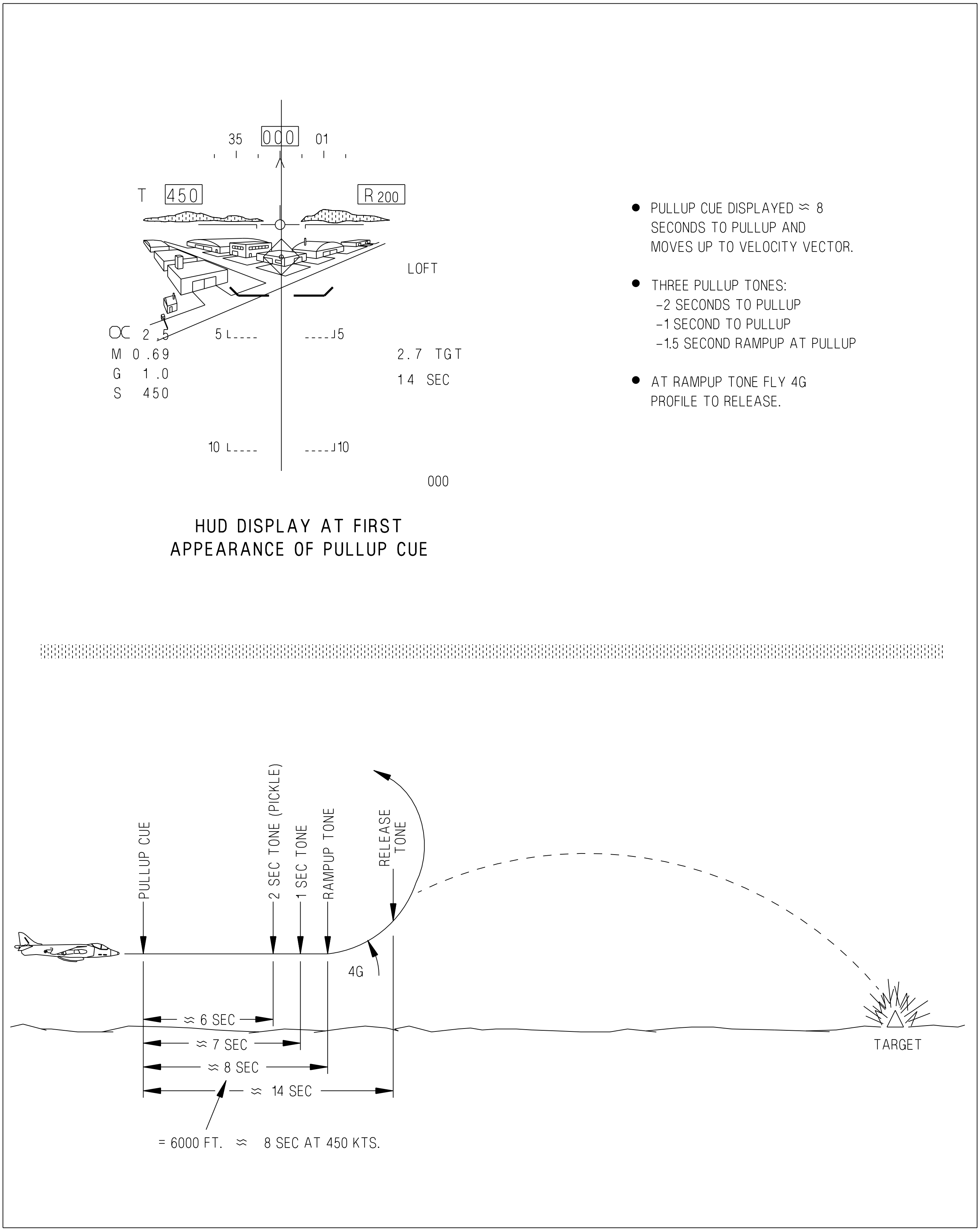

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Figure 2-56. Loft Delivery Mode

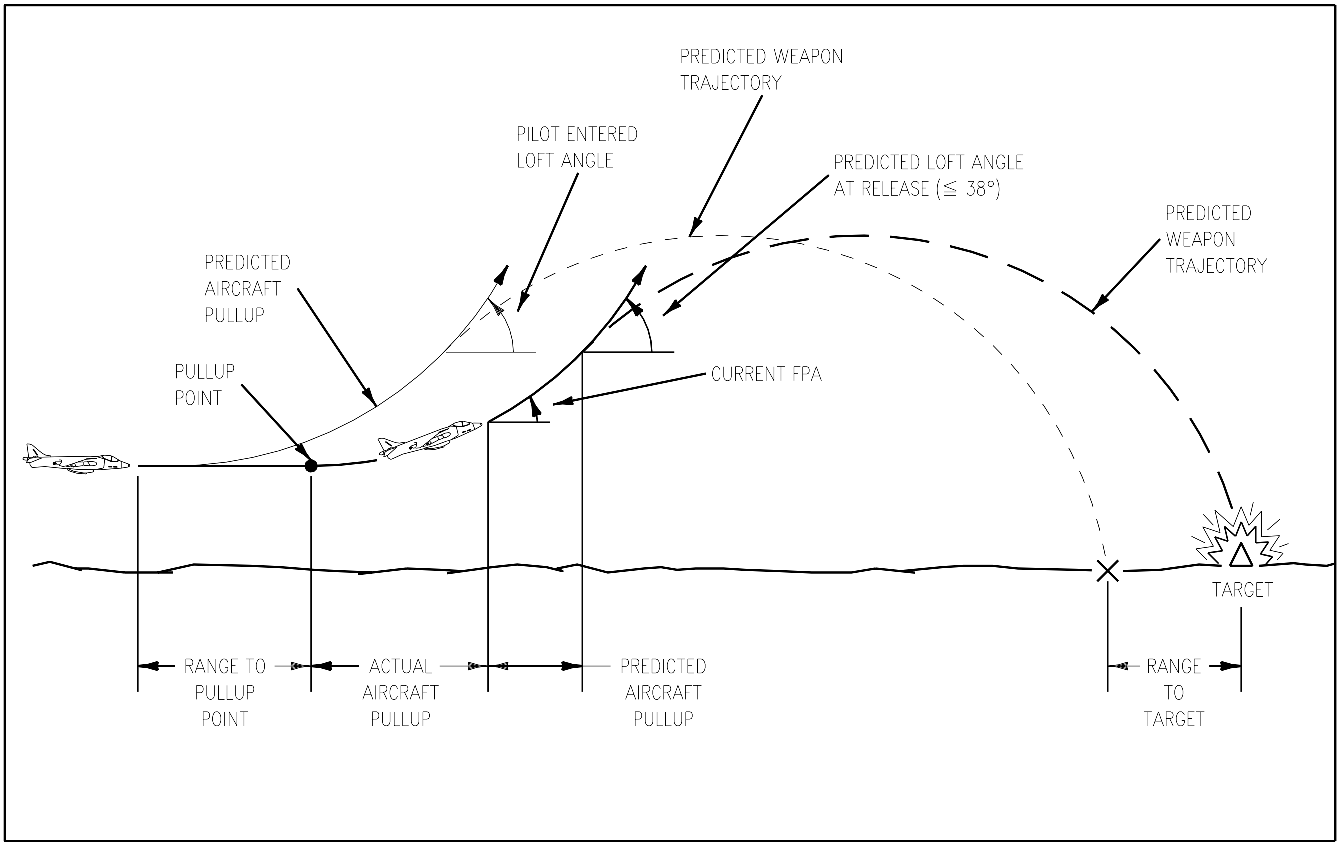

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Figure 2-57. Loft Computations

and attempt to fly at wings level, and pull up the azimuth steering line to the release cue.

4. For weapons using the FMU-140 fuze, the following situation may occur, depending on what master mode the weapon is programmed or selected and if ingress altitude is currently below HOF altitude. These may have a direct impact on LOFT delivery symbology.

(a) If a weapon with an FMU-140 fuze is programmed or selected in the A/G master mode, while the aircraft is below the HOF altitude, the system is computing AUTO ballistics and believes the weapon will dud. The system will display a flashing ″DUD″ cue as long as AUTO mode is selected. The ″DUD″ cue will be removed when LOFT is selected.

(b) If the weapon is programmed or selected in the NAV or VSTOL master mode, normal attack symbology will be available during the LOFT delivery.

2.5.2.5 Loft Computations and Limitations. Prior to reaching the pullup point, the pilot-entered loft angle is used by the system to predict the aircraft pullup trajectory and the weapon trajectory. See Figure 2-57. When the aircraft is past the pullup point and the target is in-range the system continuously adjusts the loft angle to keep the predicted impact point on the target. This continues up to the point of weapon release, so long as the loft angle internal to the system is less the 38°. Typically the internal loft angle will be greater than the pilot entered angle in situations where the actual g-profile is greater than the predicted 4g schedule. In LOFT mode weapon release occurs when the aircraft flight path angle equals the internal loft angle.

NOTE

This is unlike AUTO mode where weapon release occurs when weapon range equals target range and time-to-go is determined by range-to-go and range rate. That's the difference between a Continuously Computed Impact Point (CCIP) and a Continuously Computed Release Point (CCRP).

When the internal loft angle is ″saturated″ (equal to 38°) the computations are limited and the system can no longer keep the impact point on the target. In situations where the internal loft angle is limited weapon release occurs when aircraft flight path angle reaches 38°, regardless of the range to the target. There is nothing displayed to the pilot to indicate this condition exists. *For accurate weapon delivery it is important to keep the velocity vector at or below the pullup cue as much as possible.*

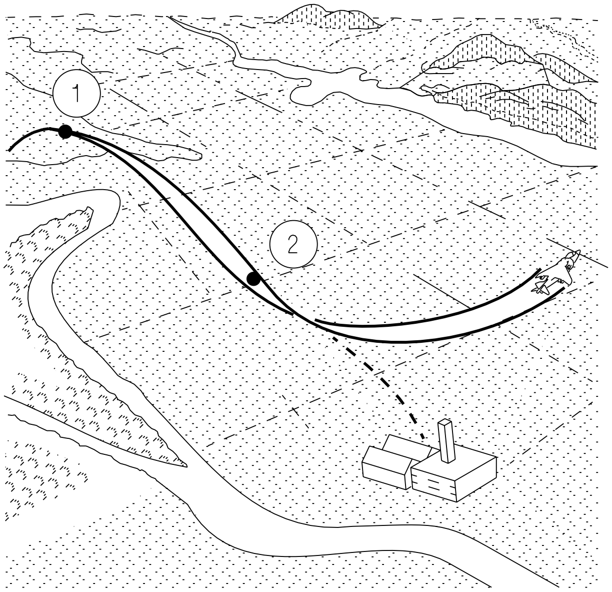
To provide some margin for error in following the pullup cue, Night Attack and Radar aircraft use an internal loft angle that is initialized at 5° less than the pilot entered angle. This is done internal to the system; there is no action required by the pilot. Day Attack aircraft do not have any such buffer. Therefore, Day Attack aircraft are more likely to have short impacts if the pullup cue goes below the velocity vector (over-pull). Because of this internal buffer Night Attack and Radar aircraft limits the angle entry to be between 9° and 38° instead of 4° and 38° like Day Attack aircraft. If short impacts are experienced in Day Attack aircraft the pilot should enter angles less than 38° (default). Because there are other variables involved besides normal acceleration, leading the pullup cue (pulling more than 4g's) does not necessarily mean impacts will be short. However, given a choice, it is better to lag, rather than to lead, the pullup cue.

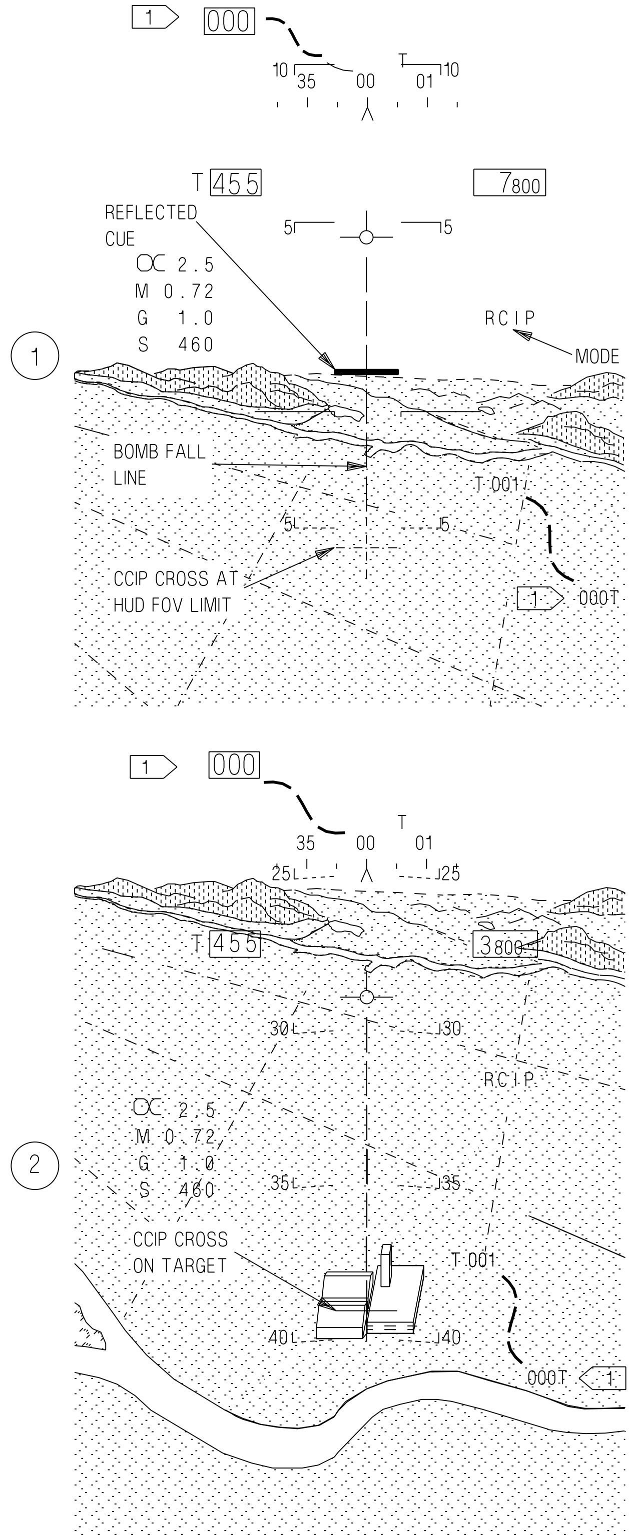
Only the internal loft angle is adjusted: loft angle entered by the pilot and displayed on the Stores page remains unchanged. Because of variations in the pullup profile (g-onset rate, increasing throttle setting, lagging/leading the pullup cue) the flight path angle at release (as seen on the WRD) typically will not be the same as what was entered by the pilot.

2.5.2.6 LOFT Ripple Deliveries. For ripple deliveries in LOFT mode the angle entered by the pilot is the desired angle at the last release in the stick. Here again, once the pullup point is passed and the pullup has begun the system adjusts the internal loft angle to keep the mid-point of the stick on the target. The limitations of adjusting the loft angle above 38° also apply to ripple deliveries and the mean point of impact (MPI) will likely be short if the last weapon release occurs at 38°.

2.5.3 CCIP Delivery Mode. The CCIP delivery mode is a computed visual delivery mode with manually initiated weapon release. It is selectable by the pilot for bomb deliveries. It is automatically enabled with gun or rocket selection if the DSL mode has not been selected by the pilot or auto-reversion has occurred. In the CCIP mode, the ground impact point is continuously computed and displayed as a cross on the HUD. The pilot's task is to maneuver the aircraft to position the CCIP cross on the target. At coincidence, the pilot presses the bomb pickle button to drop bomb(s). CCIP delivery is summarized in Figure 2-58.

The vertical line originating just below the velocity vector in Figure 2-59 is the bomb fall line (BFL). The BFL consists of 20 milliradian segments with 5 mils between segments, and may be used as a reference to judge tracking motion of the CCIP cross to the target. The CCIP cross becomes dashed when limited and the reflected CCIP symbol appears. Immediate weapon





- FLY AIRCRAFT TO POSITION CCIP CROSS ON TARGET
- PRESS BOMB PICKLE BUTTON

LEGEND

1 DAY ATTACK AIRCRAFT

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Figure 2-58. CCIP Delivery

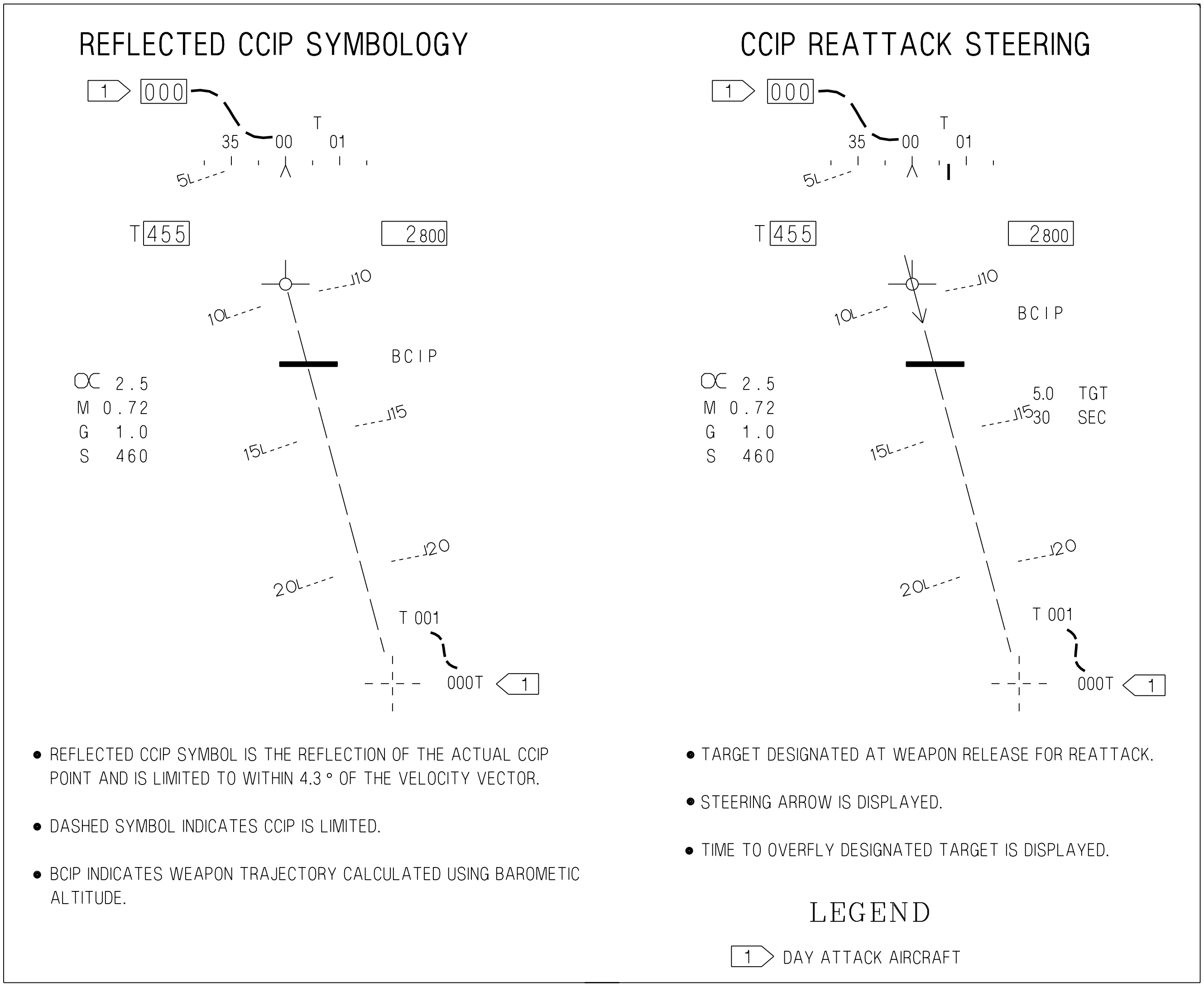

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Figure 2-59. CCIP Mode Symbology

release is inhibited in CCIP when the reflected CCIP symbol appears. The heavy line across the bomb fall line is the reflected CCIP symbol.

The reflected CCIP symbol indicates how far the impact point is below the HUD field of view. It is reflected about the end of the bomb fall line. (The closer the reflected symbol is to the velocity vector, the further the actual CCIP cross is from the HUD FOV.) As the weapon impact point approaches the HUD FOV, the reflected symbol begins to fall. When it reaches the bottom of the bomb fall line, it is replaced by the solid CCIP cross. This mechanization provides a cue to the pilot for the CCIP cross entering the HUD FOV.

At weapon release, the computed impact point is designated for reattack and the TD diamond appears at the CCIP symbol. The steering arrow appears at the velocity vector after overfly indicating relative bearing to the designated target as shown in Figure 2-59. If a target is designated in the CCIP delivery mode, by any means, time to overfly the designated point from the aircraft present range is displayed on the HUD below the TGT legend regardless of bearing when time is less than 99 seconds.

After release an attack line is displayed on the EHSI/EHSD through the TD diamond as in the AUTO mode.

2.5.3.1 CCIP-to-AUTO Conversion. When the computed impact point is outside the HUD FOV in the CCIP mode, the MC inhibits weapon release. If the pilot determines from the flight conditions and the reflected cue position that the computed impact point will not be brought within the HUD FOV, he must either rapidly alter the flight profile or designate the target and convert to the AUTO mode. Refer to Figure 2-61. Target designation and conversion to the AUTO mode can be rapidly accomplished on the first pass by placing the dashed CCIP cross on the target and pressing the bomb pickle button. This action designates the point under the dashed cross and the weapon system converts to an AUTO mode delivery. The pilot follows the AUTO mode steering and the weapon is automatically released on the designated target. The CCIP mode HUD symbology returns when the pilot releases the bomb pickle button.

2.5.3.2 Maximum Altitude for CCIP Display. In Day and Night Attack aircraft CCIP symbology for all weapons is displayed up to 40,000 feet MSL. In Radar aircraft, CCIP symbology is displayed for all low drag weapons up to 40,000 feet MSL, but is not displayed if the airspeed, altitude, and flight path angle of the aircraft are outside the ballistic algorithm envelope for high drag weapons (CBU, rockets, guns, HD bombs). See Figure 2-60.

2.5.4 DSL Delivery Mode. The DSL mode provides a weapon delivery capability should the MC, ADC, INS, HUD, or avionics multiplex data bus fail or any time the pilot feels a manual delivery is necessary. The DSL mode is only selectable on the ACP. Two different reticles are available; either the roll stabilized sight reticle (selected on the DDI) or the standby reticle (selected on the HUD control panel) may be used in the DSL mode. Either of these two reticles may be selected with a full up weapon system. However, the roll stabilized sight is the preferred reticle when available. The roll stabilized sight is not available after loss of the INS, HUD, or avionics multiplex data bus. The standby reticle is only available on Day Attack aircraft. After sight selection, the pilot maneuvers the aircraft to position the reticle cursor on target while meeting predetermined release conditions, and manually initiates weapon release.

WEAPON	FPA	ALTITUDE
2.75 inch Rockets (Store Code 87)	0° -10° -20° -30° -45° -60°	5400 9500 14000 19000 26000 31000
Mk 80 Series High Drag (Store Code 96)	0° -10° -20° -30°	3300 4200 5000 5700
WEAPON	FPA	ALTITUDE
Mk 20 Rockeye (Store Code 37/38)	0° -10° -20° -30° -45° -60°	6100 7300 8500 9600 10500 12000

Figure 2-60. Radar Aircraft Max ORD Release

The HUD DSL mode symbology is shown in Figure 2-62. If the standby reticle is used, the selected cursor depression angle in milliradians is displayed just beneath the reticle diamond. Fly the aircraft to position the cursor on the target or aim point while meeting the predetermined airspeed, altitude, and dive angle release conditions for which the cursor depression angle was selected. Press the bomb pickle button when these conditions are met. When a stick release is being performed, the SMC controls the interval spacing in milliseconds, and the release sequencing. The SMC updates the stores inventory status at weapon release and relays the information to the MC for display.

Target designation may be performed in this mode. However, the only purpose is for target finding (navigation designation) and for maintaining the target location for reattack.

The standby reticle is independent of normal HUD symbology; it is turned on and depression angle selected using the STBY RET controls on

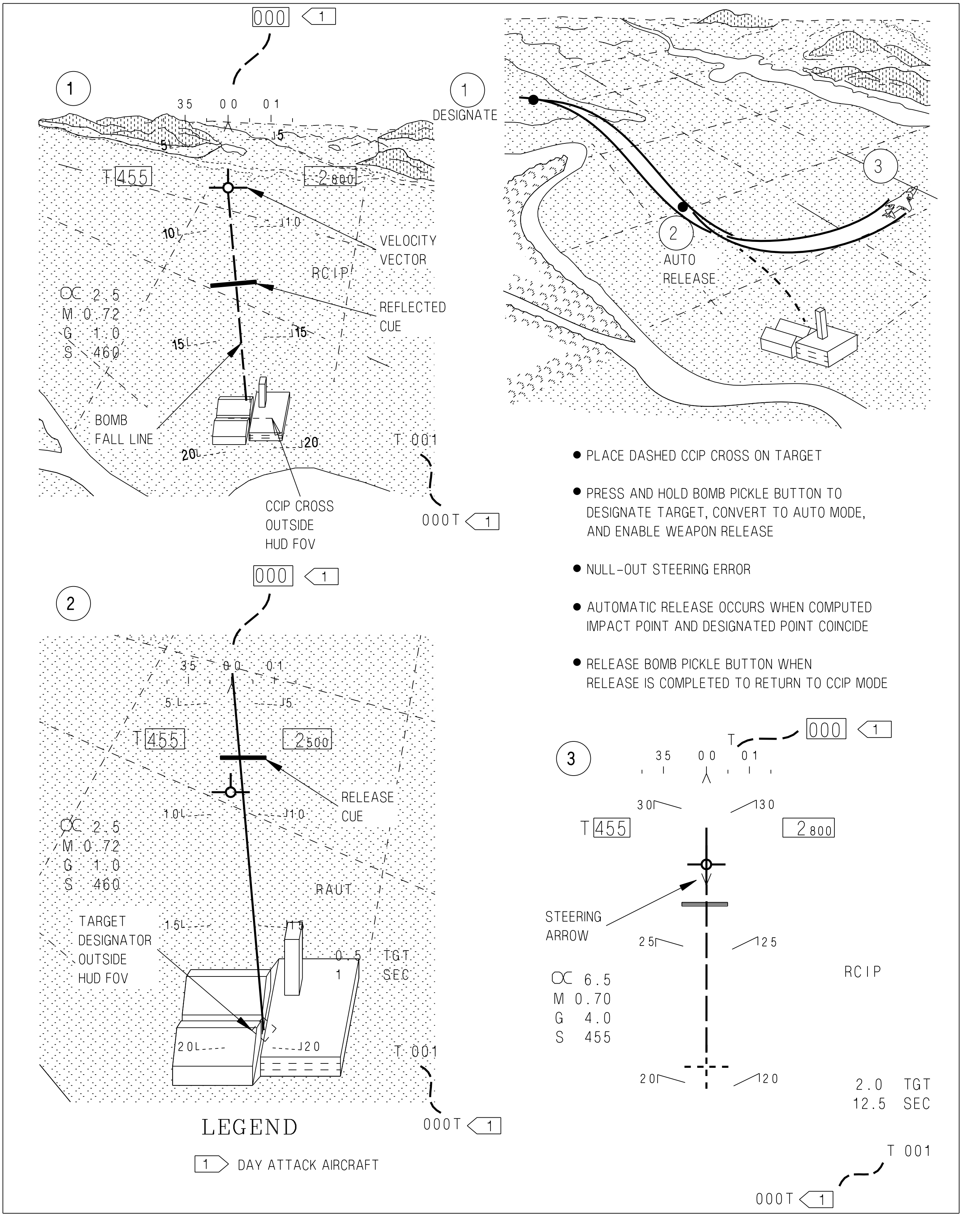


Figure 2-61. CCIP to AUTO Conversion

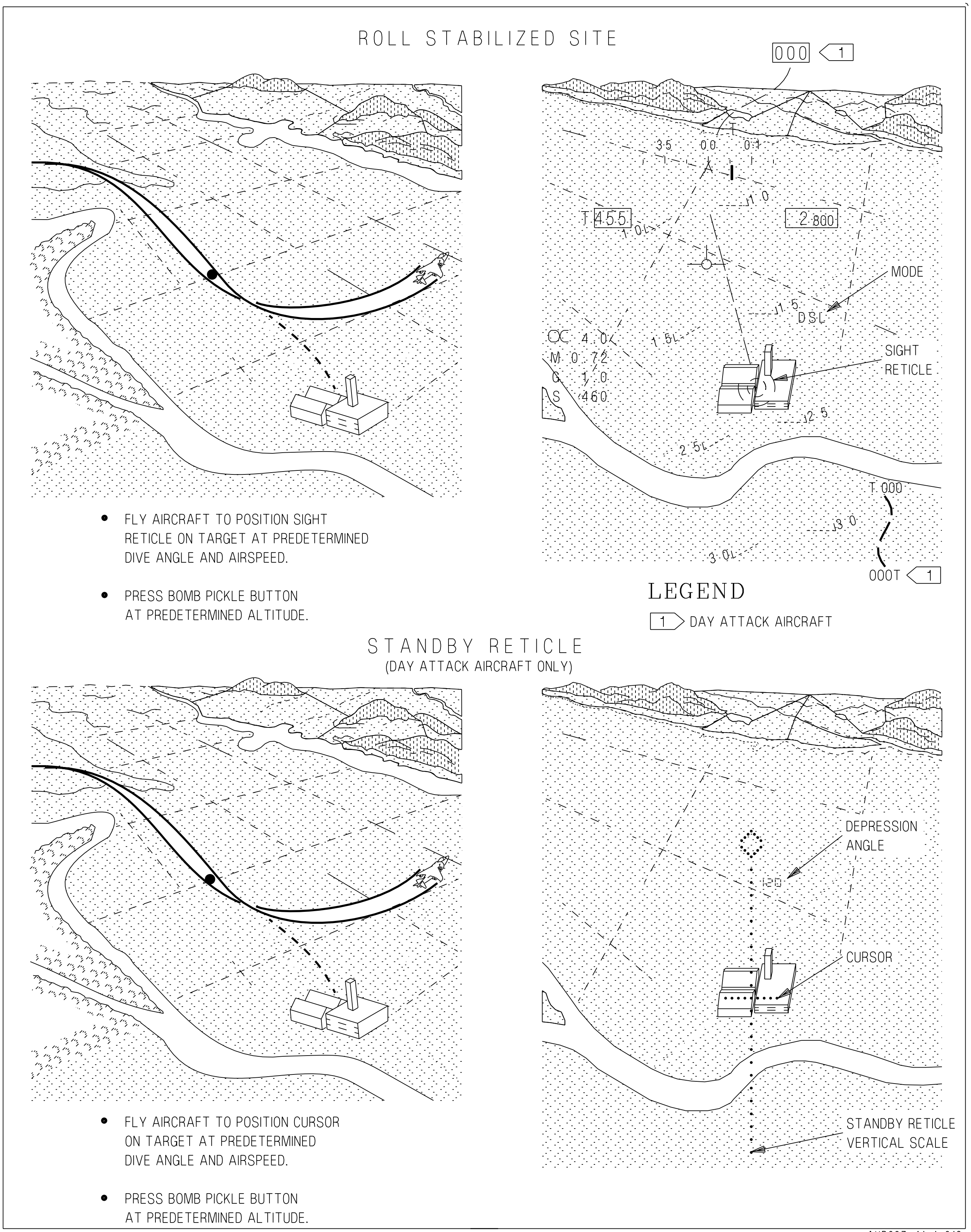


Figure 2-62. DSL, DIR, and DSL(1) Delivery.

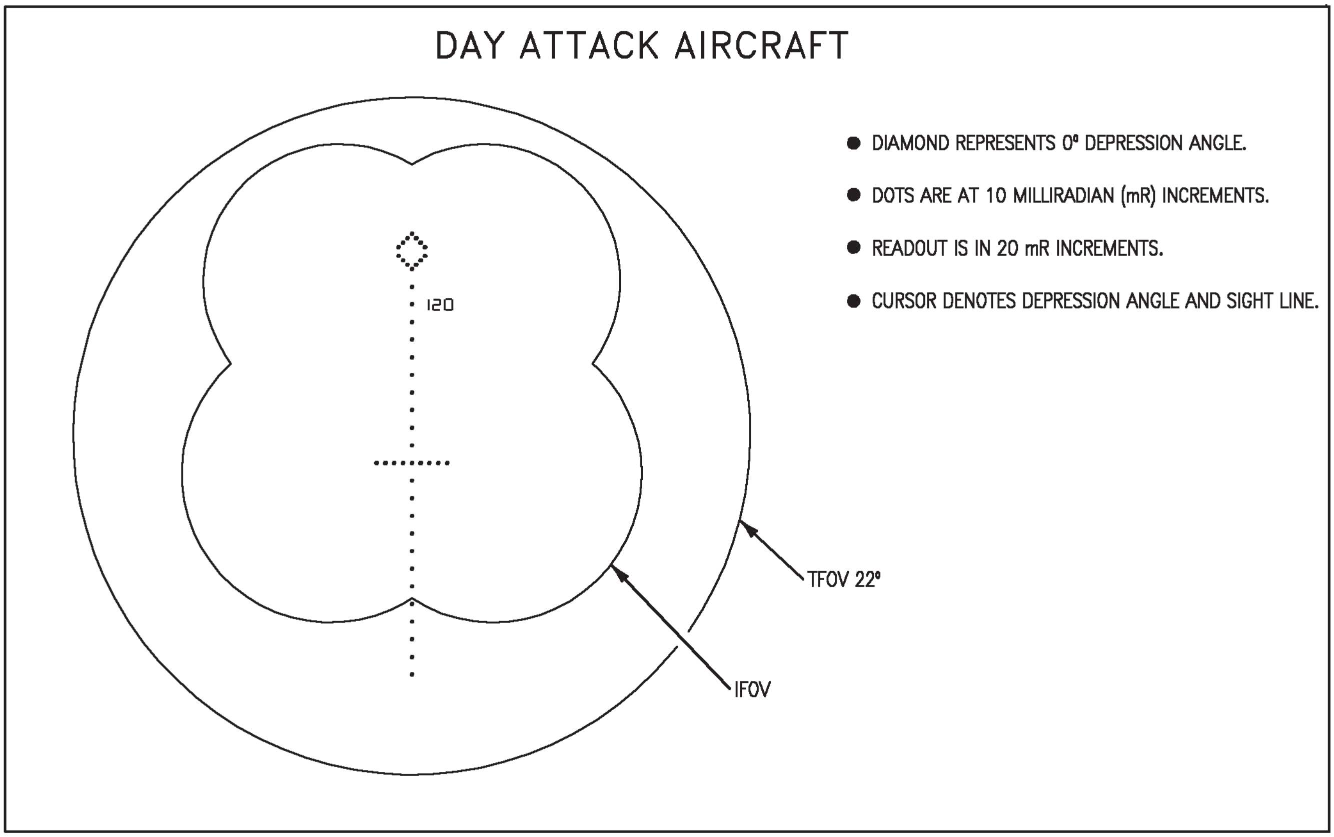


Figure 2-63. HUD Standby Reticle

the HUD control panel as described in Chapter 1. It may be selected in any master mode.

As shown in Figure 2-63, the standby reticle is graduated in 10 milliradian increments. The pilot can enter depression angles of zero to 240 milliradians in 20 milliradian increments. A digital readout of the depression setting and a cursor are provided on the standby reticle display to indicate depression angle setting.

The roll stabilized sight can be provided on the HUD in the A/G master mode. Symbology displayed depends upon the delivery mode selected. It is available for AUTO, CCIP, DSL, DIR, and DSL(1) weapon deliveries. The roll stabilized sight is not available after loss of the INS, HUD, MC, or avionics mux data bus. However, when it is available, it is the preferred noncomputed aiming reticle. The pilot enables sight selection by pressing the SITE pushbutton on the DDI stores display and SITE option select button on the ODU as described in Chapter 1. The last entered depression angle is displayed on the scratch pad and the UFC is enabled for entry of a new depression angle. The depression angle may be changed in 1 milliradian increments between 0 and 270 mils. If the SITE option is cued, the roll stabilized sight or the roll stabilized carets appear on the HUD in the A/G mode. If not cued, the sight is removed from the HUD. The SITE option is automatically deselected when transitioning from weight-off-wheels to weight-on-wheels. The roll stabilized sight emanates from the waterline position (imaginary point midway between top of airspeed and altitude boxes) and terminates at the pilot selected depression angle as shown in Figure 2-64.

The inner circle of the aiming reticle is a 15 milliradian diameter dashed circle with a dot in the center. Outer circle segments are displayed 15 milliradians from the center (for a 30 mil diameter). The dashed line emanating from the waterline consists of 20 milliradian segments separated by 5 milliradians.

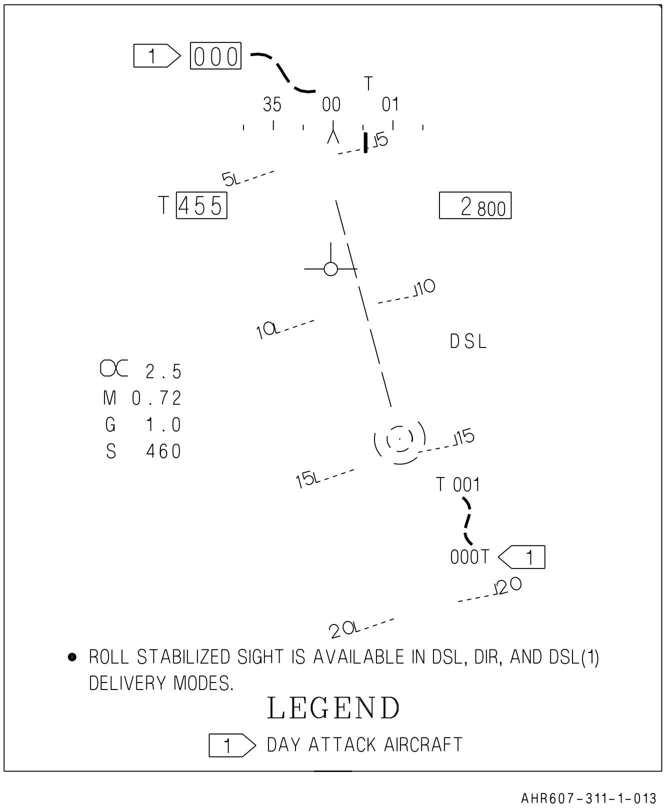


Figure 2-64. Roll Stabilized Sight

When the roll stabilized sight is selected in the AUTO or CCIP mode, the sight is removed, but the selected depression angle referenced to the waterline is depicted by aiming carets as shown in Figure 2-65. The AUTO and CCIP modes operate as previously described, with the additional aid of a manual aiming reference as a computed solution cross check. In addition, if the system reverts to DSL or any backup mode, or the pilot selects DSL, DIR, or DSL(1), the roll stabilized sight appears.

2.5.5 DIR Delivery Mode. The DIR mode provides a backup weapon delivery capability for limited weapon employment. The system reverts to DIR when the SMC fails, resulting in loss of the AUTO, CCIP, AGM, and DSL modes. No electrical bomb fuzing is available and the roll stabilized sight or standby reticle must be employed in the same manner as explained in the DSL mode. The DIR mode HUD symbology is shown in Figure 2-62. If a program is available, the ACP selects and displays the backup program when the DIR mode is selected. If another type of weapon was selected and the weapon system reverts to the DIR mode, the weapon type, station selection, and weapon parameters may therefore change. The DIR mode may be manually selected and a different program entered when desired.

The pilot may select the DIR mode by deselecting all weapon stations (ACP indicators display dash or zero), selecting A/G master mode, then selecting DIR on the ACP. Select the weapon(s) by selecting the weapon stations. When a station is initially selected, FUZ changes to SAFE, QTY and MULT change to 1, and INTV remains 0. After this initial programming, the interval can be changed. Refer to NWP 3-22.5-AV8B, Vol. II, Chapter 5; see General Note regarding minimum allowable interval selection in DIR mode.

When the multiple is greater than one, the minimum is 60 milliseconds. Pilot selection of the minimum allowable interval, however, does not assure that a safe interval has been selected. If more than one station is selected, the only multiples selectable are one and a number equal to the stations selected. For example, if you have 10 Mk 82's (on ITERS) loaded on stations 2, 3, 5 and 6 and you select all four stations on the ACP, you will only have a choice of a multiple of one or four. If you select a multiple of one you will be able to select a quantity from 1 to 10. If, however, you attempt to increase the multiple it gives you a multiple of four and the only quantity choices are 4, 8, or 12. Releasing a multiple greater than two is not authorized; therefore, to ripple pairs, only select two stations at a time. You will be able to select a multiple of one or two and quantity can be increased to equal the total number of bombs on those stations. If a multiple of one is selected, the quantity can be increased sequentially up to the total number of bombs possible on the stations selected (maximum of 14). If a multiple equal to the stations selected is used, each time quantity is increased it increases by the multiple selected; however, increase in quantity is limited by the number of bombs available on each station selected. Quantity can be decreased in the reverse manner.

DIR programming can and should be done in the planning phase for weapons and the ACP

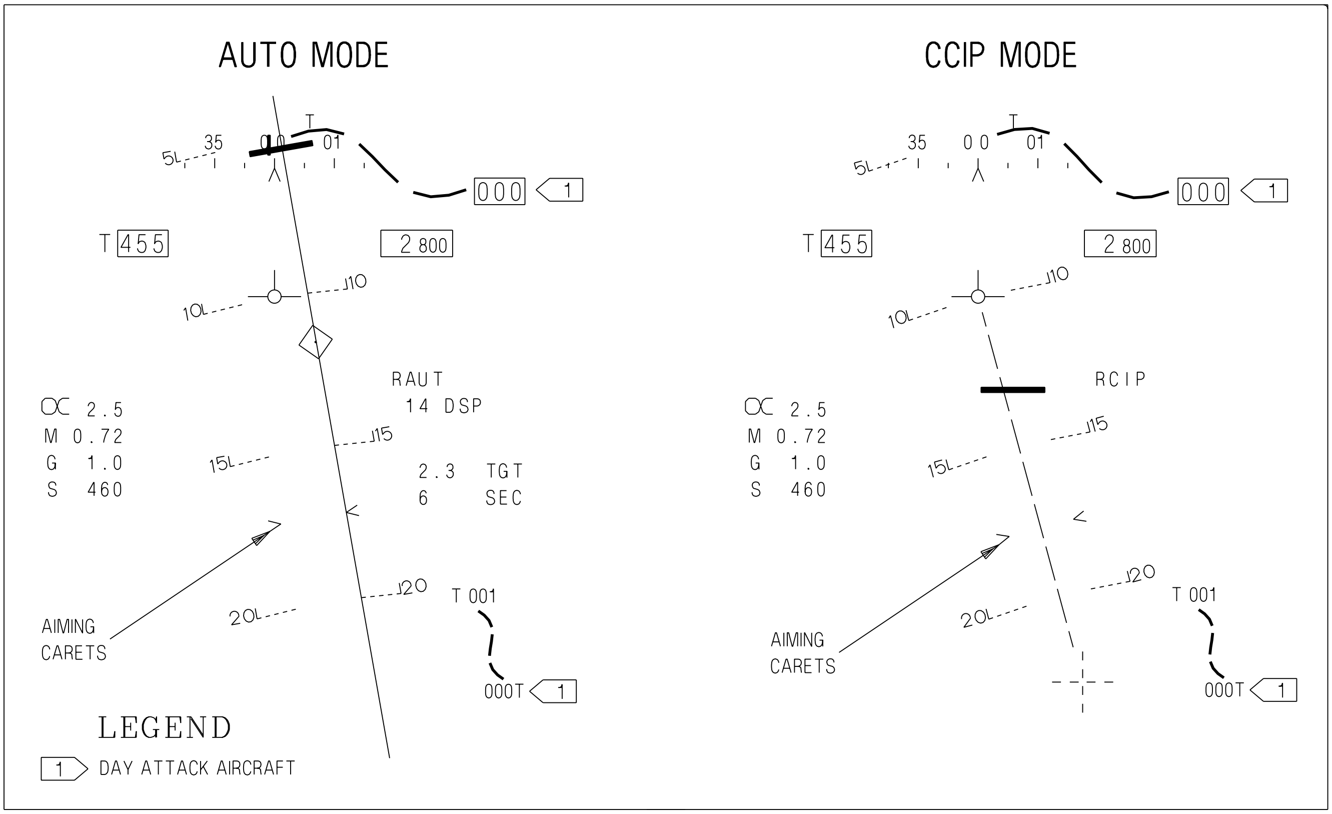
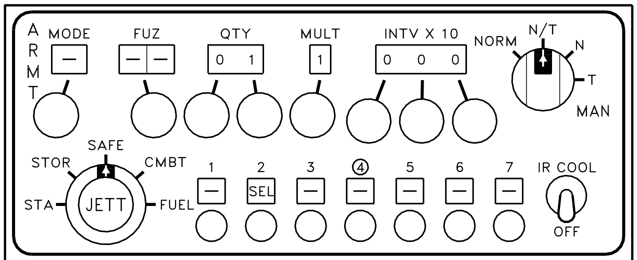


Figure 2-65. Roll Stabilized Sight Carets

programming conducted while in the line prior to taxi or at a minimum during the ″fence check.″ If the system fails in flight and reverts to DIR the program initializes to what was last selected. With the roll stabilized sight colonized the site automatically appears and the pilot is able to deliver ordance without a lot of ″heads down″ time.

It is important to realize that in the DIR mode, even if pilot selected with a full up SMCS, the interval and desequencing of bombs is not controlled by the SMC. The processor in the ACP controls all desequencing and spacing based on pilot station selection and a preprogrammed maximum capacity bomb load. The ACP does not have a loadout insertion panel like the SMC and, therefore, has no real world knowledge of what weapon is on what station. (More than one type of bomb may be selected.) This means the pilot retains the capability to drop singles, ripples, salvos, and salvo ripples, but it is his responsibility to ensure it is a safe drop since the SMC is taken out of the loop.

2.5.6 DSL(1) Delivery Mode. The DSL(1) (manual) mode provides a backup weapon delivery capability when the SMC and ACP fail, allowing manual fuze arming to be used to arm the weapons. The roll stabilized sight or standby reticle must be employed in the same manner as explained in the DSL mode. The DSL(1) mode symbology is shown in Figure 2-62. The DSL(1) mode is selected by rotating the manual control knob (Figure 2-66) to one of the backup arming positions. No electrical bomb fuzing is available. When the DSL(1) mode is selected, the last weapon station(s) selected in the DSL(1) mode are reselected and the bombs carried on those stations are manually armed. More than one type of bomb can be released if the weapon stations selected are loaded differently. If different stations/weapons are desired, the pilot must manually select them with the station select buttons. The ACP weapon program controls are deactivated and only one bomb from each selected station can be released with each actuation of the bomb pickle button.



1. MANUAL (MAN) CONTROL KNOB–N/T, N OR T

(A) MOVING KNOB OUT OF NORM SELECTS DSL(1) AND FUZING OPTION.

(B) PROGRAM OPTION SWITCHES ARE INOPERATIVE AND DISPLAY DASH (–) OR ZERO (0).

(C) SELECTION OF THE DSL(1) MODE WILL CAUSE THE STATIONS LAST SELECTED IN DSL(1) TO BE RESELECTED.

2. STATION SELECT BUTTON(S)–AS REQUIRED

(A) MORE THAN ONE TYPE OF WEAPON CAN BE SELECTED WHEN STATIONS ARE LOADED DIFFERENTLY.

AV8BB–TAC–00–(265–1)12–CATI

Figure 2-66. DSL(1) Mode Selection

Like the DIR mode, the SMC does not control weapon selection; therefore, it is the pilot's responsibility to ensure a safe drop. The pilot has the capability of selecting a single or salvo release in DSL(1). In the DSL(1) mode, a maximum of two stations may be selected only when the two stations selected meet these conditions:

1. The two stations selected are symmetric to each other (i.e., 1 and 7)

2. The two stations selected are loaded with the same store type.

2.5.7 CCIP Gun Mode. The fuselage gun is normally fired in the CCIP mode and can be fired in the DSL mode. The CCIP mode is automatically enabled with gun selection if the DSL mode is not enabled. The DSL mode is selected via the ACP or as an automatic reversion mode with the loss of the CCIP mode.

The GAU-12/U 25mm fuselage gun is selected by pressing the GUN option on the DDI stores display. When enabled the GUN legend is boxed (Figure 2-67).

With fuselage gun selected or master arm in ARM, the SMS opens the engine air shut off valve and verifies that it has opened. The engine air valve open time ranges between 0.75 and 3.0 seconds. To achieve the conditions necessary for gunfire the following must be accomplished:

1. Fuselage gun selected (boxed) on DDI.

2. Master arm switch to ARM.

3. Engine air shut off valve open.

4. Engine fan speed sufficient to provide 60 psi air to the gun (Figure 2-68).

5. SMS BIT has not detected a SMC gun related failure.

6. Fuselage gun installed

7. Trigger squeezed to second detent

If the SMC processor has failed, the fuselage gun is selected whenever A/G master mode is selected.

As shown, the stores display also displays the rounds remaining at the center of the wing form. Waypoint offset entered target elevation and the current gun mode (CCIP) are also displayed. The maximum and minimum range selected for the A/G gun reticle is displayed below the target elevation. The NOT CLEAR legend is displayed for the fuselage gun if a live round remains in the breech. A flashing WPN FAIL legend is displayed for an SMS function failure or for fuselage gun not clear. The pilot must select the SMSFF option on the BIT display to determine the cause. The pilot can assume that the fuselage gun is not clear if a flashing inhibit cue is present on the HUD when the gun is selected and the rounds remaining indication is not zero. The pilot must select the SMSFF option to remove the release inhibit cue. A live round can remain in the breech due to a gun malfunction or when power is removed before the clearing cycle is completed. To prevent this, the pilot should not

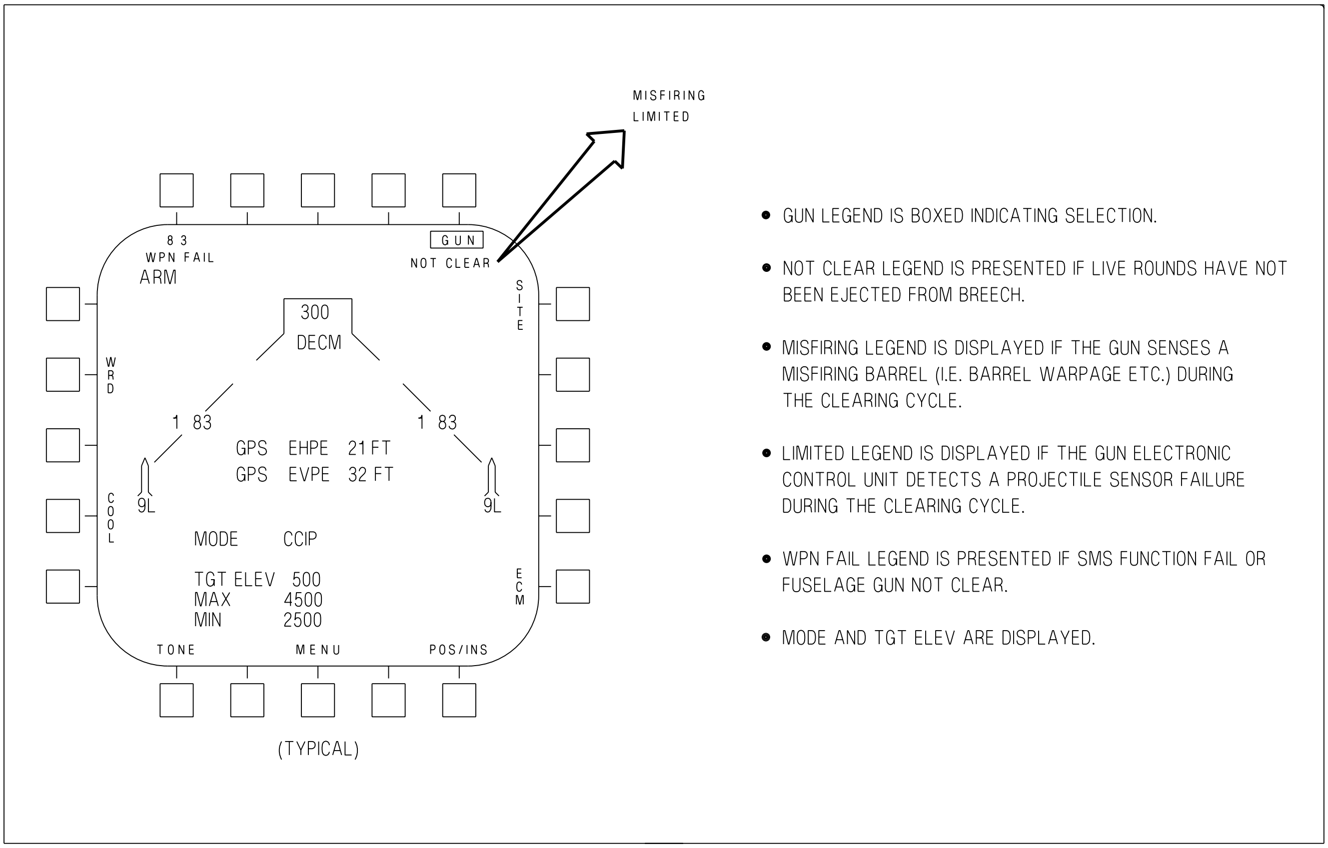


Figure 2-67. Gun Selection

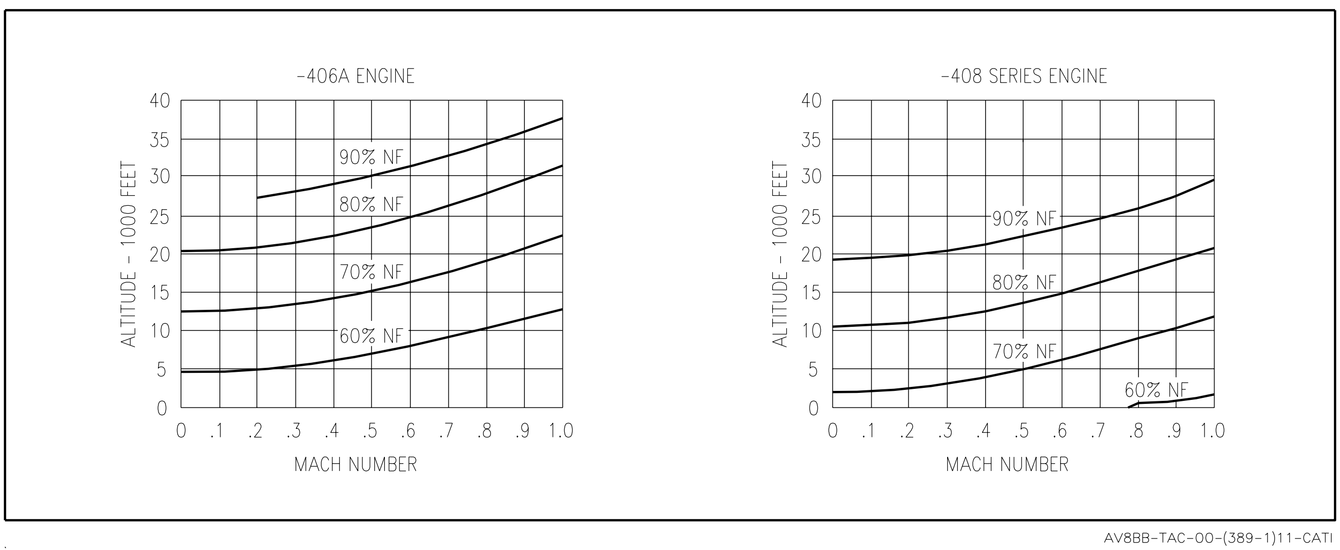


Figure 2-68. Power Setting Required to Provide 60 PSI Air Pressure to 25 mm Gun

place master arm to OFF (SAFE) or deselect the gun on the DDI until 1 or 2 seconds after trigger release. The gun normally takes 0.5 second to clear after trigger release.

On Day and Night Attack aircraft two additional fail indications, MISFIRING and LIMITED, can also be displayed. The fail indication MISFIRING is displayed if the gun senses a misfiring barrel (i.e. warped barrel, etc.) during the clearing cycle.

Under this condition, only one 20 round burst capability remains. Subsequent actuation of the trigger *will not* fire the gun. If the gun electronic control unit (ECU) detects a projectile sensor failure during the clearing cycle, the fail indication LIMITED will be displayed.

When the LIMITED indication is displayed the gun will only provide a 20 round burst capability with each actuation of the trigger. This means that no matter how long the pilot holds the trigger, only 20 rounds will be fired.

If the pilot does not fire the gun after a LIMITED failure occurs, the gun should remain clear. However, if the pilot does fire the gun with a LIMITED failure indication, there is no guarantee that the gun will completely clear. With a LIMITED failure, the ECU safes the gun after a 20 round limited burst and proceeds into the clearing sequence. If the pilot holds the trigger, the reverse command is locked out and the gun will continue to rotate forward (not firing). Under these conditions (defective projectile sensor), once the pilot releases the trigger the gun will only backup a default number (8) of sprocket counts. This will more than likely result in a HOT gun, and appropriate measures should be taken. This also results in rounds downstream which will not be available for firing.

CAUTION

- When a flashing release inhibit cue appears on the HUD with fuselage gun selected and rounds remaining and/or a flashing WPN FAIL legend appears on the DDI, a gun malfunction should be assumed.

- If the NOT CLEAR legend is present 2 seconds after trigger release, a gun malfunction should be assumed. The fuselage gun (GUN) should be deselected on the DDI and master arm placed to OFF (SAFE) to close the engine air shut off valve.

If the fuselage gun is not deselected and master arm placed to SAFE, the aircraft will continue to provide engine bleed air to the gun. If the gun system failure is such that air is allowed to flow through the gun drive unit, overheat conditions could occur which would result in cook off of rounds in the breech area. Gun damage could result if gun fire is attempted when the gun NOT CLEAR and/or WPN FAIL legend is displayed on the DDI.

The 25 mm gun GUN NOT CLEAR legend is displayed on the SMSFF page of the BIT display until BIT is cleared after touchdown. At touchdown (weight-on-wheels) the engine air shut off valve is automatically closed if still open.

Gun selection is indicated on the HUD by the presence of the A/G gun aiming reticle and the rounds remaining/gun legend.

The A/G gun reticle appears as a circle with range markings. Tape around reticle represents slant range to impact point. The dot in the center of the reticle indicates the computed bullet impact point on the earth surface (Figure 2-69). Carets are displayed on the outside of the reticle to indicate the maximum and minimum firing range selected by the pilot. The maximum and minimum range selected matches the clock position of the carets. Typical range selections and the representative caret position on the reticle circumference are as follows:

Slant Range	Caret Position
1,500 feet	12:00 o'clock
2,333 feet	3:00 o'clock
3,167 feet	6:00 o'clock
4,000 feet	9:00 o'clock
5,000 feet	10:30 o'clock
6,000 feet	12:00 o'clock

When the fuselage gun rounds count reaches zero, the weapon inhibit cue is presented on the HUD. The aiming reticle remains displayed and the gun still may be fired due to possible miscount of rounds remaining.

The aiming task for the pilot is to (1) check the maximum and minimum range values for the A/G gun reticle, (2) maneuver the aircraft to position the reticle on the target, and (3) when in range, squeeze the trigger until the target is destroyed or minimum range is reached.

The gun aiming reticle is limited to a 10° radius from the HUD TFOV center. It becomes dashed at the limit. Whenever the gun reticle touches the velocity vector, the velocity vector is removed to declutter the HUD.

Once selected in A/G, the fuselage gun remains selected unless deselected by pressing the gun pushbutton again on the DDI. Selecting another A/G weapon either before or after selecting the fuselage gun results in both weapons being selected. It does not deselect the fuselage gun. This condition is known as “hot gun” is indicated by the boxed GUN and primary weapon legends on the DDI stores display (Figure 2-70).

Gun firing can then be initiated with the trigger, and weapons released with the bomb pickle button. Hot gun is indicated on the HUD by display of a gun cross in addition to the appropriate attack symbology shown in Figure 2-70.

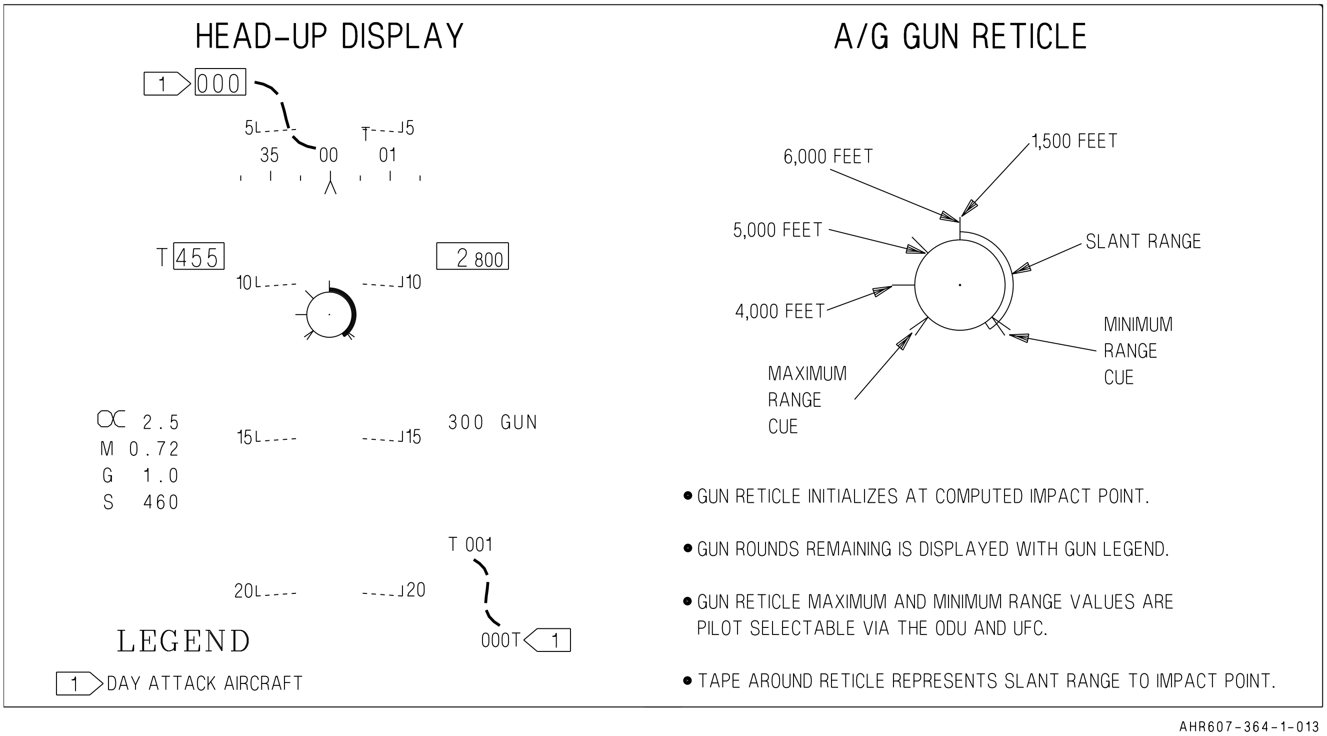


Figure 2-69. HUD Gun Symbology (A/G)

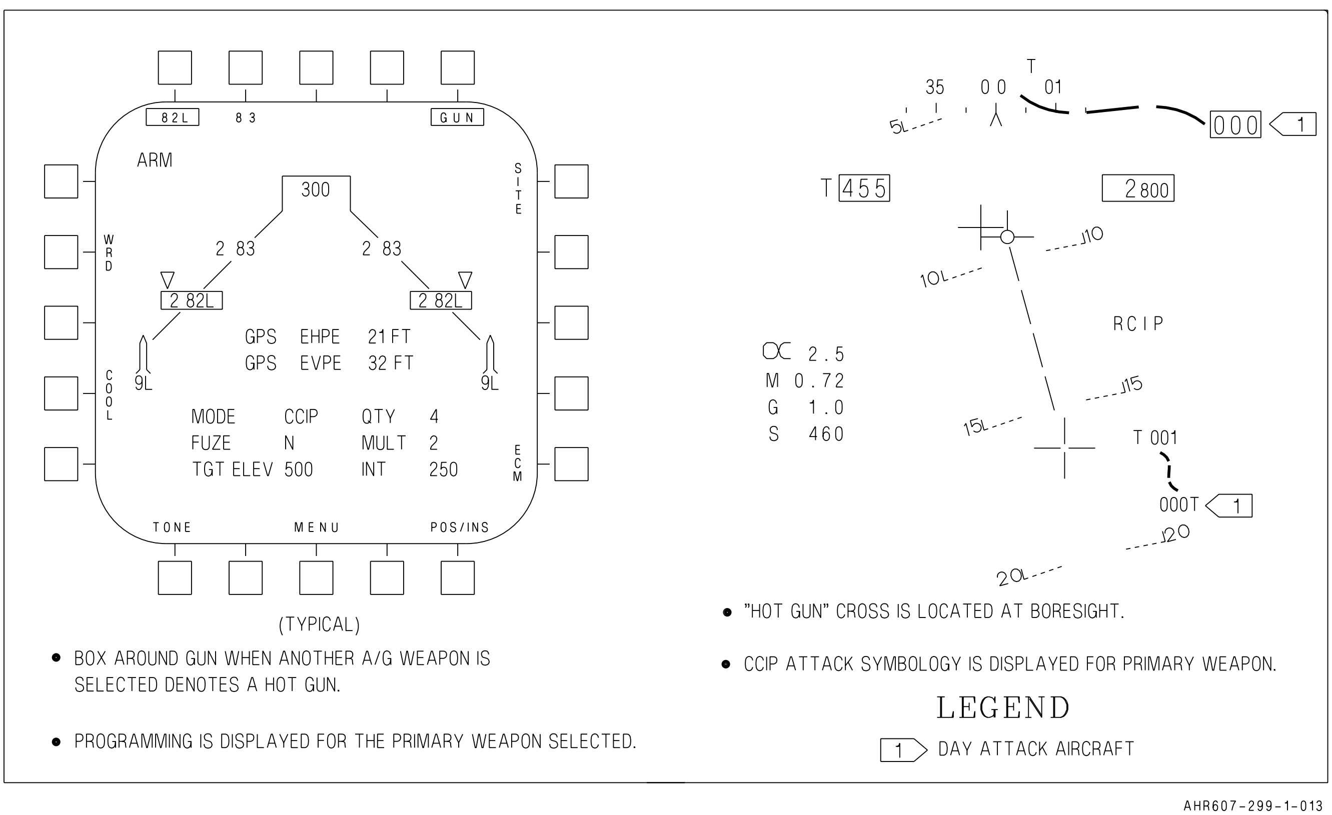


Figure 2-70. Hot Gun Selection

2.5.7.1 Gun Arming. Prior to arming make the following checks:

1. Master arm switch - OFF (SAFE)

2. Engine - IDLE

3. Engine nozzles - AFT

4. Upon signal from arming crew safety man, verify all armament switches OFF or SAFE and place both hands in FULL VIEW of safety man.

5. Arming crew safety man will give indication that gun is armed.

2.5.7.2 In-flight Gun Firing

1. Master mode - A/G

2. Select weapon - GUN (Boxed on DDI)

3. Select delivery mode - CCIP/DSL
   CAGE/UNCAGE switch alternates selection.

4. Release ready - NO INHIBIT CUE

5. Master arm switch - ARM
   GUN legend stops flashing on HUD

6. Maneuver aircraft to satisfy gunfire parameters

7. Ensure sufficient fan speed

8. Command firing - SQUEEZE TRIGGER

9. Master arm switch - OFF (SAFE)

10. Deselect GUN

11. Monitor DDI stores display for NOT CLEAR, MISFIRING, LIMITED and/or WPN FAIL

CAUTION

- When a flashing release inhibit cue appears on the HUD with fuselage gun selected and rounds remaining and/or a flashing WPN FAIL legend appears on the DDI, a gun malfunction should be assumed.

- When NOT CLEAR legend appears on the DDI stores display, a gun malfunction should be assumed. Place master arm to OFF (SAFE) and deselect the fuselage gun (GUN). Failure to do so could result in gun damage, gun overheat, or "cook-off" of rounds in the breech area. Alert landing facility of HOT GUN situation.

2.5.8 CCIP Rocket Mode. The CCIP mode is the normal delivery mode for rockets. As with A/G guns, the DSL mode is selectable by the pilot, or by the MC with auto reversion upon CCIP failure.

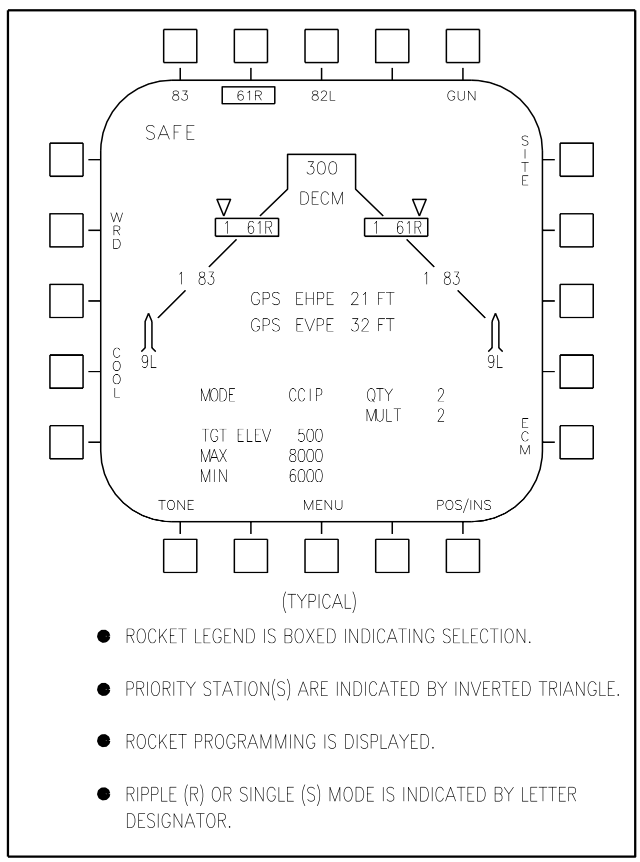


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Figure 2-71. Rocket Selection

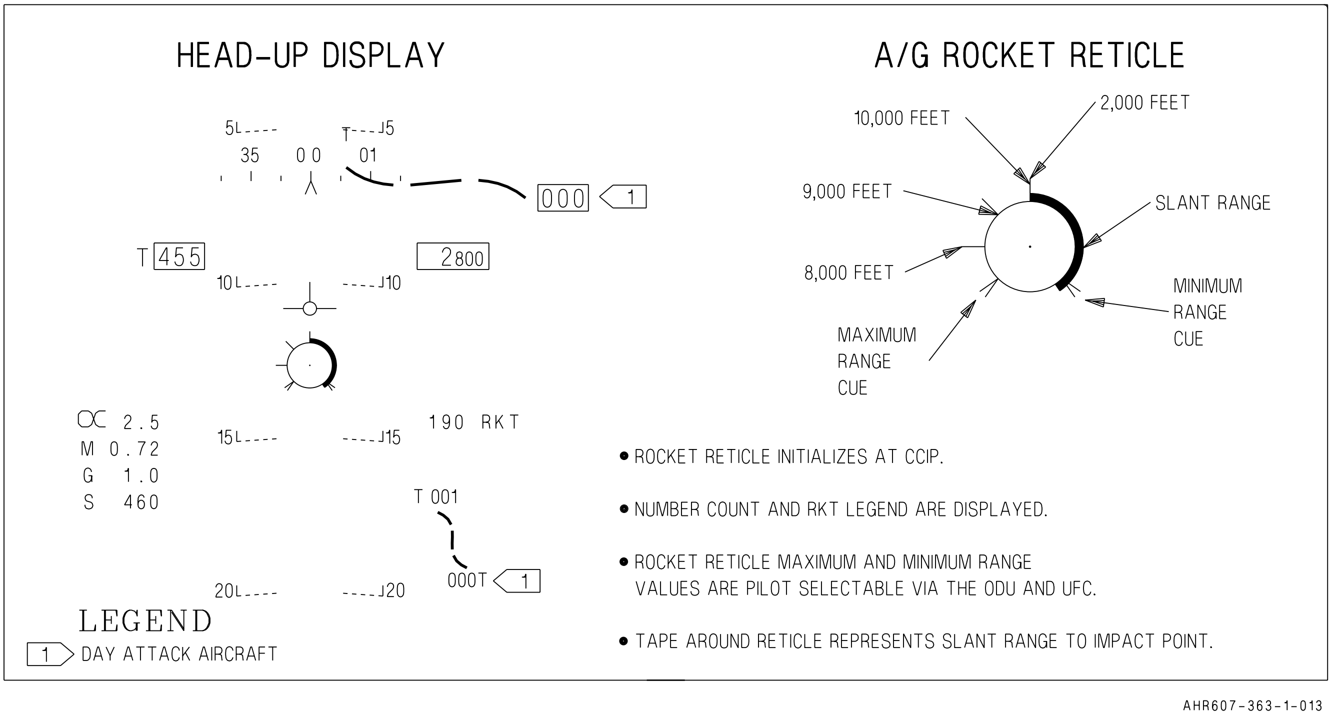

Figure 2-72. HUD Rocket Symbology

Rockets can be selected by pressing the rocket option pushbutton on the DDI shown in Figure 2-71 or by selecting, on the ACP, the weapon station carrying rockets.

The last entered rocket program is displayed on the stores display as in Figure 2-71. The firing mode, either ripple (R) or single (S), is determined from the launcher switch which is set by the ground crew. The numbers shown for QTY and MULT on the program data block indicate number of pods in the R firing mode and number of rockets in the S firing mode.

The rocket reticle appears as a circle with range markings. Tape around the reticle represents slant range to impact point. The dot at the center of the reticle indicates the computed rocket impact point on the earth surface (Figure 2-72). Carets displayed on the outside of the reticle indicate the maximum and minimum launching range selected by the pilot. The maximum and minimum range selected matches the clock position of the carets. Typical range selections and the representative caret position on the reticle circumference are listed below:

SLANT RANGE	CARET POSITION
2,000 feet	12:00 o'clock
4,000 feet	3:00 o'clock
6,000 feet	6:00 o'clock
8,000 feet	9:00 o'clock
9,000 feet	10:30 o'clock
10,000 feet	12:00 o'clock

The count shown on the HUD also equals the number of rockets if the single (S) mode is selected, or the number of pods if the ripple (R) mode is selected.

Whenever the rocket reticle touches the velocity vector, the velocity vector is removed to declutter the HUD.

2.6 REVERSION MODES

2.6.1 Air-to-Ground Backup Weapons Delivery. The AV-8B has limited automatic and/or manually selectable backup weapons delivery modes to ensure that the loss of an avionics component will not prevent weapon employment. Backup weapons delivery is provided in the A/G master mode for INS attitude failure, ADC failure, MC failure, SMC failure, SMC and ACP failure, DDI display failure, DDI complete failure, DMT failure, avionics multiplex bus failure (mux bus), and SMC data bus failure. When a reversion from a primary path occurs, the pilot is provided with appropriate cuing on the HUD and DDI only if the reversion results in some loss of capability or performance. If no reversion path exists, displayed data is removed.

Failure of a weapons system avionics component can limit the pilots choice of weapons and delivery modes. Maverick cannot be employed if the AGM mode is lost. Dispensers cannot be employed if both the AUTO and DSL modes are lost. Rockets cannot be employed if the CCIP and DSL modes are lost. The gun cannot be employed if the CCIP and DSL modes are lost. Electrically fuzed bombs cannot be employed if the AUTO, CCIP, and DSL modes are lost.

Failure of a weapons delivery mode can be caused by the loss of one or more avionics components during the course of a mission. The CCIP/AUTO modes are lost if INS attitude, ADC, MC, SMC or the avionics multiplex bus fails. The DSL mode is lost if the SMC fails. The AGM mode is lost if the avionics multiplex bus or SMC fails. The DIR mode is lost if the ACP fails. If the AUTO, CCIP, AGM, DSL, and DIR modes cannot be selected, and weapon load (bombs only)/fuzing (mechanical only) permits, the pilot can manually select the DSL(1) mode and continue the mission.

The following paragraphs discuss the various failures and provide alternate methods for weapon delivery. Figure 2-73 details the procedures for AUTO and DSL modes following HUD failure. Figure 2-74 summarizes lost capabilities, backup displays, and alternate selections for avionics failures that may affect air-to-suface weapon employment.

2.6.1.1 HUD Failure. If the HUD fails, weapon selection is unaffected and AUTO mode weapons delivery can still be utilized employing HUD attack symbology on the DDI. On Day Attack aircraft the standby reticle can be used as an aiming reference on the HUD. The diamond symbol on the standby reticle is used as an aiming point for AUTO mode target designation after the HUD has been turned off. The TD is coincident with the diamond symbol on the HUD at the moment of designation although the TD is not displayed.

Three different types of delivery modes are available for selection by the pilot following a HUD failure. Two of these types are AUTO delivery modes. Selection is based on the amount of time available before reaching the release point and pilot preference. The types of AUTO mode designations/deliveries are: TV and HUD. If the AUTO mode cannot be selected, weapon delivery is still possible in the DSL mode by using the standby reticle on the HUD or roll stabilized site on the DDI. The pilot selects the weapons, depression angle, and actuates the bomb pickle button when the predetermined weapon delivery conditions are met.

If MAV (Maverick) is the selected weapon or the LST mode is selected, HUD failure prevents display of the Maverick cross and/or LST cross on the HUD. However, these displays can be selected on the DDI by first selecting MENU, then the HUD option. HUD scan selection/ employment and LST/Maverick automatic target designation are unaffected.

2.6.1.1.1 AUTO Mode TV Designation. Following HUD failure if the DMT is on, the pilot can select the ARBS/TV sensor mode and still make an accurate target designation as soon as the target is in sight.

a. Day Attack Aircraft. On Day Attack aircraft select the standby reticle on the HUD. If AUT mode is not enabled (ACP mode window), select AUT mode with the cage/uncage button on the throttle. Maneuver the aircraft to place the standby reticle diamond symbol on the target and momentarily press the TDC to the action position to command TV track. This action designates the target to the MC, enables a weapon release point computation, and provides TV video of the target on the DDI.

The TDC can be used to sweeten the TV designation on the DDI if required. The TV display also allows the pilot to verify the target at a greater range than is possible through the HUD (TV display has 6 to 1 magnification).

After target verification, select the HUD option from the DDI menu to display HUD attack symbology on the DDI. When the release cue appears on the DDI, press and hold the bomb pickle button until release is completed.

A disadvantage of AUTO mode TV designation/delivery is that although the HUD and TV sensor video displays provide accurate guidance/release information, much head-down attention is required.

b. Night Attack Aircraft. On Night Attack aircraft the NAVFLIR is used to enhance the visual image of the target at night and during conditions of low visibility. To enable the NAVFLIR set the FLIR power switch to FLIR, the DAY/AUTO/NIGHT switch to NIGHT and slide the sensor select switch to the right.

If the AUT mode is not enabled (ACP mode window), select AUT mode with the cage/uncage button on the throttle.

On the left MPCD enable the HUD display by selecting MENU and then HUD. If the HUD display does not have FLIR video, press the sensor select switch down, this action toggles the HUD FLIR video on/off.

Enable the DMT/TV sensor mode by sliding the sensor select switch aft. The DMT display appears on the right MPCD. Maneuver the aircraft to place the velocity vector on the target and momentarily press the TDC to the action position to command TV track. This action designates the target to the MC, enables a weapon release point computation, and provides TV video of the target on the right MPCD.

The TDC can be used to sweeten the TV designation on the MPCD if required. The TV display allows the pilot to verify the target at a greater range than is possible through the HUD (TV display has 6 to 1 magnification).

After target verification, fly MPCD attack symbology to weapon release.

2.6.1.1.2 AUTO Mode INS Designation. This method is similar to AUTO mode TV designation except the INS sensor mode is selected directly.

The AUTO mode INS designation/delivery requires less head-down attention than the AUTO mode TV designation/delivery. However, it does not allow for TV verification or TD sweetening. This method is more desirable when HUD failure does not permit time to perform a DMT/TV designation.

a. Day Attack Aircraft. On Day Attack aircraft select the standby reticle on the HUD. If AUT mode is not enabled (ACP mode window), select AUT mode with the cage/uncage button on the throttle. Maneuver the aircraft to place the standby reticle diamond on the target and command AUTO mode target designation by momentarily pressing the TDC to the action position. This action selects command steering but does not display attack symbology until the pilot selects the HUD option. Select the HUD option from the MENU to display HUD attack symbology on the DDI. Use the HUD symbology for guidance to complete the attack. When the release cue appears on the DDI, press and hold the bomb pickle button until release is completed.

b. Night Attack Aircraft. On Night Attack aircraft the NAVFLIR is used to enhance the visual image of the target at night and during conditions of low visibility. To enable the NAVFLIR set the FLIR power switch to FLIR, the DAY/AUTO/NIGHT switch to NIGHT and slide the sensor select switch to the right. FLIR video is displayed on the right MPCD.

If the AUT mode is not enabled (ACP mode window), select AUT mode with the cage/uncage button on the throttle.

On the right MPCD enable the HUD display by selecting MENU and then HUD. If the HUD display does not have FLIR video, press the sensor select switch down, this action toggles the HUD FLIR video on/off.

Enable the INS sensor mode by sliding the sensor select switch forward. Maneuver the aircraft to place the velocity vector on the target and momentarily press the TDC. This action designates the target, enables weapon release point computation, and provides command steering to the target. When the release cue appears on the right MPCD, press and hold the bomb pickle button until release is completed. An alternate method is to place the velocity vector on the target, press and hold the bomb pickle button, and then fly the attack symbology until weapon release.

2.6.1.1.3 DSL Mode. If a HUD failure occurs and an AUTO mode delivery is not possible, weapon delivery is still possible by selecting a backup mode. If the computed modes (AUTO/CCIP) fail, the DSL mode is automatically selected.

a. Day Attack Aircraft. Select the standby reticle and, if not set during preflight, set the depression angle for the type of weapon selected and canned delivery to be performed. If the system did not automatically revert to DSL (CCIP mode delivery is not practical after HUD failure), manually select it on the ACP. The DSL mode is more desirable than DIR (direct) or DSL(1) manual modes because electrical fuzing and minimum safe release interval protection is provided.

If the DDI is functional, select HUD symbology on the DDI by selecting the HUD option from the MENU. If the DDI is not functional, use the standby instruments and press and hold the bomb pickle button when the predetermined release conditions are met and weapon release is completed.

b. Night Attack Aircraft. Select the roll stabilized site and, if not set during preflight, set the depression angle for the type of weapon selected and canned delivery to be performed. The roll stabilized site is enabled by selecting MENU/STRS/SITE on the right MPCD. This action enables the ODU for site selection (cue the SITE option) and the UFC for depression angle entry.

If the system did not automatically revert to DSL (CCIP mode delivery is not practical after HUD failure), manually select it on the ACP. The DSL mode is more desirable than DIR (direct) or DSL(1) manual modes because electrical fuzing and minimum safe release interval protection is provided.

To enhance target visibility enable the NAVFLIR video. Set the FLIR power switch to FLIR, the DAY/AUTO/NIGHT switch to NIGHT and slide the sensor select switch to the right. FLIR video is displayed on the right MPCD. Display HUD symbology on the right MPCD by selecting MENU/HUD. If FLIR video is not displayed, press the sensor select switch down, this action toggles the HUD FLIR video on/off.

Fly the roll stabilized site over the target and press and hold the bomb pickle button when the predetermined release conditions are met and weapon release is completed.

2.6.1.2 INS Failure. Several different types of INS failures can occur which will affect weapons delivery. In general, INS failures result in the loss of AUTO/CCIP computed weapons delivery modes and require the pilot to use standby instruments to complete weapons delivery. The system automatically reverts to the DSL mode when the computed modes are lost. In DSL, weapon programming remains unimpaired. The waypoint/mark number is removed from the HUD when aircraft present position is invalid; however, the WYPT legend continues to be displayed as long as waypoint steering is selected.

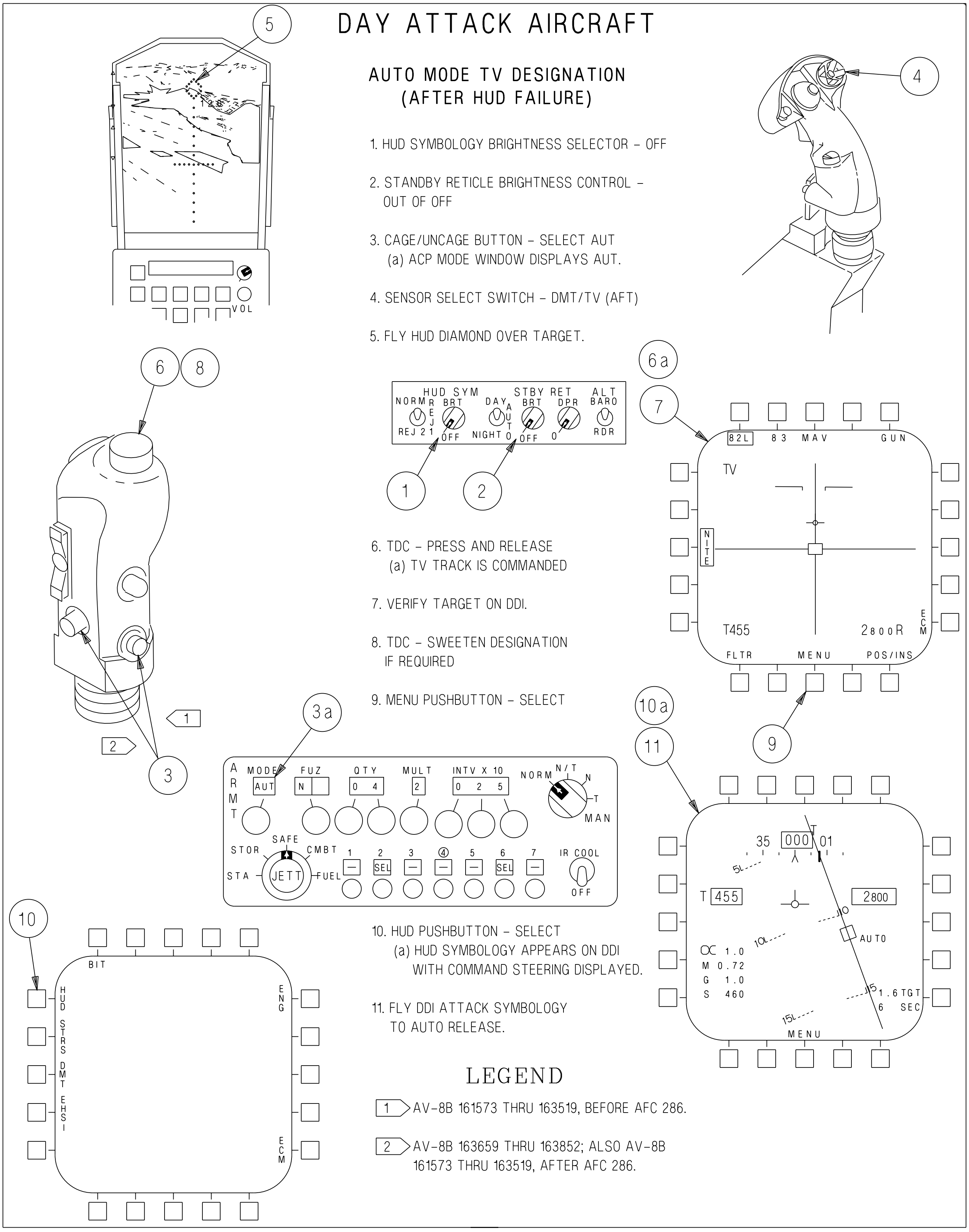

Figure 2-73. HUD Failure (Sheet 1 of 6)

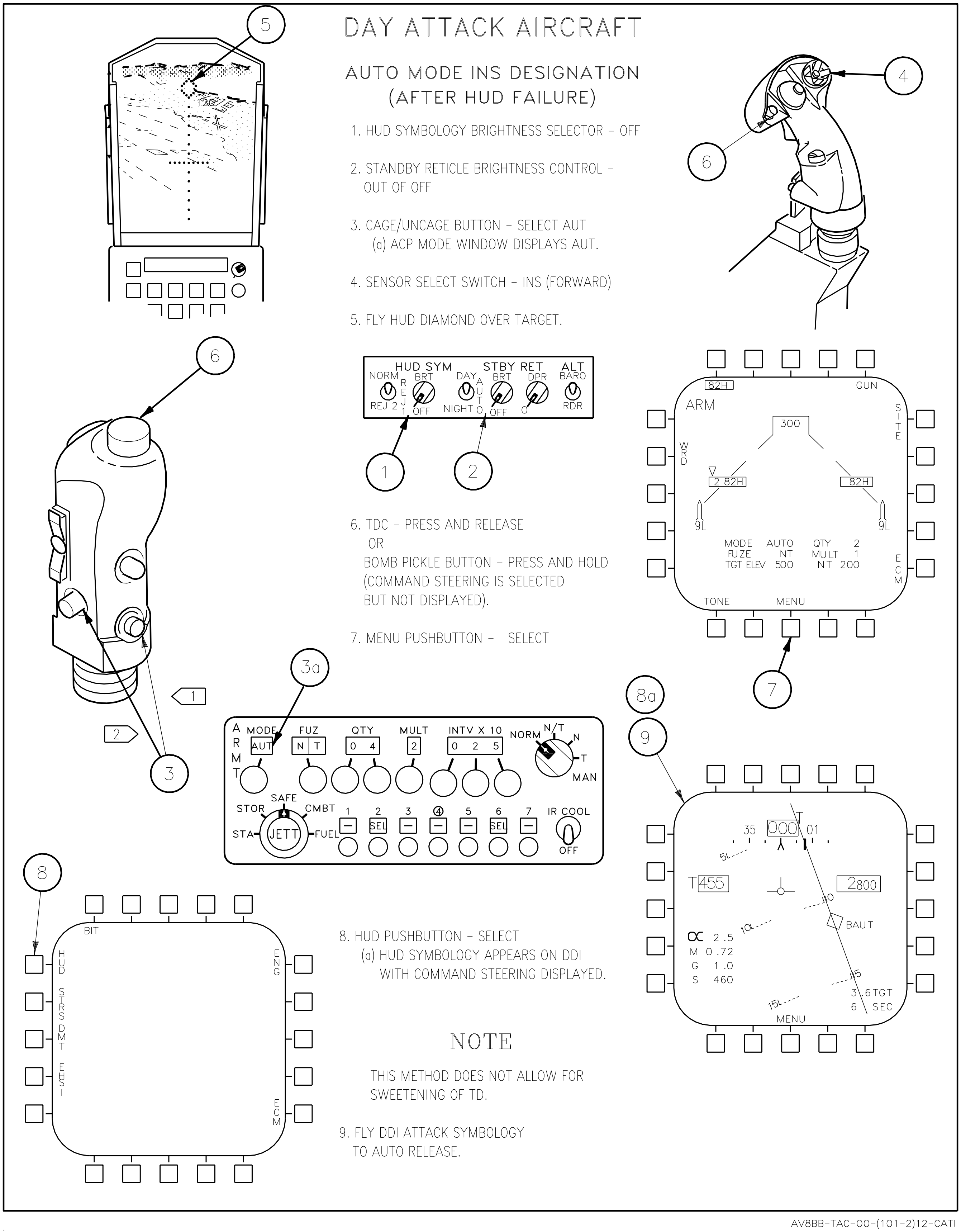

Figure 2-73. HUD Failure (Sheet 2 of 6)

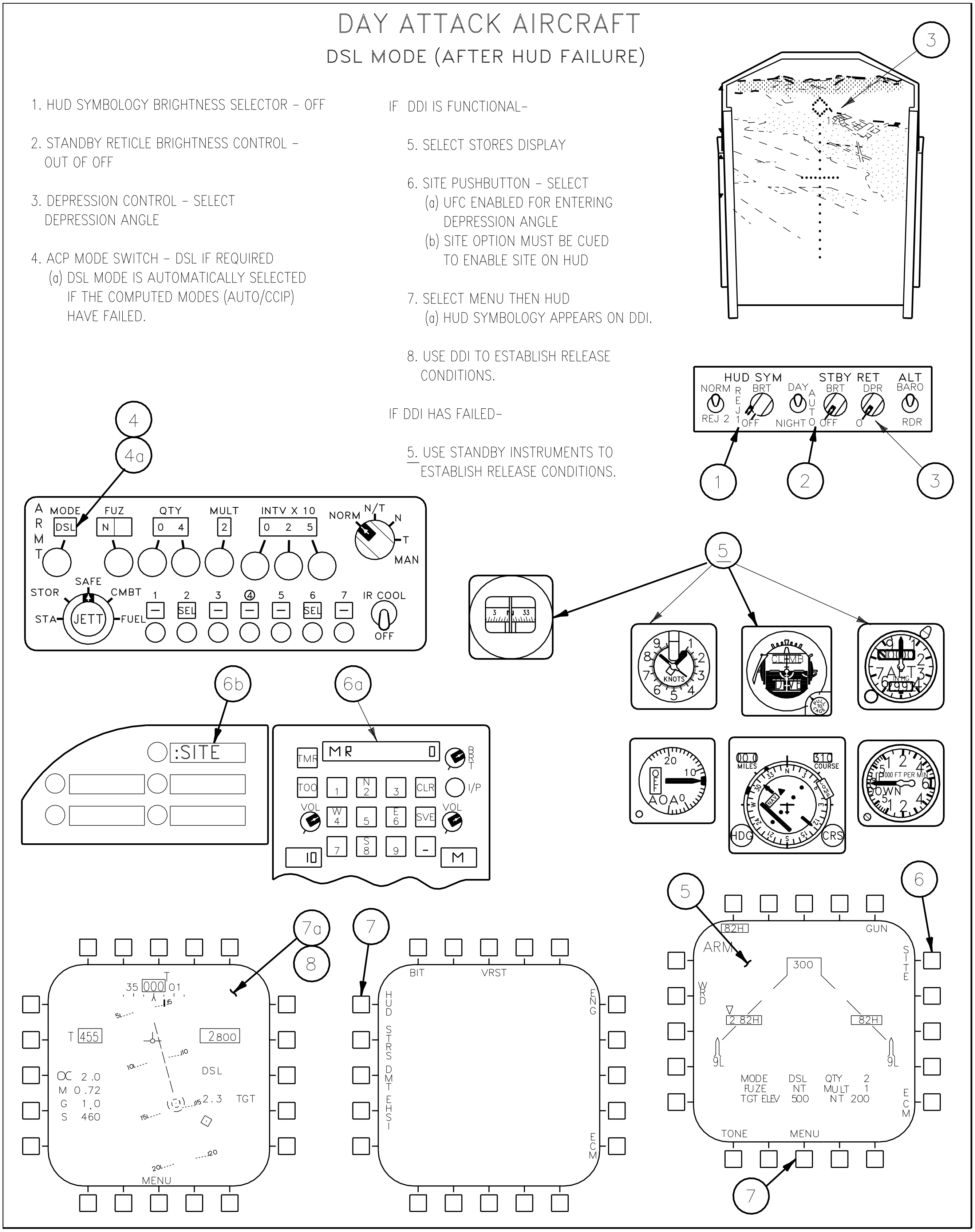

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Figure 2-73. HUD Failure (Sheet 3 of 6)

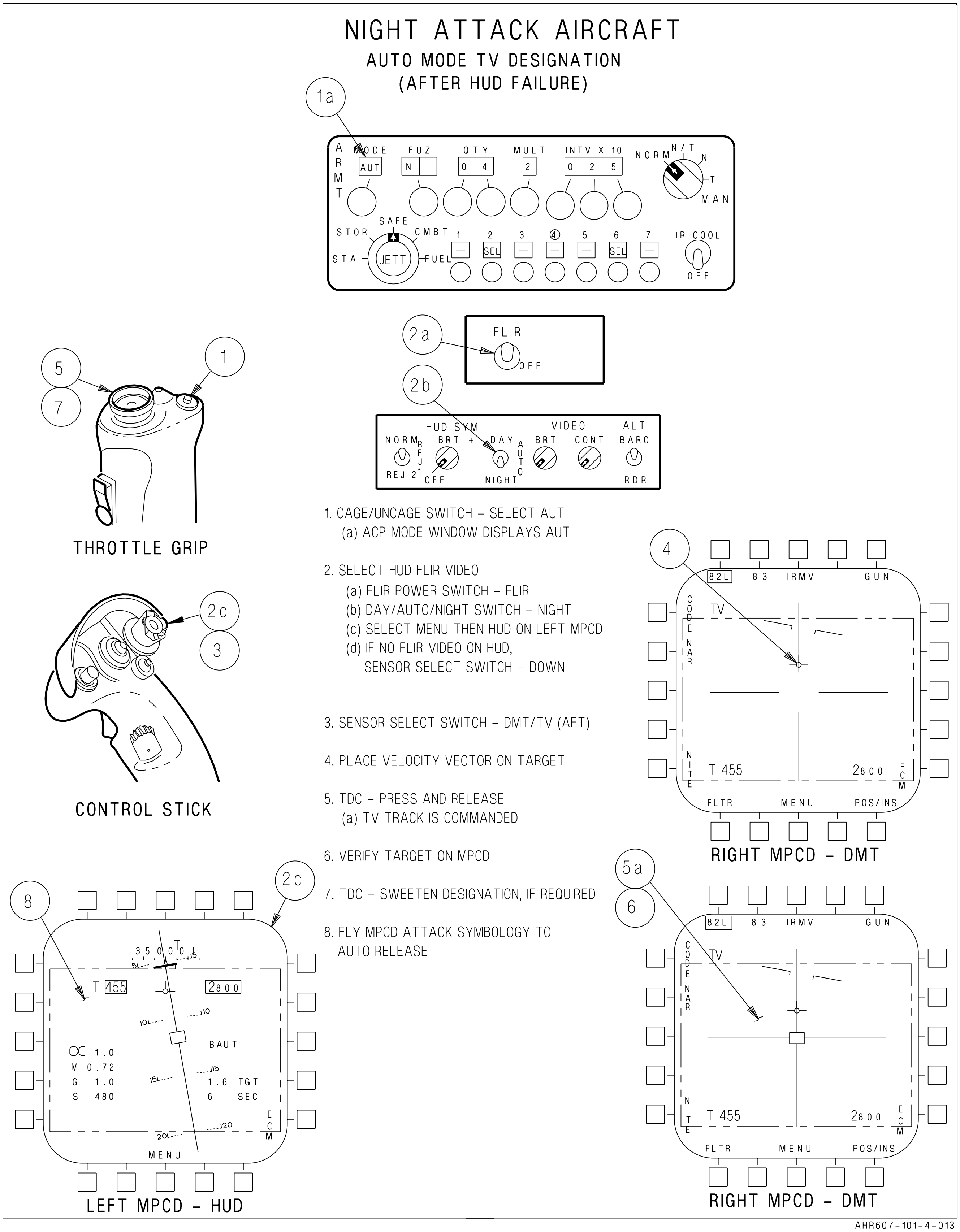


Figure 2-73. HUD Failure (Sheet 4 of 6)

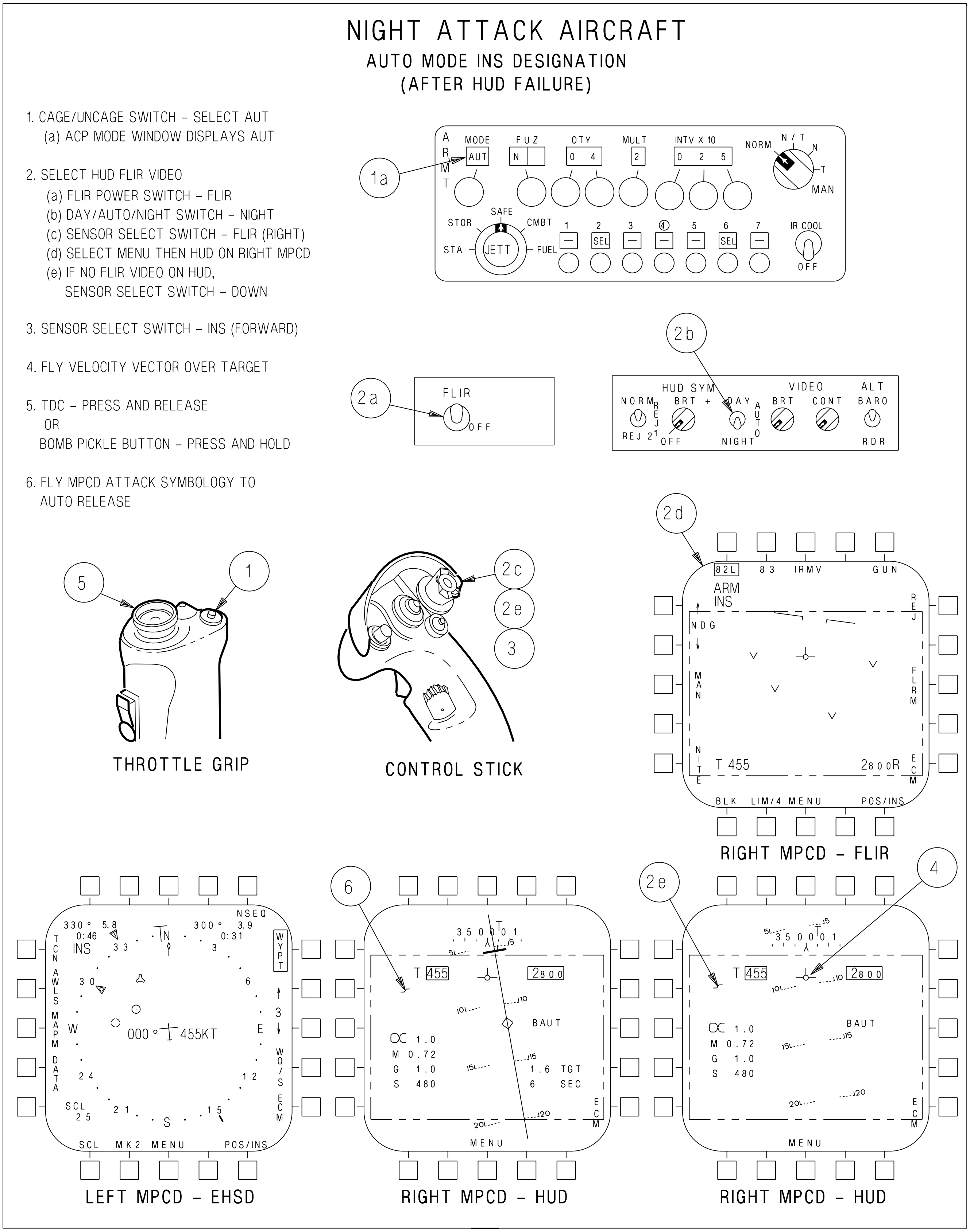


Figure 2-73. HUD Failure (Sheet 5 of 6)

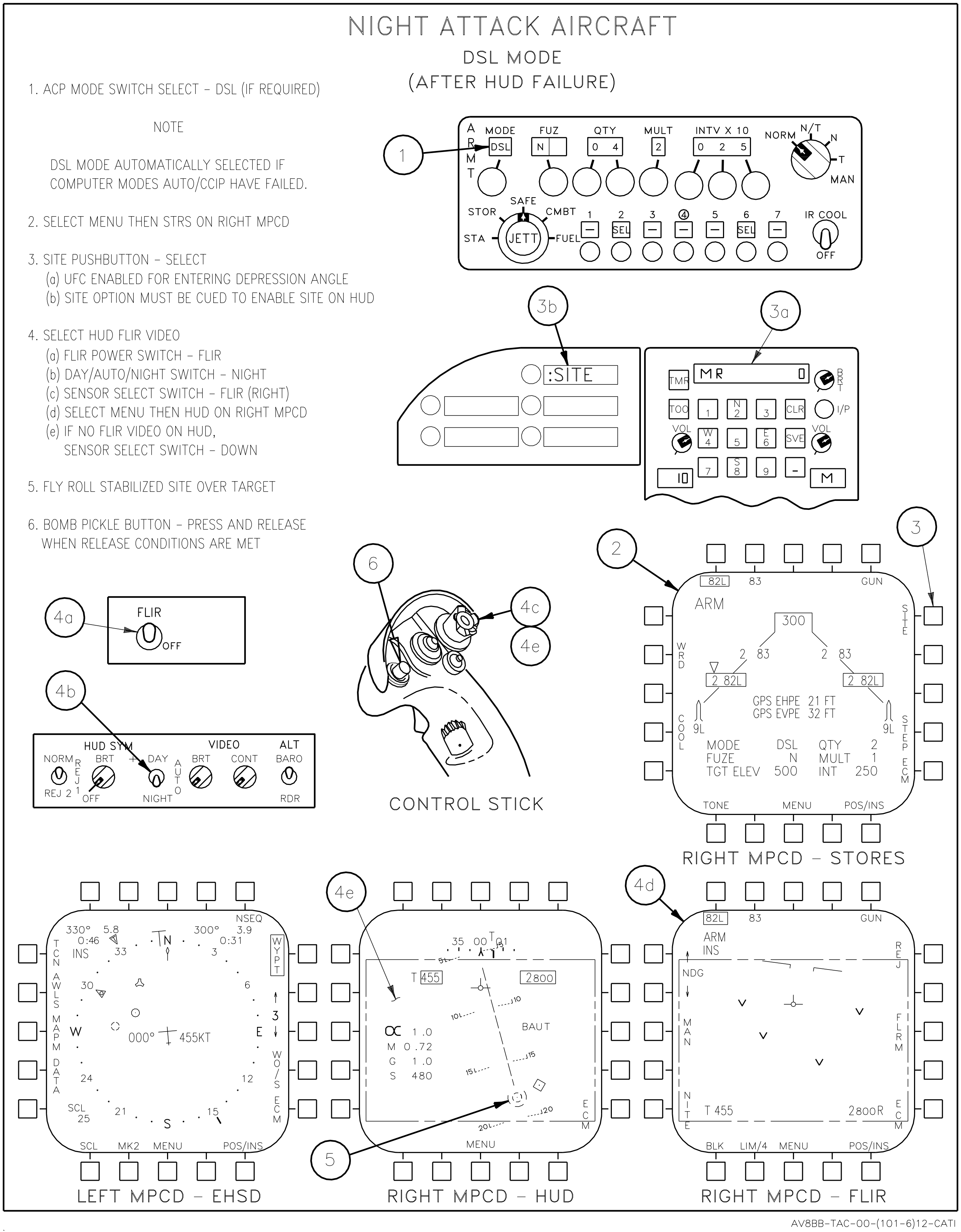


Figure 2-73. HUD Failure (Sheet 6 of 6)

2.6.1.2.1 INS Velocity Failure. If INS velocity fails, the pilot loses INS position keeping and the true heading from the INS. The pilot is alerted to INS failure by illumination of the MASTER CAUTION light and INS light. The velocity vector, HUD attitude display, and roll stabilized sight are not affected. The AUTO and CCIP modes are still available; however, accuracy is degraded.

When INS velocity failure occurs, the MC automatically reverts to GPS (if installed) or higher order AHRS. The DGD/GPS or DGD/ADC legend appears in the lower right corner of the EHSI/EHSD display above the adjacent option pushbutton.

Continue the attack using the AUTO/CCIP modes if the ARBS will lock on and cross check the weapon release solution against the roll stabilized sight carets.

2.6.1.2.2 INS Velocity and True Heading Failure. Same as INS velocity failure except MC automatically reverts to GPS (if installed) or first order AHRS.

2.6.1.2.3 INS Attitude Failure. If INS attitude fails, the pilot loses HUD attitude, CCIP/AUTO modes, DMT roll stabilization, INS position keeping, true heading from INS, aircraft g displays, and manual target designation capability. Maverick/LST automatic designation is unimpaired. The pilot is alerted to INS failure by illumination of the MASTER CAUTION light, CIP/AUT light, and INS light. The roll stabilized sight is not available when HUD attitude is lost and the velocity vector is replaced by the waterline symbol.

When INS attitude failure occurs, the MC automatically reverts to DGD/GPS (if installed) or DGD/ADC. The DGD/GPS or DGD/ADC legend appears in the lower right corner of the EHSI/EHSD display above the adjacent option pushbutton.

Continue the attack using the standby attitude indicator, selecting the standby reticle, and setting the depression angle for the type of weapon and canned delivery to be employed.

NOTE

With INS failure, the pilot can attempt to regain the attitude display on the HUD by selecting GYRO on the miscellaneous switch panel while maintaining a level flight attitude.

2.6.1.3 ADC Failure. If the ADC fails, the pilot loses airspeed, barometric altitude, AOA, and the vertical velocity (FPM) symbology on the HUD, also CCIP/AUT modes and manual target designation capability. The pilot is alerted to ADC failure when the MASTER CAUTION, CIP/AUT, AUT FLP, DEP RES, and the GEAR lights illuminate.

ADC derived information is removed from the HUD and DDI, the waterline symbol replaces the velocity vector on the HUD, and the system automatically reverts to the DSL mode. Loss of ADC derived information causes true heading to revert to pilot entered variation. If the AGM or LST modes are selected, Maverick/LST automatic designation is still available.

Continue the attack using the standby airspeed indicator, altimeter, AOA, and vertical velocity indicator. Select the roll stabilized sight or standby reticle, and set the depression angle for the type of weapon and canned delivery to be employed. Select radar altitude if desired.

2.6.1.4 MC Failure. If the MC fails the system automatically reverts to a backup mode operation. This is indicated by the presence of the HUD symbology on both the HUD and DDI, the MASTER CAUTION and CIP/AUT lights illuminated, and the DSL mode automatically selected on the ACP.

In backup mode the display computer provides limited communications with other avionic systems on the mux bus in order to provide the HUD VSTOL or HUD NAV display. This occurs automatically if the MC switch on the miscellaneous switch panel is set to AUTO (normal flight position) or OFF. In the OVRD position, STANDBY will be displayed on the DDI and HUD because the automatic backup mode function is overridden and no communications is taking place on the mux bus.

In the backup mode all master modes NAV, VSTOL, A/A, and A/G are selectable; however, only the HUD NAV or HUD VSTOL displays are available. If A/A or A/G is selected the HUD NAV display will appear. True heading, true airspeed, aircraft G, and the roll stabilized sight are not available for display. The capability of selecting/changing a weapon program on the DDI is lost and no weapon parameter option selection is available on the UFC.

Continue the attack by selecting the standby reticle and setting the depression angle for the type of weapon and canned delivery to be employed.

2.6.1.5 SMC Failure. If the SMC fails, the pilot loses CCIP/AUTO, DSL, and AGM weapon delivery modes, DDI weapon selection, electrical fuzing, Maverick launch, dispenser firing, and rocket firing capability. The pilot is alerted to SMC failure when the MASTER CAUTION and CIP/AUT lights illuminate, weapon legends disappear from beneath the weapon select pushbuttons on the DDI, and the system automatically reverts to the DIR mode.

WARNING

If fuselage gun is selected when operating in training mode, firing pulse with trigger activation will not be inhibited and the gun will fire if an SMC processor failure occurs.

When the stores display is selected, the station information will be blanked from the wing form. If a weapon was already selected when the SMC failed, the weapon selection, stations selected, and weapon parameters selected could change automatically when reverting to the DIR mode. The DIR mode will automatically display the program that was last entered in that mode if no power interruption has occurred. If the DIR mode is not programmed or displays a different program than desired, the pilot must manually enter selections for weapon delivery. In the DIR mode, an unsafe interval can be selected.

Continue the attack by selecting the roll stabilized sight or standby reticle and setting the depression angle for the type of weapon and canned delivery to be employed.

2.6.1.6 SMC and ACP Processor Failure. If both the SMC and ACP processor fail, the pilot loses CCIP/AUTO, DSL, AGM, and DIR modes, DDI weapon selection, electrical fuzing, Maverick launch and rocket firing capability.

The pilot is alerted to the SMC portion of the failure when the MASTER CAUTION and CIP/AUT lights illuminate and the weapon legends disappear from beneath the weapon select pushbuttons on the DDI. When the stores display is selected, the station information will be blanked from the wing form.

ACP failure is indicated by all the windows displaying dash (-) or zero (0) and no response when any control or selection pushbutton is actuated. The pilot must manually select the DSL(1) mode when the SMC and ACP have both failed.

Continue the attack by selecting the roll stabilized sight or standby reticle and setting the depression angle for the type of weapon and delivery maneuver to be employed.

2.6.1.7 DDI Display Failure. If the DDI display fails, the pilot loses all of the DDI displays (HUD, stores, DMT (ARBS/TV or ARBS/LST), EHSI/EHSD, ECM, engine, and BIT), but the DDI pushbuttons are still functional. Head-up displays, weapon delivery modes, and weapon selections are not affected.

Continue the attack, selecting options on the DDI by remembering their location and using the HUD, UFC, and ODU displays to confirm what is selected.

2.6.1.8 DDI Complete Failure. If the DDI completely fails, the pilot loses all of the DDI displays and option pushbutton selections. Some DDI functions can still be selected by using the UFC, ODU, and ACP. Use the UFC and ODU for waypoint data entry and the ACP for weapon selection and programming. Head-up displays and weapon mode selections are unaffected.

Continue the attack by turning the DDI brightness selector knob OFF (initializes ODU/UFC to waypoint data) and selecting the options required.

2.6.1.9 DMT Failure. If the DMT fails, the pilot loses ARBS/LST, ARBS/TV, and INS displays on the DDI, LST search modes, and ARBS/LST and ARBS/TV target acquisition and designation. AGM-65 Maverick missile selection, operation, and automatic designation are not affected.

Continue the attack by entering barometric (altimeter) correction for the HUD and target or area elevation (if not attacking a stored waypoint/offset) or use radar altimeter to update elevation. If only the ARBS/LST has failed, use ARBS/TV or INS. If only TV has failed, use ARBS/LST or INS. If LST and TV failed (complete DMT failure) use the INS to continue the attack.

2.6.1.10 Avionics Multiplex Bus Failure. Avionics multiplex bus (mux bus) failures affect the weapon system in various ways depending on the location and type of failure. Generally a failure would be an open/shorted wire or a remote terminal fail. Since the mux bus system is redundant, the failure must result in the loss of data before it affects the weapon system.

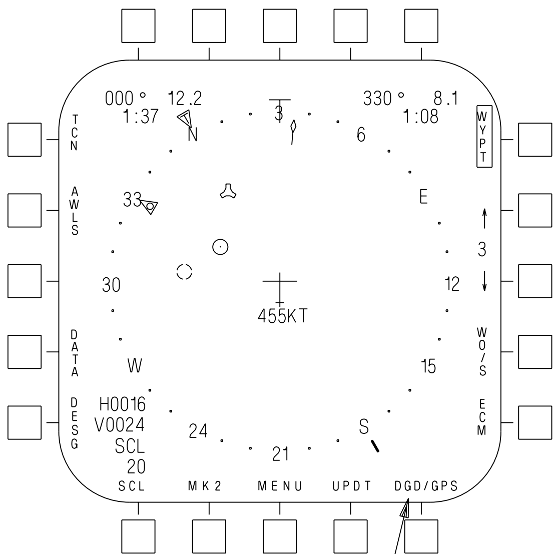
The MC gathers data from other systems on the mux bus and processes this data in order to provide weapon system control and displays. If a mux bus failure results in the loss of data from a single system such as the ADC, then the effect would be the same as the ADC failure previously described. This is true for the INS, SMC, DMT etc. If the failure resulted in the inability of the MC to communicate, then the system would go into back up mode.

2.6.1.11 SMC Data Bus Failure. If the SMC data bus fails, the windows will go blank on the ACP. The pilot must select the DIR mode or DSL(1) mode on the ACP to take command from the SMC/MC if the computed modes (AUTO/CCIP) and DSL mode fail. Continue the attack using the HUD and DDI as previously selected.

2.6.1.12 Reversion Modes Summary. Given the multitudes of failure modes and the fact that many of the failures will provide the same or similar warnings and cautions, the recommended technique is to *always set and colonize (:) the roll stabilized site and preprogram DIR and DSL(1) delivery modes*. This will enable a smooth transition to degraded modes in flight without a lot of heads down time. Remember that if you degrade beyond DSL (to DIR or DSL(1)) you will not have electrical fuzing or be able to employ electrical driven ordnance (AGM, rockets, etc.).

INS VELOCITY FAILURE (DAY ATTACK AIRCRAFT)

1 REVERTS TO GPS VELOCITIES
2 REVERTS TO HIGHER ORDER AHRS



DDI

REVERTS TO
1 DGD/GPS
2 DGD/ADC

LOSE

- INS POSITION KEEPING

USE

- TRUE HEADING ON EHSI BASED ON PILOT ENTERED VARIATION
- 1 GPS POSITION KEEPING
- 2 AIR DATA POSITION KEEPING WITH MAGNETIC HEADING (AIR DATA DEAD RECKONING)
- AUTO/CCIP MODES IF ARBS WILL LOCK ON AND CROSS CHECK AGAINST ROLL STABILIZED SIGHT CARETS.

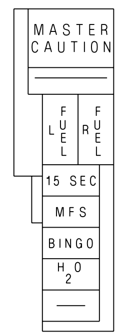
LEGEND

1 AIRCRAFT WITH GPS

2 AIRCRAFT WITHOUT GPS

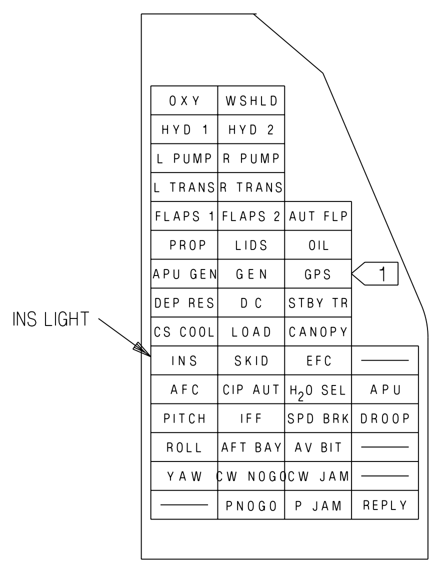
NOTE

AUTO AND CCIP MODES ARE STILL AVAILABLE; HOWEVER, ACCURACY IS DEGRADED.



PRIORITY CAUTION LIGHT PANEL

- MASTER CAUTION LIGHT ILLUMINATES



CAUTION LIGHT PANEL

- INS LIGHT ILLUMINATES

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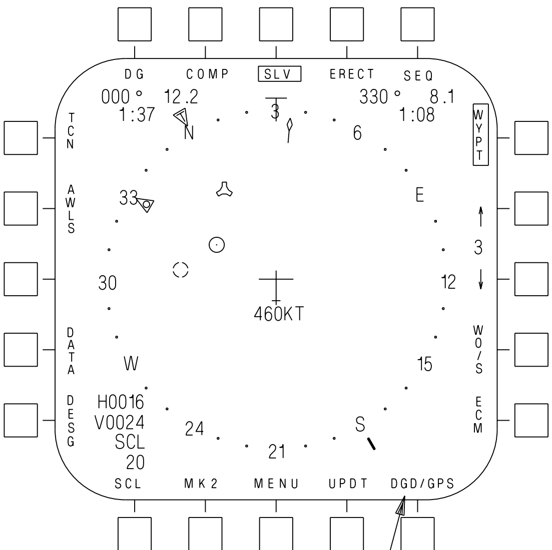
Figure 2-74. Backup A/G Weapon Delivery (Sheet 1 of 20)

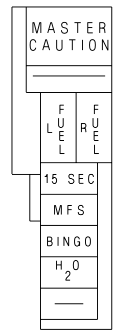
INS VELOCITY AND TRUE HEADING FAILURE (DAY ATTACK AIRCRAFT)

1 REVERTS TO GPS VELOCITY
2 REVERTS TO FIRST ORDER AHRS



DDI

REVERTS TO
1 DGD/GPS
2 DGD/ADC



PRIORITY CAUTION LIGHT PANEL

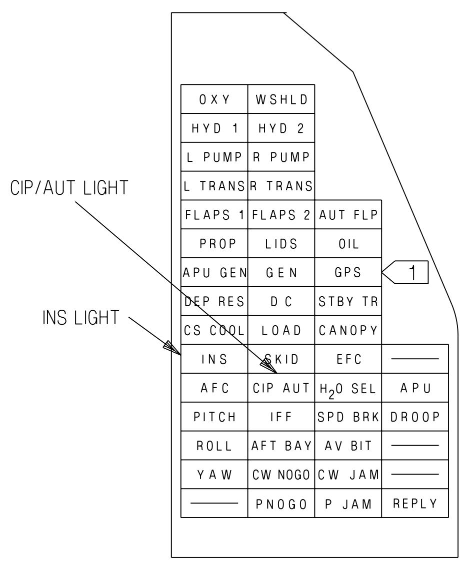
- MASTER CAUTION LIGHT ILLUMINATES

LOSE

- INS POSITION KEEPING

USE

- TRUE HEADING ON EHSI BASED ON PILOT ENTERED VARIATION
- 1 GPS POSITION KEEPING
- 2 AIR DATA POSITION KEEPING WITH MAGNETIC HEADING (AIR DATA DEAD RECKONING)
- AUTO/CCIP MODES IF ARBS WILL LOCK ON AND CROSS CHECK AGAINST ROLL STABILIZED SIGHT CARETS.



CAUTION LIGHT PANEL

- CIP/AUT LIGHT ILLUMINATES
- INS LIGHT ILLUMINATES

LEGEND

1 AIRCRAFT WITH GPS

2 AIRCRAFT WITHOUT GPS

NOTE

AUTO AND CCIP MODES ARE STILL AVAILABLE; HOWEVER, ACCURACY IS DEGRADED.

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Figure 2-74. Backup A/G Weapon Delivery (Sheet 2 of 20)

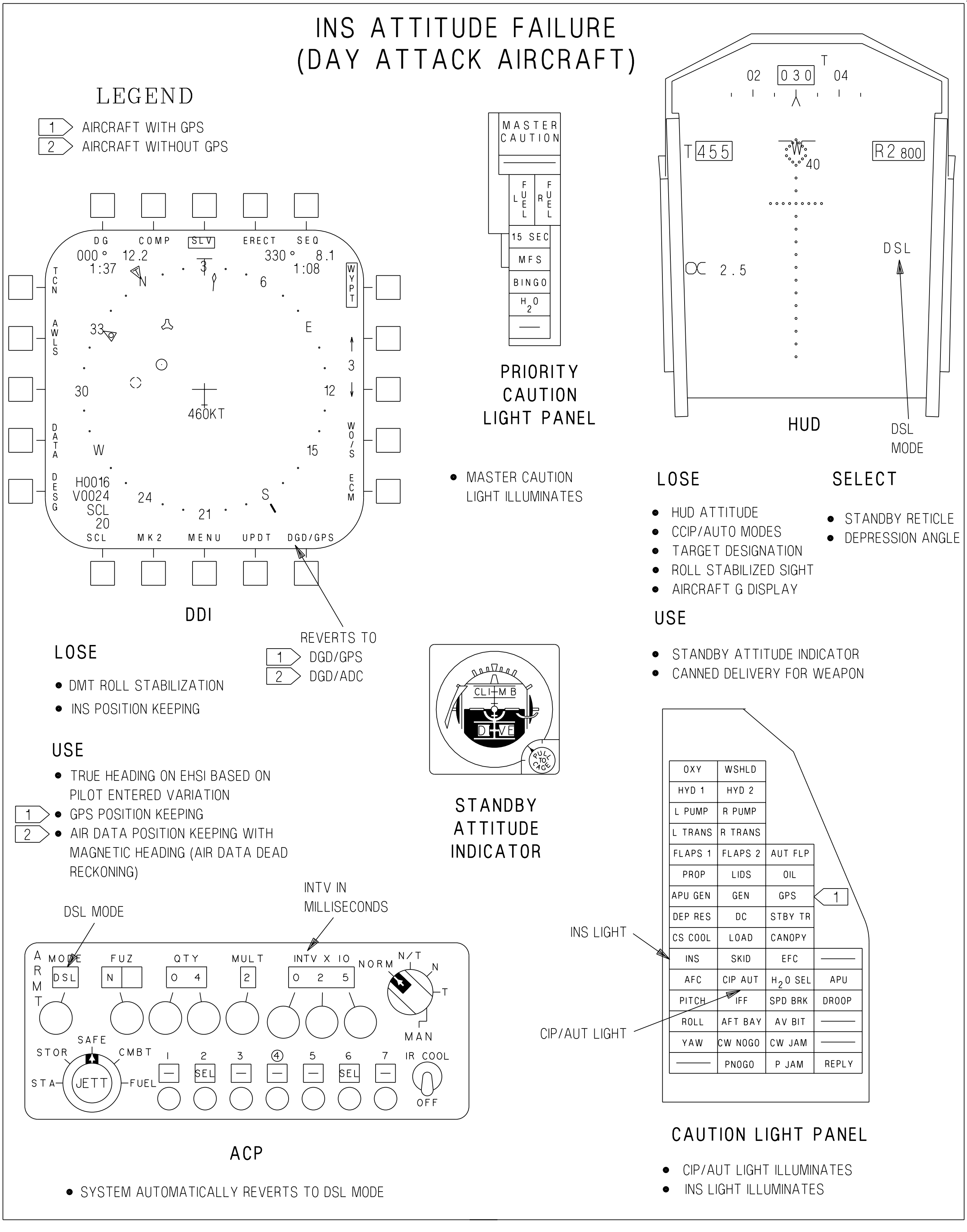


Figure 2-74. Backup A/G Weapon Delivery (Sheet 3 of 20)

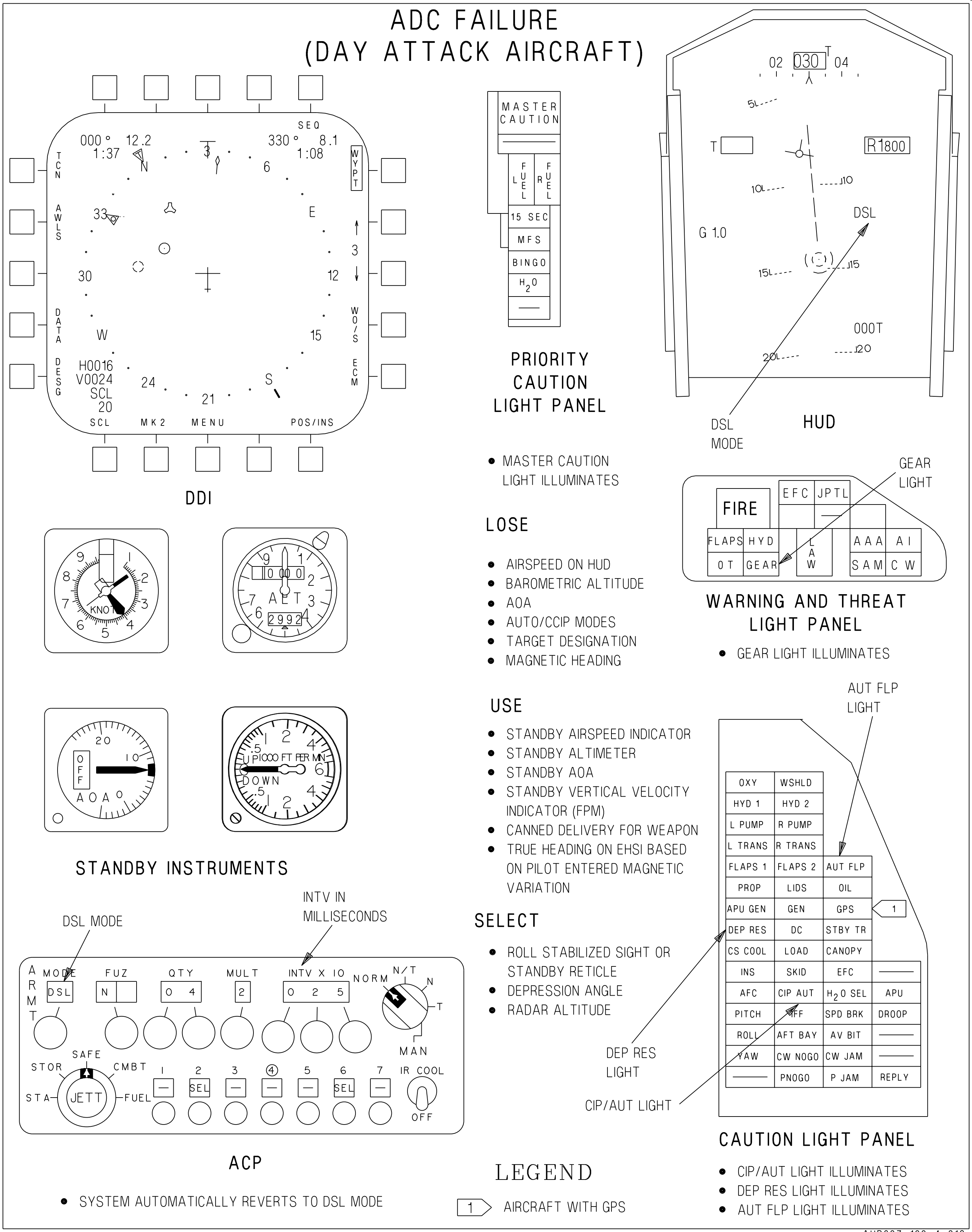


Figure 2-74. Backup A/G Weapon Delivery (Sheet 4 of 20)

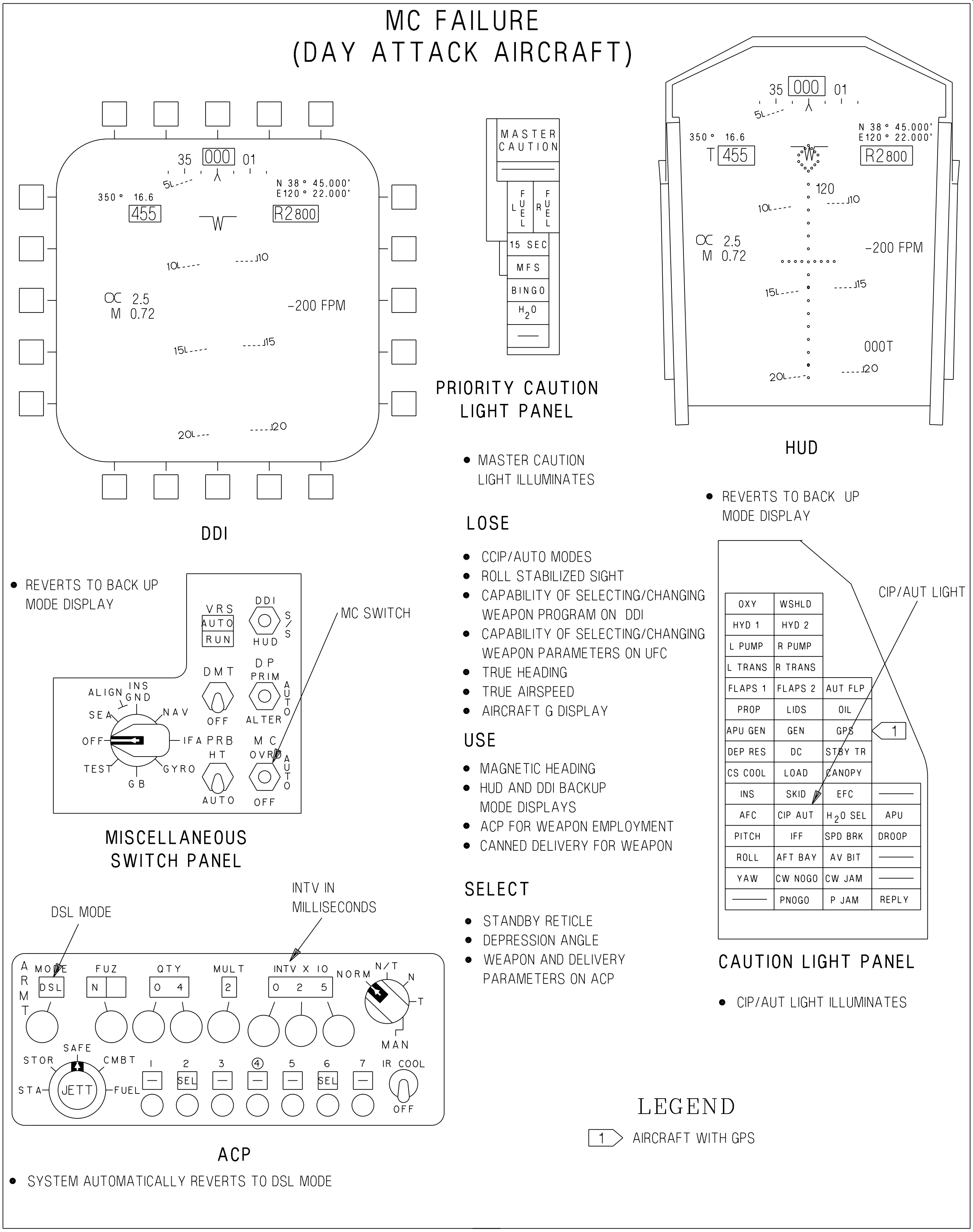
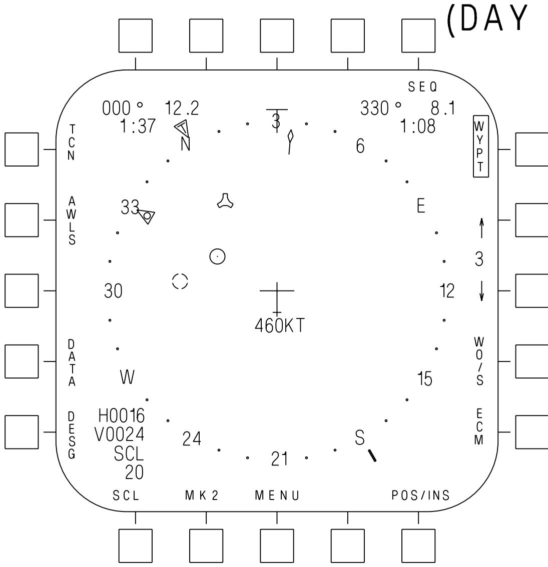


Figure 2-74. Backup A/G Weapon Delivery (Sheet 5 of 20)

SMC FAILURE (DAY ATTACK AIRCRAFT)



DDI

LOSE

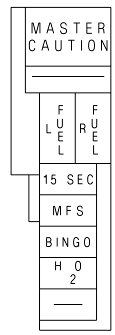
- DDI WEAPON SELECTION
- ELECTRICAL BOMB FUZING
- AGM-65 MAVERICK LAUNCH AND ROCKET FIRING CAPABILITY
- GUN LEGEND
- ROUNDS COUNT
- NOT CLEAR CUE
- WEAPON FAIL CUE

USE

- ACP FOR WEAPON EMPLOYMENT

SELECT

- WEAPON AND STATION(S) ON ACP IF REQUIRED
- WEAPON DELIVERY PARAMENTS ON ACP IF REQUIRED
- HOT GUN (AUTOMATICALLY AVAILABLE WHEN MASTER ARM IS SELECTED)

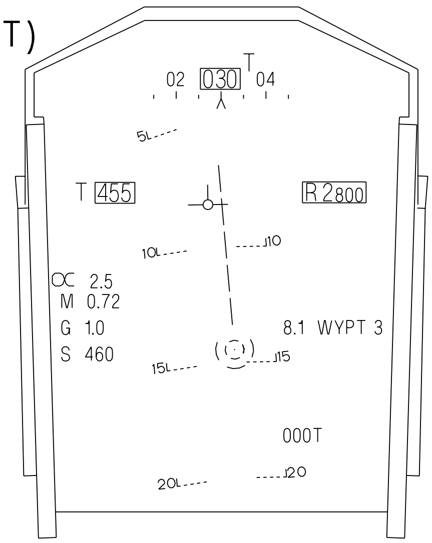


PRIORITY CAUTION LIGHT PANEL

- MASTER CAUTION LIGHT ILLUMINATES

LEGEND

1 AIRCRAFT WITH GPS



HUD

LOSE

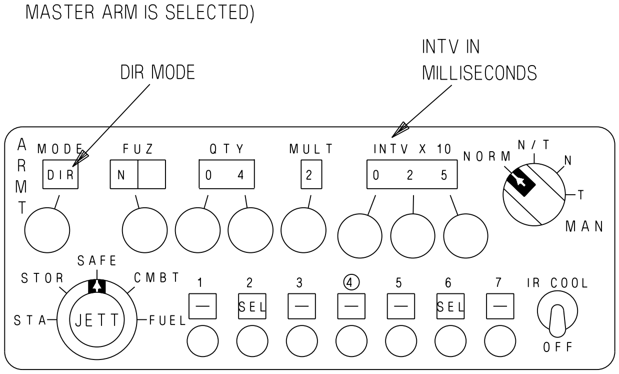
- CCIP/AUTO, DSL AND AGM MODES

USE

- CANNED DELIVERY FOR WEAPON

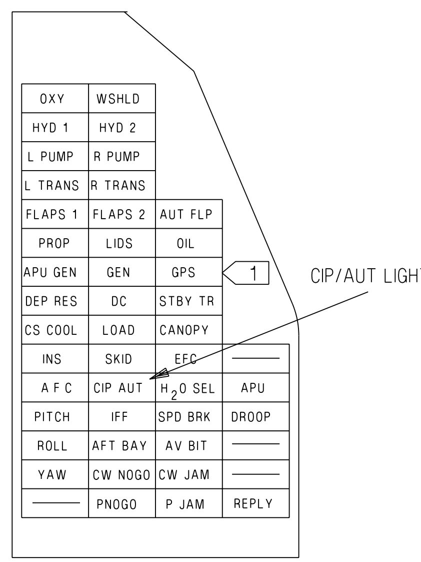
SELECT

- ROLL STABILIZED SIGHT OR STANDBY RETICLE
- DEPRESSION ANGLE



ACP

- SYSTEM AUTOMATICALLY REVERTS TO DIR MODE



CAUTION LIGHT PANEL

- CIP/AUT LIGHT ILLUMINATES

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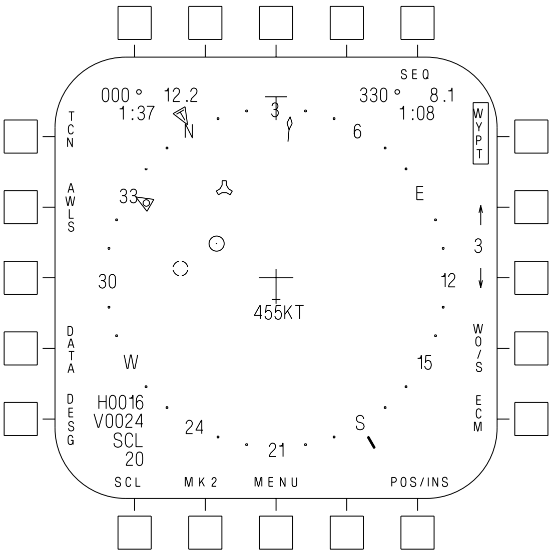
Figure 2-74. Backup A/G Weapon Delivery (Sheet 6 of 20)

SMC AND ACP PROCESSOR FAILURE (DAY ATTACK AIRCRAFT)



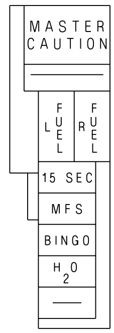
DDI

LOSE

- DDI WEAPON SELECTION AND STORES DISPLAY
- ACP PROGRAM OPTION SWITCHES
- ELECTRICAL BOMB FUZING
- MAVERICK LAUNCH AND ROCKET FIRING CAPABILITY
- GUN LEGEND
- ROUNDS COUNT
- NOT CLEAR CUE
- WEAPON FAIL CUE

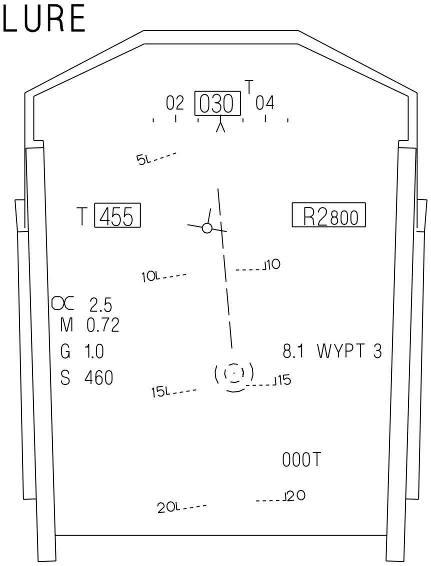
USE

- ACP FOR WEAPON EMPLOYMENT



PRIORITY CAUTION LIGHT PANEL

- MASTER CAUTION LIGHT ILLUMINATES



HUD

LOSE

- CCIP/AUTO, DSL, AGM AND DIR MODES

USE

- CANNED DELIVERY FOR WEAPON

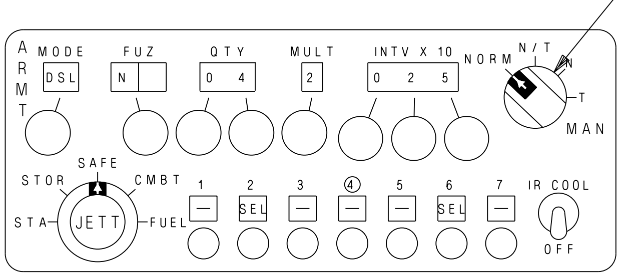
SELECT

- ROLL STABILIZED SIGHT OR STANDBY RETICLE
- DEPRESSION ANGLE

LEGEND

1 AIRCRAFT WITH GPS

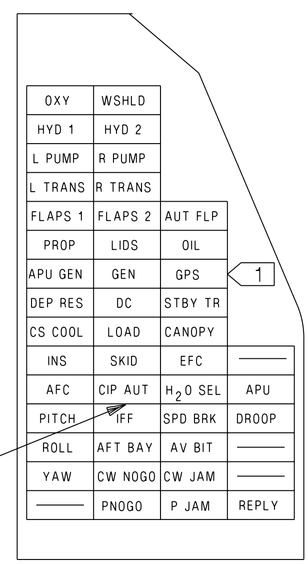
MANUAL CONTROL KNOB



ACP

SELECT

- DSL(1) MODE AND FUZING WITH MANUAL (MAN) CONTROL KNOB ON ACP
- WEAPON STATIONS ON ACP (UNLESS PREPROGRAMMED)
- HOT GUN (AUTOMATICALLY AVAILABLE WHEN MASTER ARM IS SELECTED)



CIP/AUT LIGHT

CAUTION LIGHT PANEL

- CIP/AUT LIGHT ILLUMINATES

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Figure 2-74. Backup A/G Weapon Delivery (Sheet 7 of 20)

DDI DISPLAY FAILURE (DAY ATTACK AIRCRAFT)

LOSE

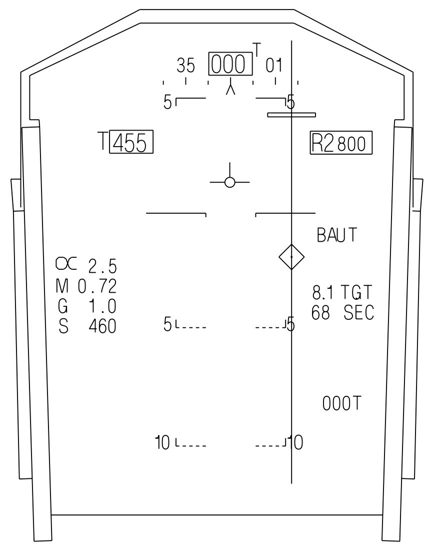
- DDI DISPLAYS FOR HUD, STORES, DMT, (ARBS/TV, INS (TV), AND ARBS/LST), EHSI, ECM, ENGINE AND BIT

USE

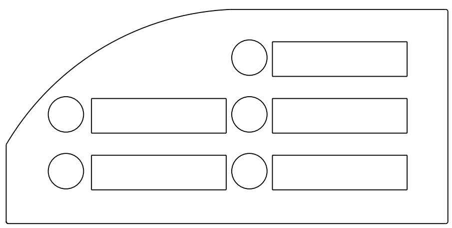
- HUD
- DDI PUSHBUTTONS

NOTE

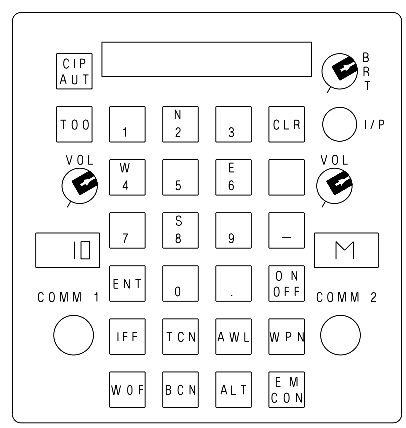
ALL DDI OPTIONS ARE PUSHBUTTON SELECTABLE BY REMEMBERING PUSHBUTTON FUNCTIONS AND OBSERVING HUD, UFC, AND ODU DISPLAYS.



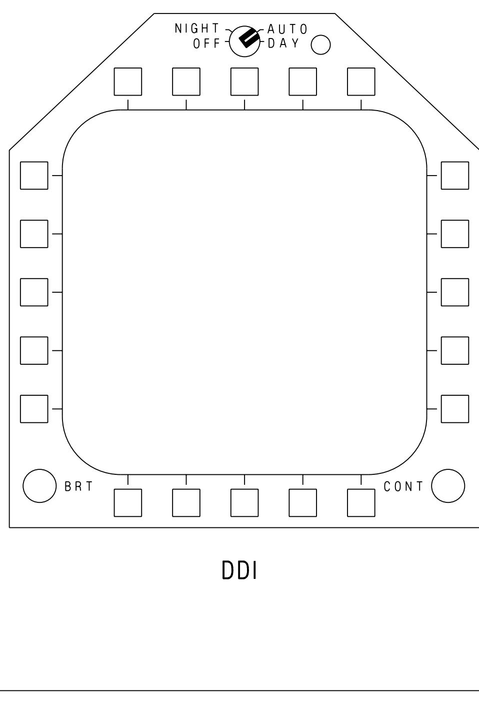
HUD



ODU



UFC



DDI

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Figure 2-74. Backup A/G Weapon Delivery (Sheet 8 of 20)

DDI COMPLETE FAILURE (DAY ATTACK AIRCRAFT)

LOSE

- DDI DISPLAYS FOR HUD, STORES, DMT, (ARBS/TV, INS (TV), AND ARBS/LST), EHSI, ECM, ENGINE AND BIT

USE

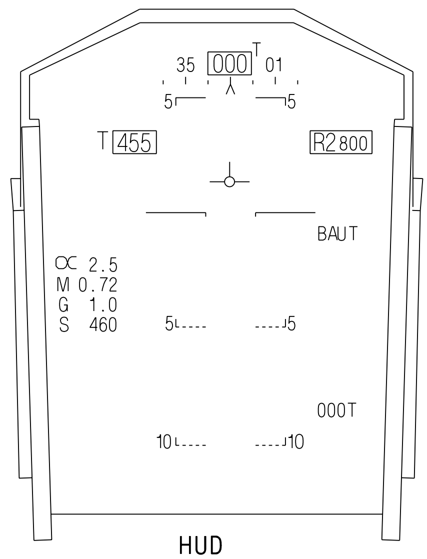
- HUD
- UFC AND ODU FOR WAYPOINT DATA ENTRY
- ACP FOR WEAPON SELECTION AND PROGRAMMING

SELECT

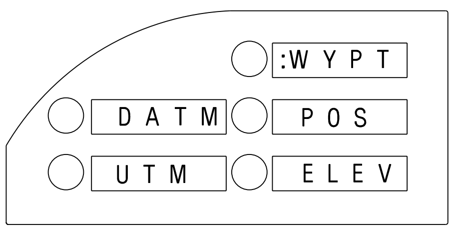
- DDI BRIGHTNESS SELECTOR KNOB – OFF

NOTE

- DESELECTING DDI INITIALIZES ODU/UFC TO WAYPOINT DATA

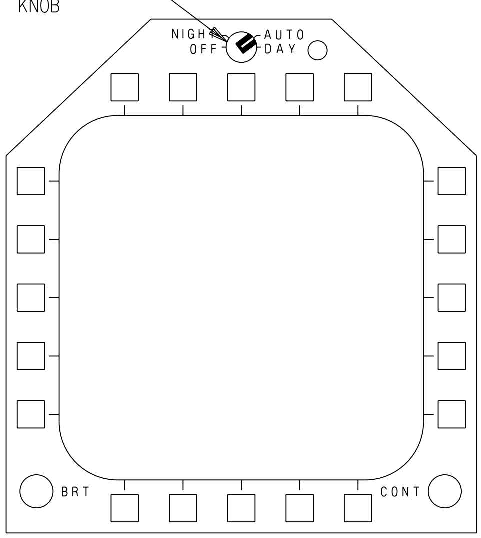


HUD



ODU

DDI BRIGHTNESS SELECTOR KNOB



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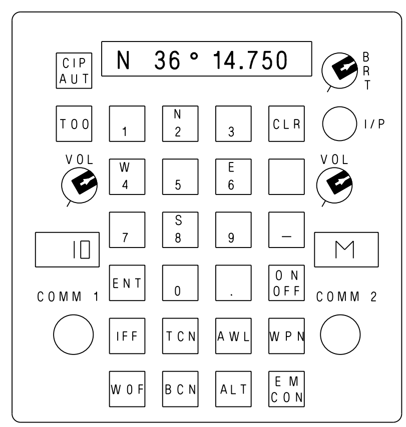

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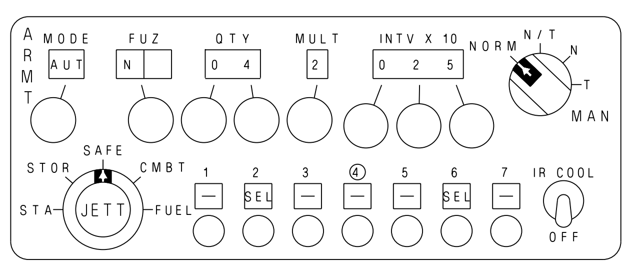


ACP

AHR607-100-9-013

Figure 2-74. Backup A/G Weapon Delivery (Sheet 9 of 20)

DMT FAILURE
(DAY ATTACK AIRCRAFT)

LOSE

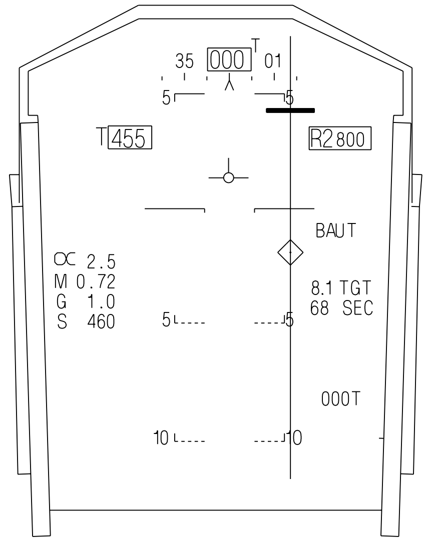
- ARBS/TV OR INS IF NO ARBS/LST
- ARBS/LST OR INS IF NO ARBS/TV
- INS IF NO ARBS/LST AND ARBS/TV

USE

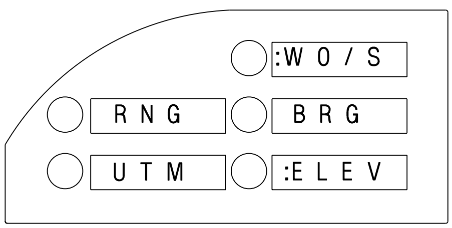
- ARBS/TV OR INS IF NO ARBS/LST
- ARBS/LST OR INS IF NO ARBS/TV
- INS IF NO ARBS/LST AND ARBS/TV

ENTER

- BAROMETRIC CORRECTION FOR HUD IF REQUIRED



HUD



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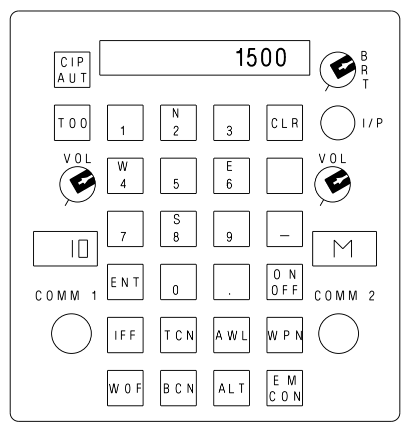
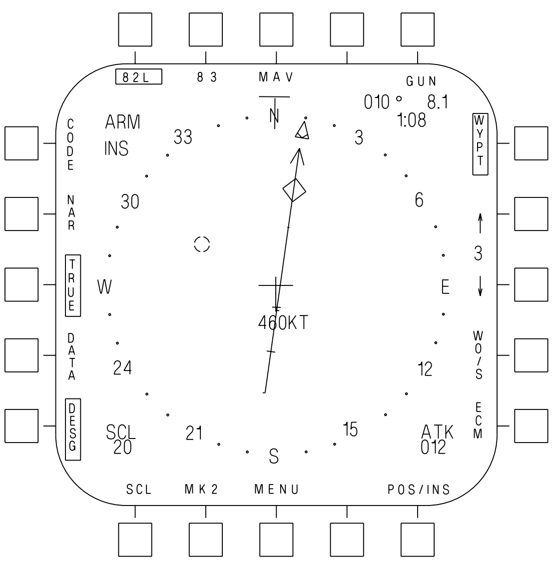


UFC



DDI

AHR607-100-10-013

Figure 2-74. Backup A/G Weapon Delivery (Sheet 10 of 20)

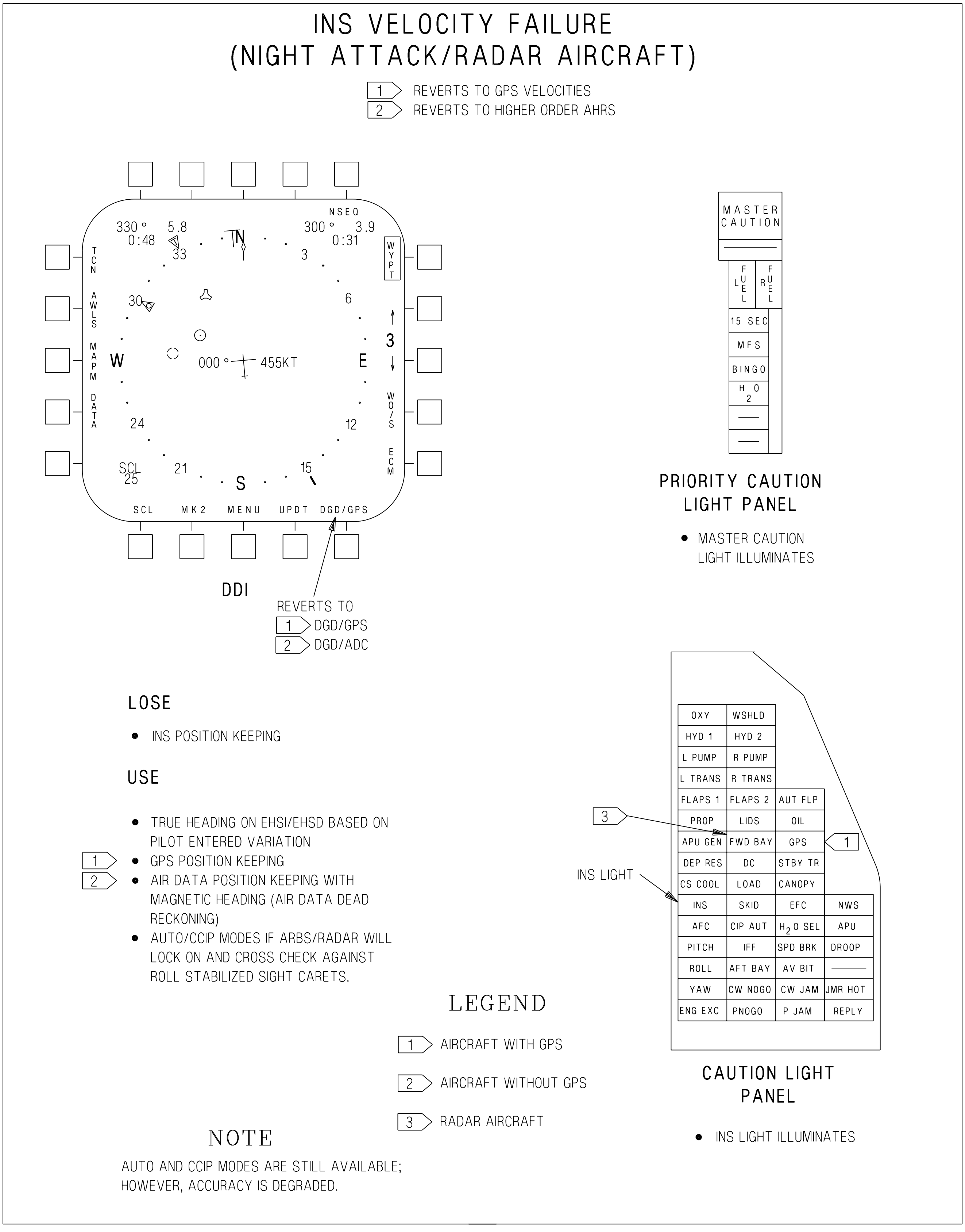


Figure 2-74. Backup A/G Weapon Delivery (Sheet 11 of 20)

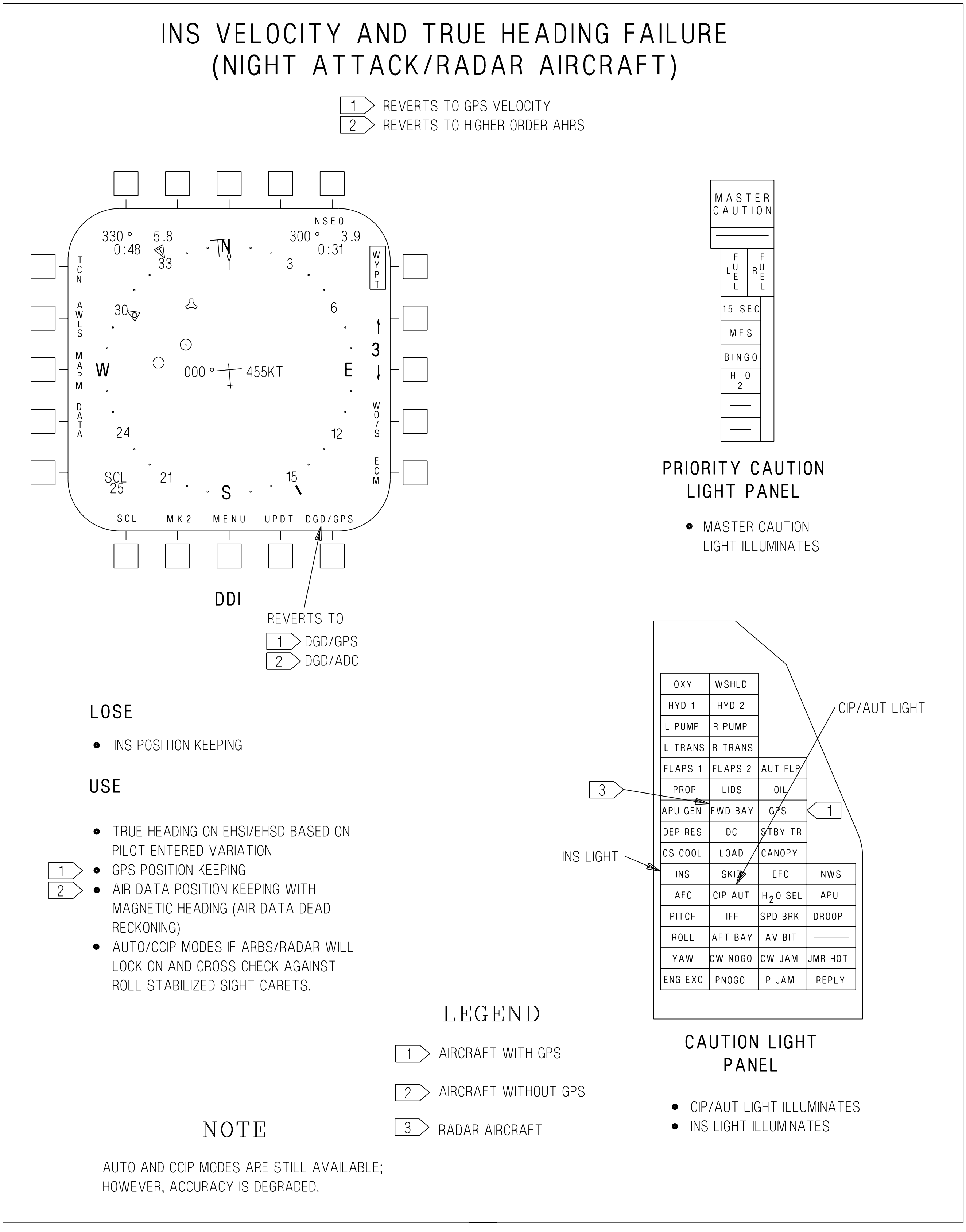


Figure 2-74. Backup A/G Weapon Delivery (Sheet 12 of 20)

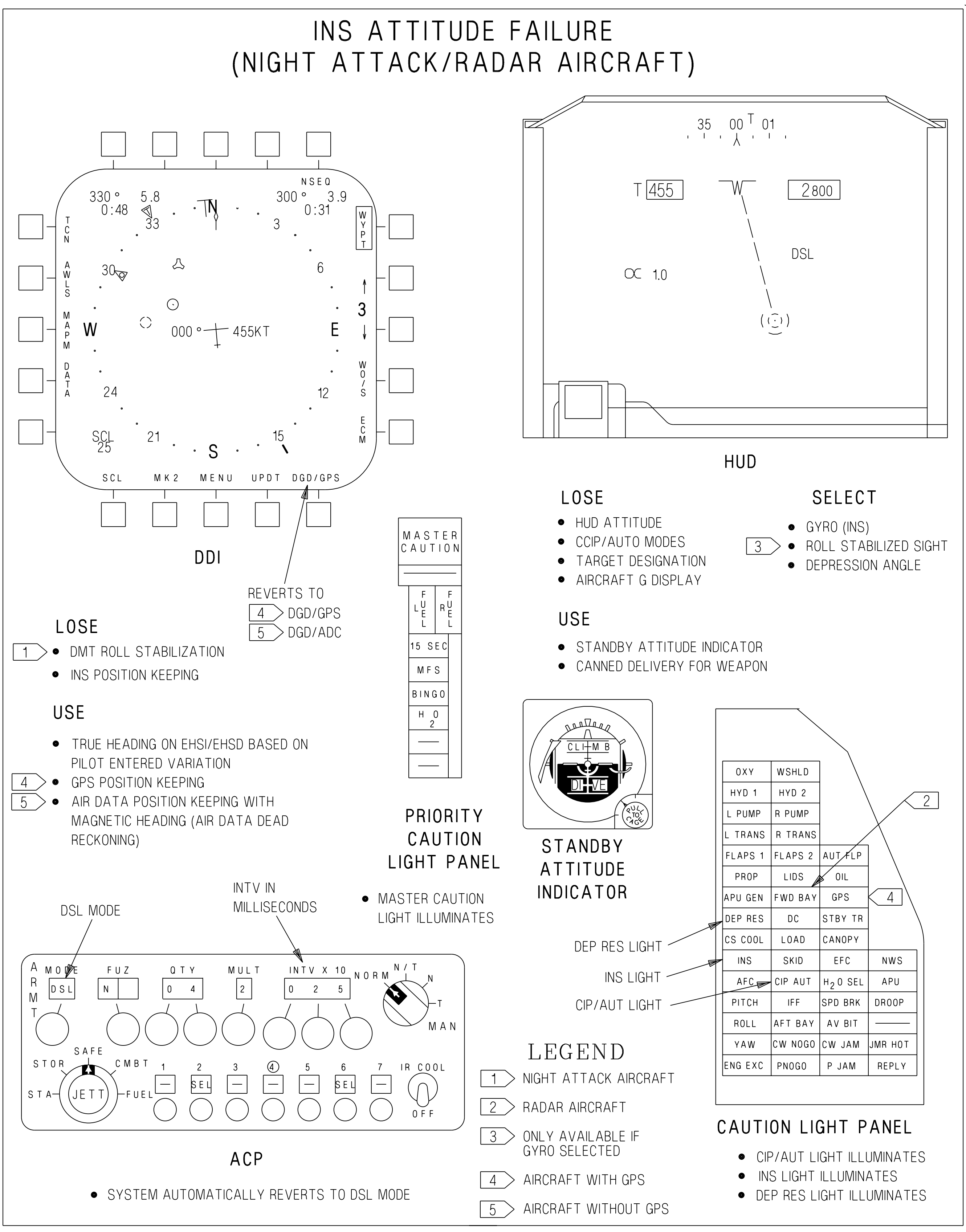


Figure 2-74. Backup A/G Weapon Delivery (Sheet 13 of 20)

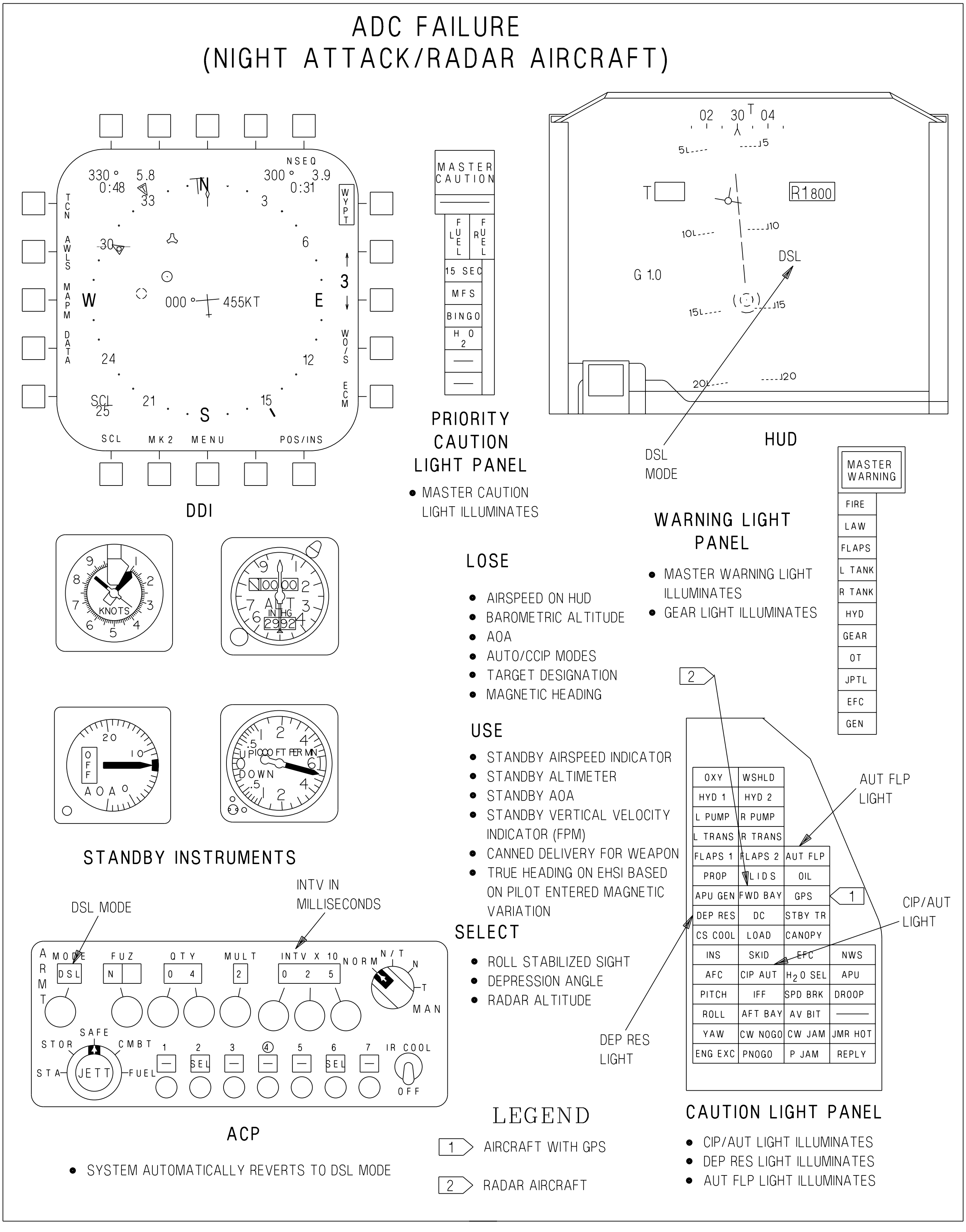


Figure 2-74. Backup A/G Weapon Delivery (Sheet 14 of 20)

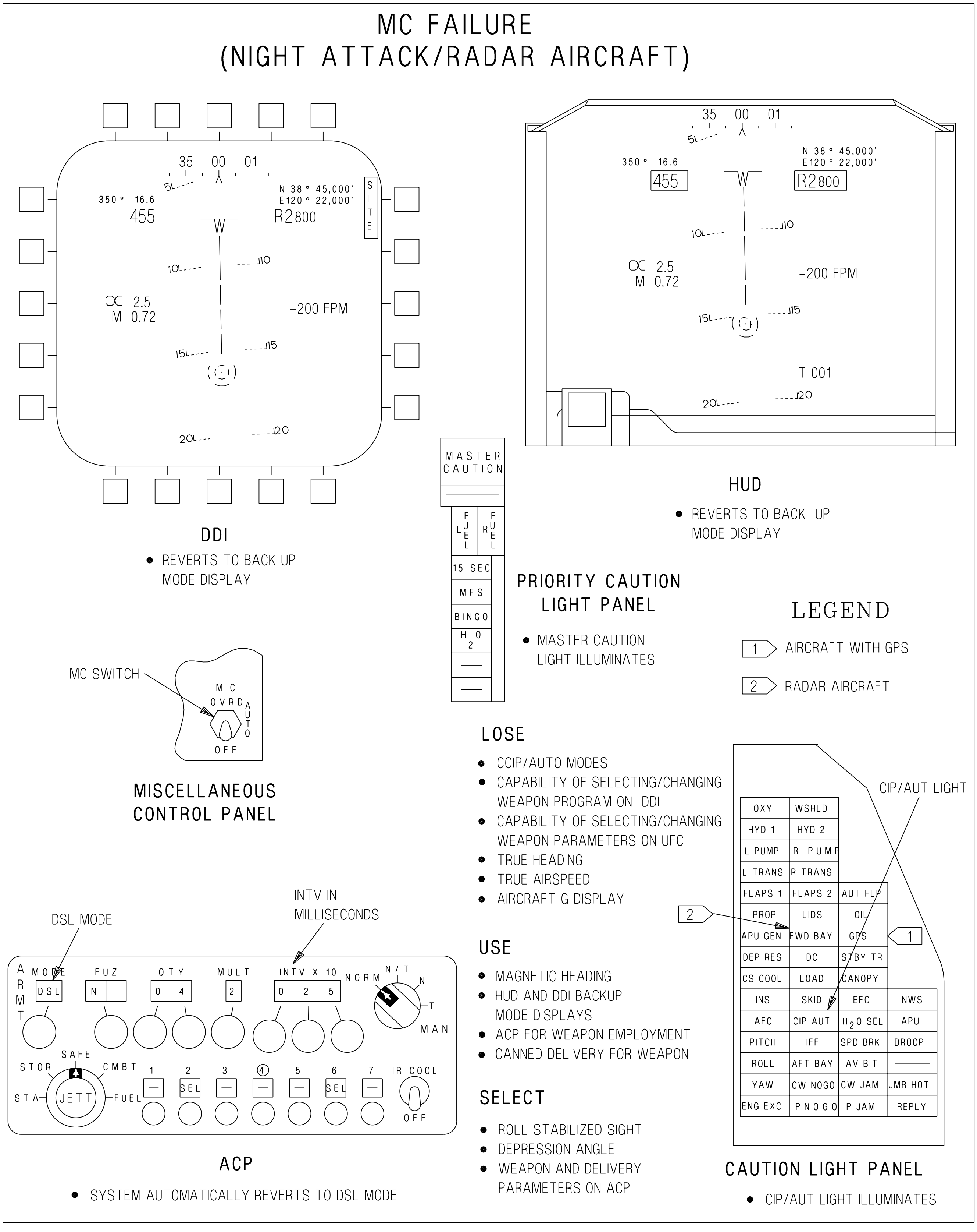
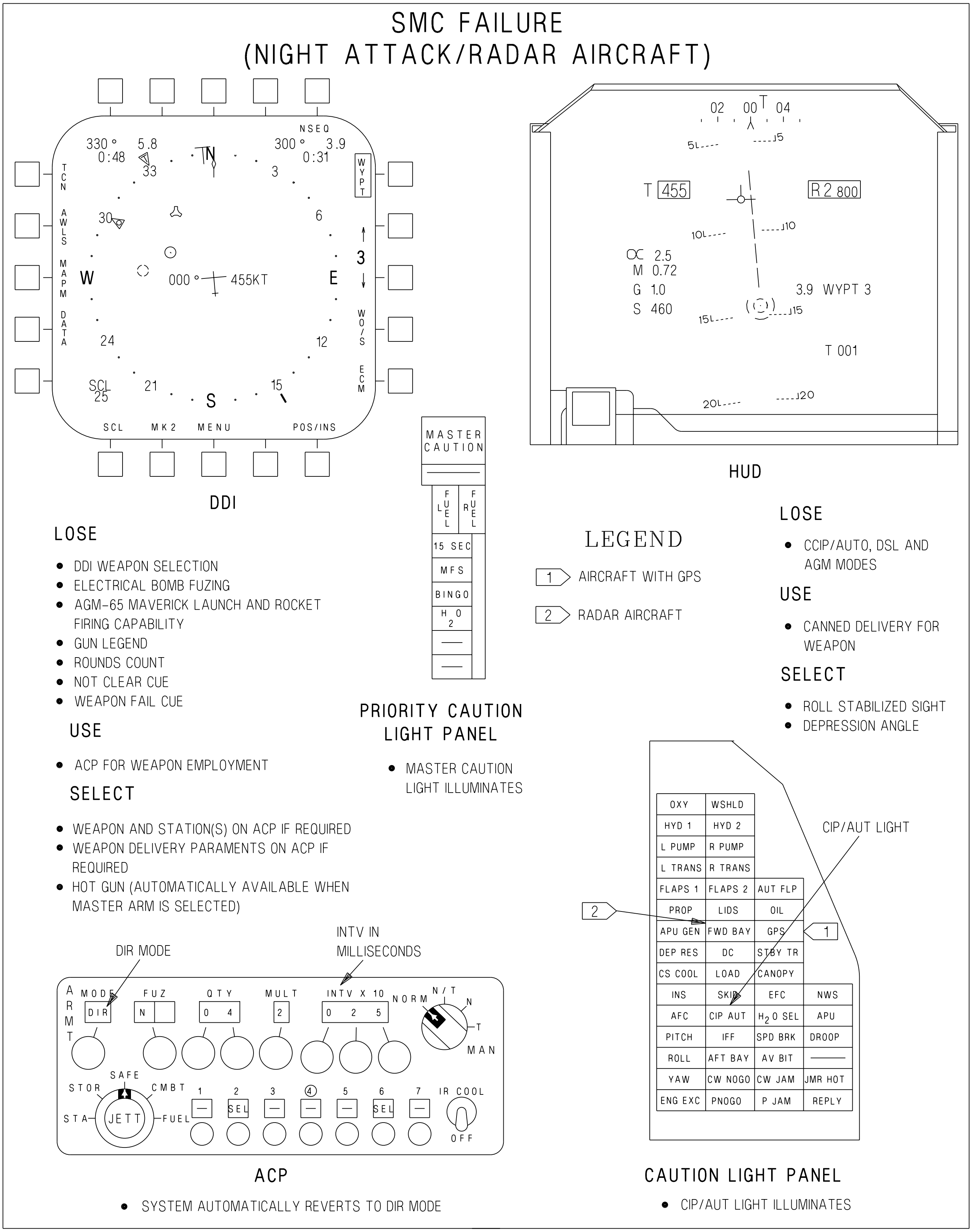


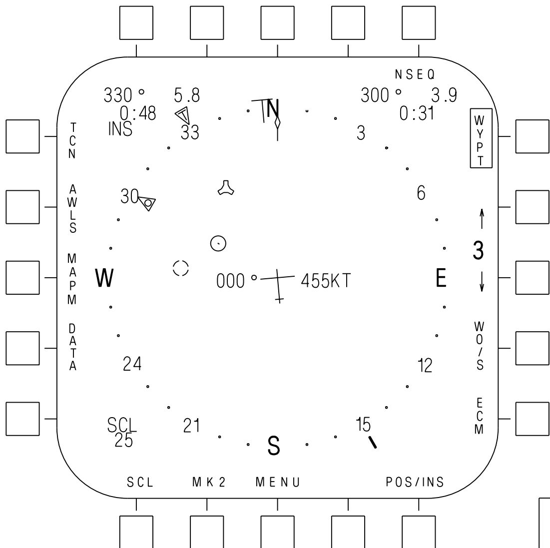
Figure 2-74. Backup A/G Weapon Delivery (Sheet 15 of 20)



AHR607-100-16-013

Figure 2-74. Backup A/G Weapon Delivery (Sheet 16 of 20)

SMC AND ACP PROCESSOR FAILURE (NIGHT ATTACK/RADAR AIRCRAFT)



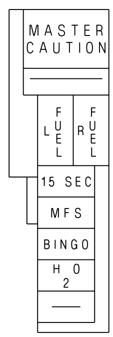
DDI

LOSE

- DDI WEAPON SELECTION AND STORES DISPLAY
- ACP PROGRAM OPTION SWITCHES
- ELECTRICAL BOMB FUZING
- MAVERICK LAUNCH AND ROCKET FIRING CAPABILITY
- GUN LEGEND
- ROUNDS COUNT
- NOT CLEAR CUE
- WEAPON FAIL CUE

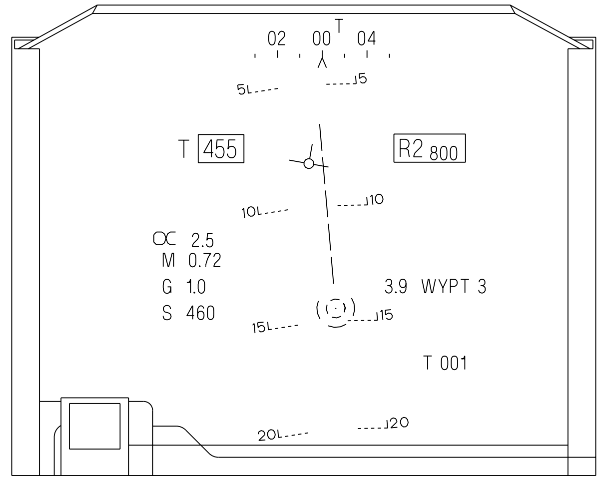
USE

- ACP FOR WEAPON EMPLOYMENT



PRIORITY CAUTION LIGHT PANEL

- MASTER CAUTION LIGHT ILLUMINATES



HUD

LOSE

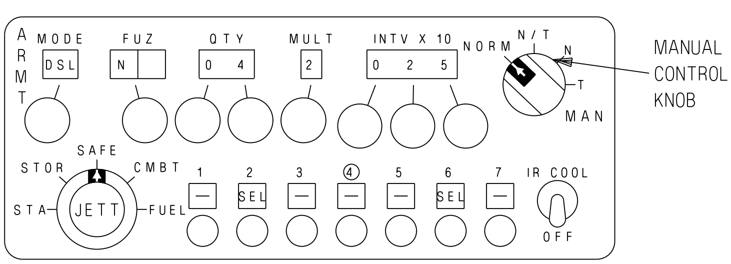
- CCIP/AUTO, DSL, AGM AND DIR MODES

USE

- CANNED DELIVERY FOR WEAPON

SELECT

- ROLL STABILIZED SIGHT
- DEPRESSION ANGLE



ACP

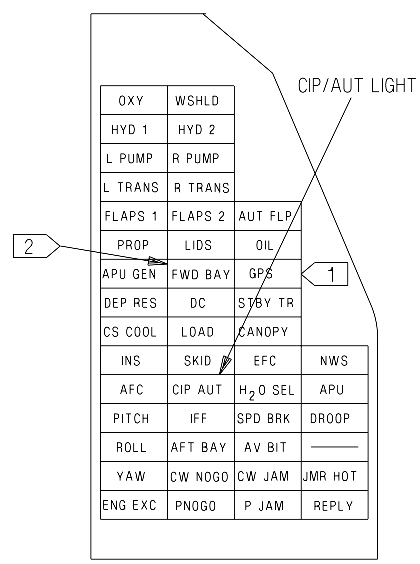
SELECT

- DSL(1) MODE AND FUZING WITH MANUAL (MAN) CONTROL KNOB ON ACP
- WEAPON STATIONS ON ACP (UNLESS PREPROGRAMMED)
- HOT GUN (AUTOMATICALLY AVAILABLE WHEN MASTER ARM IS SELECTED)

LEGEND

1 AIRCRAFT WITH GPS

2 RADAR AIRCRAFT



CAUTION LIGHT PANEL

- CIP/AUT LIGHT ILLUMINATES

AHR607-100-17-013

Figure 2-74. Backup A/G Weapon Delivery (Sheet 17 of 20)

DUAL DDI DISPLAY FAILURE
(NIGHT ATTACK/RADAR AIRCRAFT)

LOSE

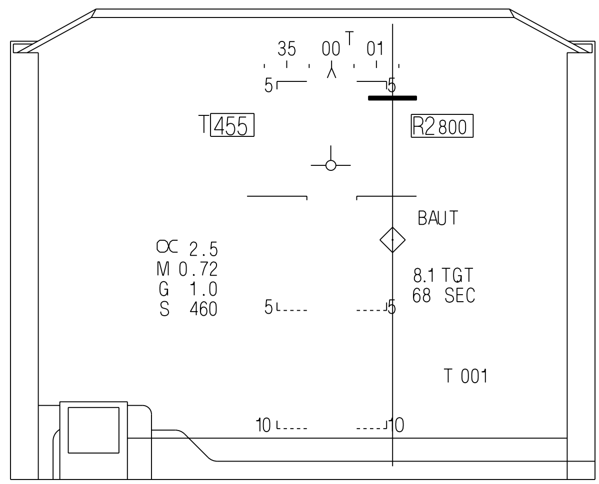
- DDI DISPLAYS

USE

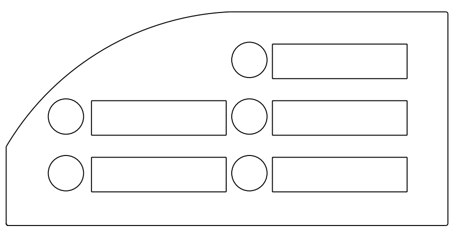
- HUD
- DDI PUSHBUTTONS

NOTE

ALL DDI OPTIONS ARE PUSHBUTTON SELECTABLE BY REMEMBERING PUSHBUTTON FUNCTIONS AND OBSERVING HUD, UFC, AND ODU DISPLAYS.



HUD



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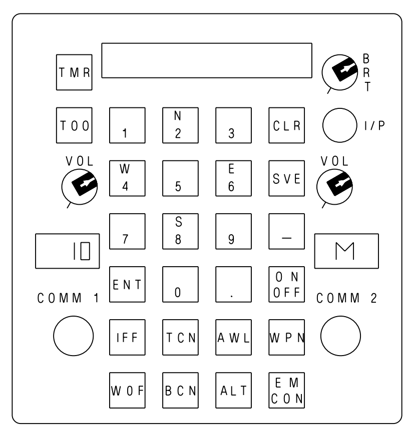
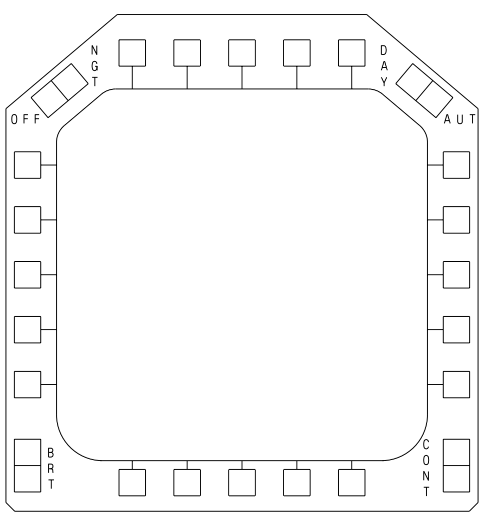


UFC



DDI

AHR607-100-18-013

Figure 2-74. Backup A/G Weapon Delivery (Sheet 18 of 20)

DUAL DDI COMPLETE FAILURE (NIGHT ATTACK/RADAR AIRCRAFT)

LOSE

- DDI DISPLAYS

USE

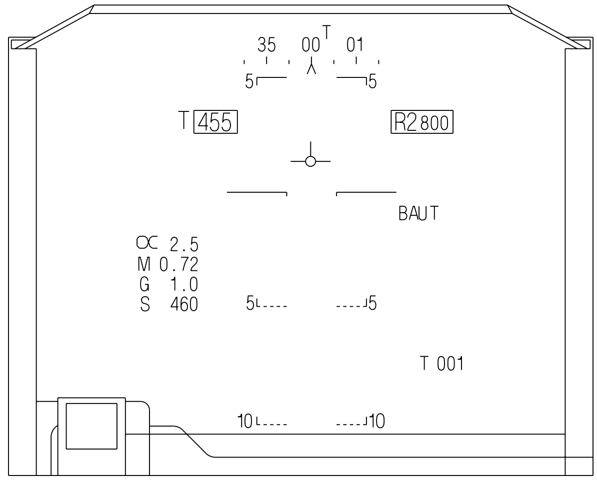
- HUD
- UFC AND ODU FOR WAYPOINT DATA ENTRY
- ACP FOR WEAPON SELECTION AND PROGRAMMING

SELECT

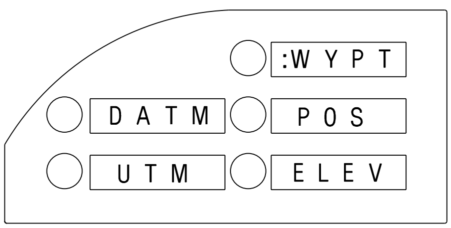
- DDI OFF/NGT SELECT SWITCH – OFF

NOTE

TURNING OFF BOTH DDI INITIALIZES ODU/UFC TO WAYPOINT DATA



HUD



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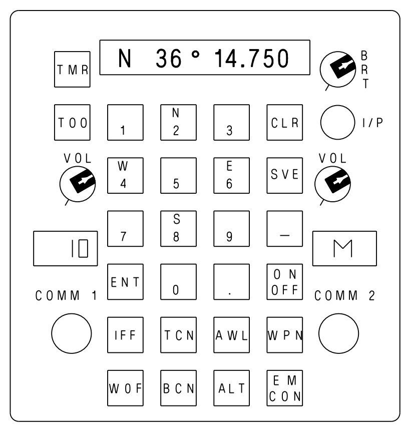
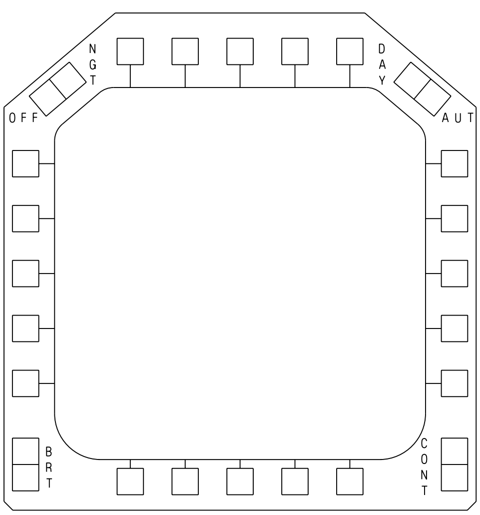
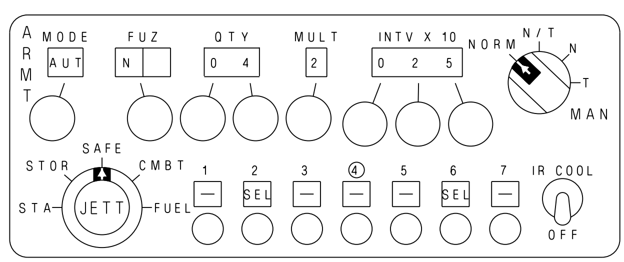


UFC



DDI



ACP

AHR607-100-19-013

Figure 2-74. Backup A/G Weapon Delivery (Sheet 19 of 20)

DMT FAILURE
(NIGHT ATTACK AIRCRAFT)

LOSE

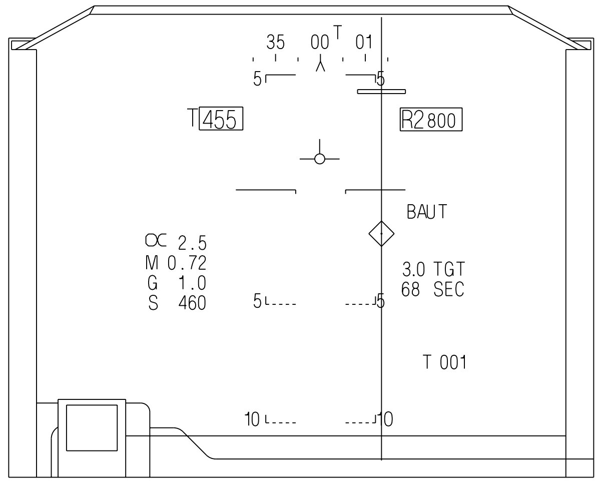
- ARBS/TV
- ARBS/LST
- NO ARBS/LST AND ARBS/TV

USE

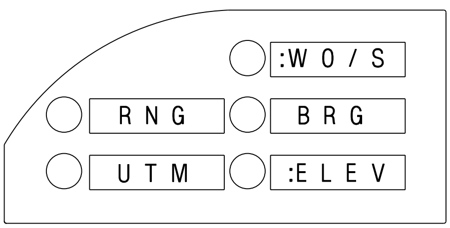
- ARBS/TV OR INS IF NO ARBS/LST
- ARBS/LST OR INS IF NO ARBS/TV
- INS IF NO ARBS/LST AND ARBS/TV

ENTER

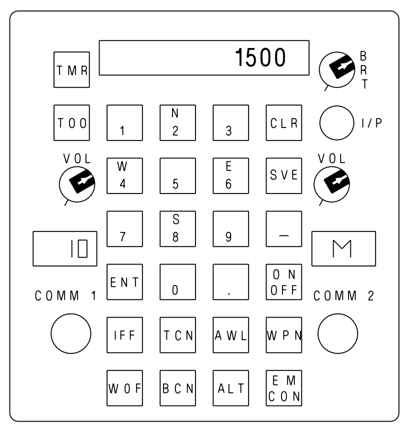
- BAROMETRIC CORRECTION FOR HUD
  IF REQUIRED



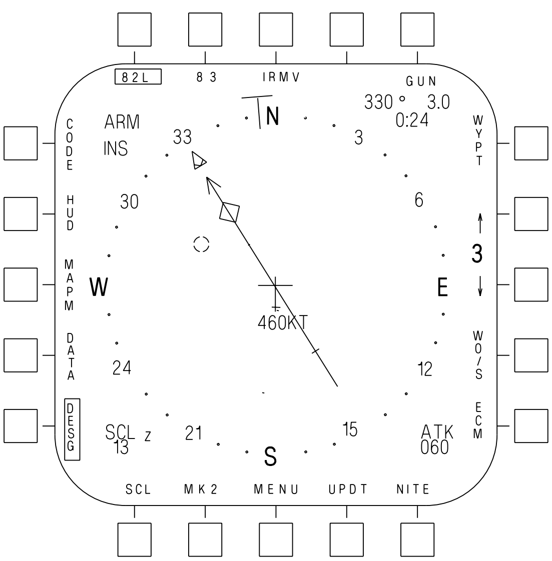
HUD



ODU



UFC



DDI

AV8BB-TAC-00_100-20-12

Figure 2-74. Backup A/G Weapon delivery (Sheet 20 of 20)

2.7 RADAR ATTACK CONSIDERATIONS

The APG-65 provides the capability to perform blind radar bombing, however, the AV-8B is not designed to be an all-weather attack aircraft. If the pilot has a good knowledge of basic radar bombing procedures, he can improve SA in the target area, and improve target designation accuracy with the radar. In this manner, the pilot can feel more confident that a radar designation or track will provide accurate steering to the target for a visual (either unaided or aided) weapon delivery.

The DBS (Doppler Beam Sharpened) and MRSAR (Medium Resolution Synthetic Aperture Radar) expand displays provide a seemingly simple and accurate method of designating targets. They provide magnified, relatively high resolution ground maps of selected areas that the real beam ground map is not capable of providing. However, if the pilot wishes to optimize expand display accuracies, he should realize that the expand modes are synthetically created displays which require accurate data to be correct. Improper technique when using the expand modes and poor management of system derived velocities can yield significant designation errors and poor target position stabilization which can add up to the target not being where you expect to find it.

2.7.1 Target Designation and Stabilization Considerations. The beauty of the expand modes is the excellent resolution they provide in comparison to the real beam ground map. In the DBS modes (EXP1 and EXP2), the radar distinguishes small differences in doppler shift produced by objects at different azimuth bearings. Thus, these modes have the capability to resolve objects in azimuth that would otherwise be lost in the radar's real beam. In this case, the range rate of a patch of ground, as derived by the return's doppler shift, is determined solely by ownship (aircraft) velocity and the angle to the area on the ground. The radar does not determine target azimuth by using line-of-sight position of the antenna as it does in the real beam map modes. This produces an inherent error in the expand mode displays of which the pilot should be aware. Any error in the velocities provided by the MC to the radar will result in an erroneous azimuth calculation which will produce an error known as "map shift".

The radar measures the doppler shift of a target as produced by the relative movement of the target towards the aircraft. To determine the target's azimuth, the radar calculates the angle from a point at the same range that will produce an equivalent doppler shift, using the MC's velocity. The angular difference between actual target azimuth and computed target azimuth produces map shift. The aircraft designates the target at the computed azimuth and measured range, which is different from the actual target's position. A larger velocity error will produce a larger amount of map shift. In fact, every point in the expanded area will be shifted, thus the entire map is shifted in azimuth, not just any one target.

Although map shift error is caused by system velocity error, there are several additional factors which affect the magnitude of any system induced map shift. These include:

1. Aircraft Velocity - A higher velocity reduces the amount of map shift.

2. Range-to-target - Map shift is an angular error. The closer you are to the target when you build the radar map, the less distance the angular error will cover.

3. Squint angle - Squint angle is the angle between the velocity vector and the line-of-sight to the designation (Figure 2-75).

System derived velocity and the first two factors listed above, aircraft velocity and range, all have a linear effect on map shift. In other words, reducing system derived velocity error from 2 knots to 1 knot will improve map accuracy by 50 percent, increasing airspeed from 360 knots to 480 knots will reduce the map shift error by 25 percent, and a map made at 10 nm will have half the error of a map made at 20 nm.

One of the most important contributing factors to control is the squint angle. Small squint angles - mapping targets near the nose - increase

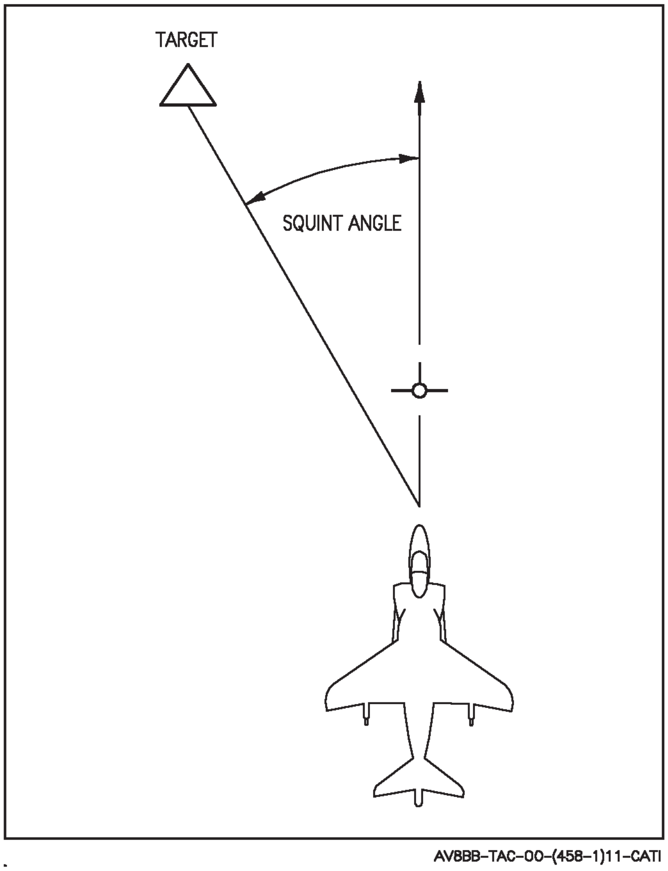


Figure 2-75. Squint Angle

the potential for large map shift errors. Initially, small increases in squint angle produce significant improvements in map accuracy. As the squint angle approaches 45°, the trade-off between angle and accuracy approaches one to one and beyond 45°, map accuracy continues to improve but at a lower rate. Mapping angles of 30° to 45° appear to be most effective. Resist the temptation to update the designation during the turn back to the target as it enters the notch. The map shift phenomena is most apparent during this maneuver and manifests itself as apparent stab cue drift on the radar display, so don't try to "sweeten up" the stab cue at the last second. Also, remember not to attempt refining the designation in the MAP mode.

The Medium Resolution SAR mode (EXP3) is also a synthetically processed display, however, velocity errors have a different affect on this display. In the EXP3 mode, the forward motion of the aircraft is used to synthesize the equivalent of a very long sidelooking array antenna from the radar returns received over a period of up to several seconds or more. Since the length of the synthetic array is increased in direct proportion to the range of the area being mapped, EXP3 provides a constant resolution display (1.2 nm x 1.2 nm) which is independent of range. The EXP3 mode is capable of providing display resolution on the order of 30 feet, however, if inaccurate system (i.e., INS) velocities are supplied, display resolution will be degraded. In this case, the map is not "shifted", rather the pilot's ability to discern closely spaced objects as separate is degraded.

Once you have located and designated the target, the MC must maintain target stabilization - a continual update of the target's position relative to the aircraft. To do this, the MC uses inputs from several sources on a "best-available" basis. When using a radar designation, the stab cue position is maintained by best available MC derived velocities. Alternatively, the pilot could initiate a radar track (i.e., FTT) on the target. This would result in both horizontal ranges and vertical altitudes being resolved through radar tracking data.

Both a radar designation and a radar track have their advantages and their disadvantages. A FTT is capable of providing more accurate target stabilization, especially if the INS has an appreciable drift. The radar provides a continuous measurement of slant range and line-of-sight angles to the target. In this manner, the radar accurately determines ground range, target bearing, and height above target. This serves to maintain the TD box on the target and provide data for weapon delivery computations when using the AUTO delivery mode. In the CCIP mode, height above target is determined by the RALT if the :BOMB option is cued and RALT data is valid. If BOMB is not cued or RALT is invalid, height above target is determined by pilot entered elevation (i.e., WYPT or WO/S). If the pilot wishes to utilize radar derived height above target in the CCIP mode, he must select (sensor select switch forward) the AGR mode prior to delivery.

On the other hand, there are cases in which the radar may not be able to track a target that is detected from an expanded display. It may end up tracking any radar return in its beam coverage and not necessarily the intended target. This is because FTT is a real beam mode and does not take advantage of the doppler processing techniques utilized in the expand modes. As such, it simply cannot resolve the detail available from an expanded display. When FTT is initiated from an expanded display, the radar may “wander” between several significant radar returns that are within its limited resolution cell. Eventually the radar locks onto the strongest return since FTT uses amplitude acquisition to establish the track. The lock could very likely be displaced from the intended acquisition point, especially in areas with multiple possible targets.

Additionally, since the FTT radar display only displays a synthetic target symbol and no map video, the pilot cannot tell from the display if the radar is tracking the intended target or has locked onto another target that is adjacent to the desired target. For this reason, FTT is not recommended unless the target is somewhat isolated and the pilot has high confidence that the track is correct.

A radar designation may provide slightly less accurate target stabilization but it offers other advantages over FTT. In this case, stabilization accuracy is largely dependent on the accuracy of the aircraft’s system velocities. Velocity errors in the MC cause the target position to drift after final designation, in addition to causing map shift errors. For example, with a final “sweetening” of the designation at 7 nm, a ground speed of 480 knots and a system velocity error of 1 knot, the designation (stab cue) will drift almost 90 feet by the time the aircraft overflies the target. Recognizing and correcting system velocity errors is probably the most important task the pilot can accomplish to improve target stabilization with a radar designation. Thus, velocity errors affect target stabilization as well as causing map shift.

There are several simple methods that can be used to recognize velocity errors. Monitoring system navigation accuracy during the mission is the most obvious technique. Accurate waypoint steering, accurate placement of the stab cue on the radar display with minimal drift, and the TD diamond overlying the waypoint in the HUD all indicate minimal velocity errors. Another method is to initiate air-to-ground (AGR) ranging anywhere along your route. Remember, the MC slaves the radar antenna LOS in AGR in the following priorities; CCIP, designation, velocity vector. The AGR radar display provides a delta velocity readout that reflects the difference between radar velocities as measured along the commanded LOS and the best available (i.e., INS) system velocity. Significant delta velocities indicate the system has built up a velocity error. Remember, the delta velocity displayed on the AGR display is only an advisory that a PVU may be necessary.

Another technique is utilizing the precision velocity update (PVU) feature. A velocity (VEL) update is the only method that allows the pilot to measure and correct the current velocities in the MC for weapon delivery computations. In order to perform a velocity update, the pilot first selects the PVU option on the RDR, EHSD, or NAVFLIR display, and then selects the VEL option on the ODU. In the PVU mode, the radar commands the antenna to three distinct look angles to obtain an accurate measurement of the aircraft’s ground speed. The applicable LAND (default selection) or SEA option should be selected by the pilot to optimize the radar lookdown angle for the type of terrain surface.

The PVU derived error is displayed on the scratch pad in the form of a radial (degrees) and velocity (knots/tenths) errors. PVU accuracy depends on the length of time the radar is in the mode and on the type of terrain over which you are flying. An error will appear quickly, but it may change and then stabilize as the PVU progresses. Generally, 15 seconds should be sufficient to provide an accurate PVU. Under optimal conditions, the PVU is designed to provide velocity accuracies to +3 feet per second (approximately 1.75 knots). Thus, when the aircraft’s velocity error is small - less than 2.0 knots - the PVU may apply a correction that actually makes the system velocity worse. For this reason, performing a PVU may not be necessary or desirable when operating with GPS or a fully aligned ″tight″ INS.

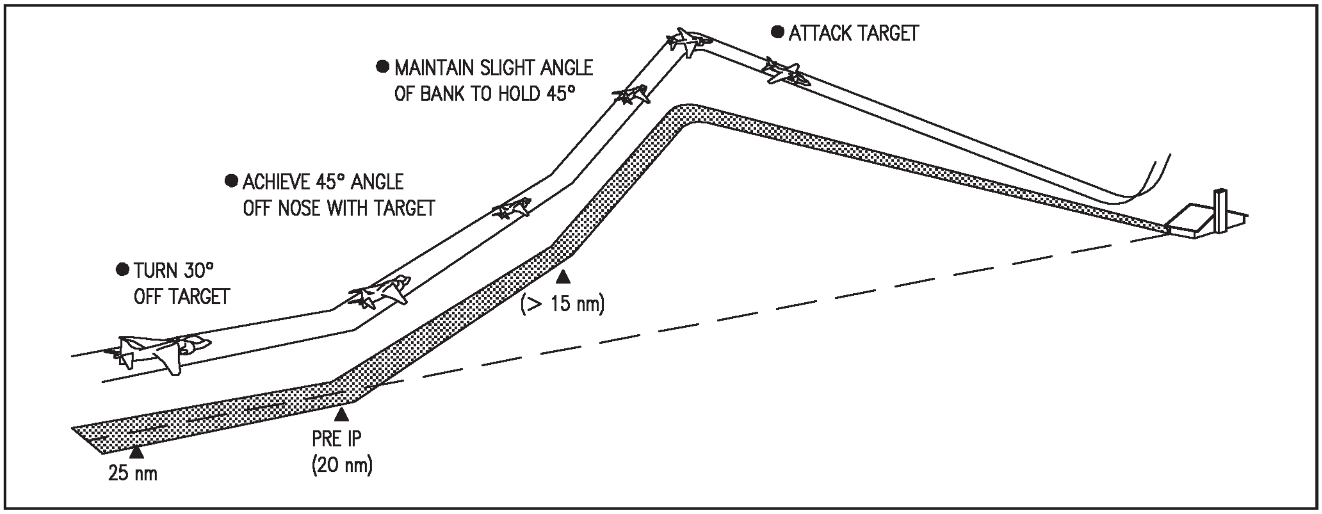


Figure 2-76. Generic Radar Bombing Attack Profile

Accept/reject criteria will vary depending upon the quality of INS operation (i.e., FULL INS, FIRST ORDER AHRS, etc.) and system performance during the mission, however, generally errors of more than 2 knots should be considered for acceptance in order to maximize weapon delivery accuracy. If accepted, the PVU correction is retained by the MC for weapon delivery computations for a period of approximately 10 minutes, with the correction being gradually phased out over the last 5 minutes. The PVU correction does not affect INS velocities for navigation purposes.

The tactical situation and the threat will drive the tactics (i.e., high, medium, or low). This is not an ″All Weather″ attack, but an attack that may be prosecuted from VFR on top conditions to either a visual acquisition or an actual blind release as per current ROE or clearance. The same procedures may also be used in clear weather for systems refinement. This profile optimizes the radar's capability to ground map by striving for the optimum squint angle just before the final designation refinement. Initial mapping should be done at 15 to 18 nm from target at a squint angle that clears the target from the ″notch.″ An altitude should be selected that will establish a good radar line of sight to the area that is being mapped. EXP1 is used initially as a quick check to ensure that the target is reasonably well located and will remain within the EXP2 window (12.6°). Prior to the mapping evolution, the airspace must be sanitized either by the mapping aircraft or a flight member through a prebriefed contract. Always remember the importance of keeping the ″eyes out the window″ and mission cross-check times. Staring at the map during the building stage is not normally beneficial. Use that time to check other mission essential items. The following blueprint attempts to drive the target to a 45° squint prior to turning inbound. See Figure 2-76.

Pre-IP: (20 nm)

(a) Ensure target area is sanitized

(b) PVU, within 5 minutes of attack

IP: (outside 15 nm)

(a) WOF or select A/G master mode - WINC - designate

(b) Ensure CCIP mode is selected

(c) Turn off heading by 30°

(d) Create adequate radar LOS if at low level (pop-up)

(e) Select EXP1 and validate stab cue position

(f) Refine designation and select EXP2

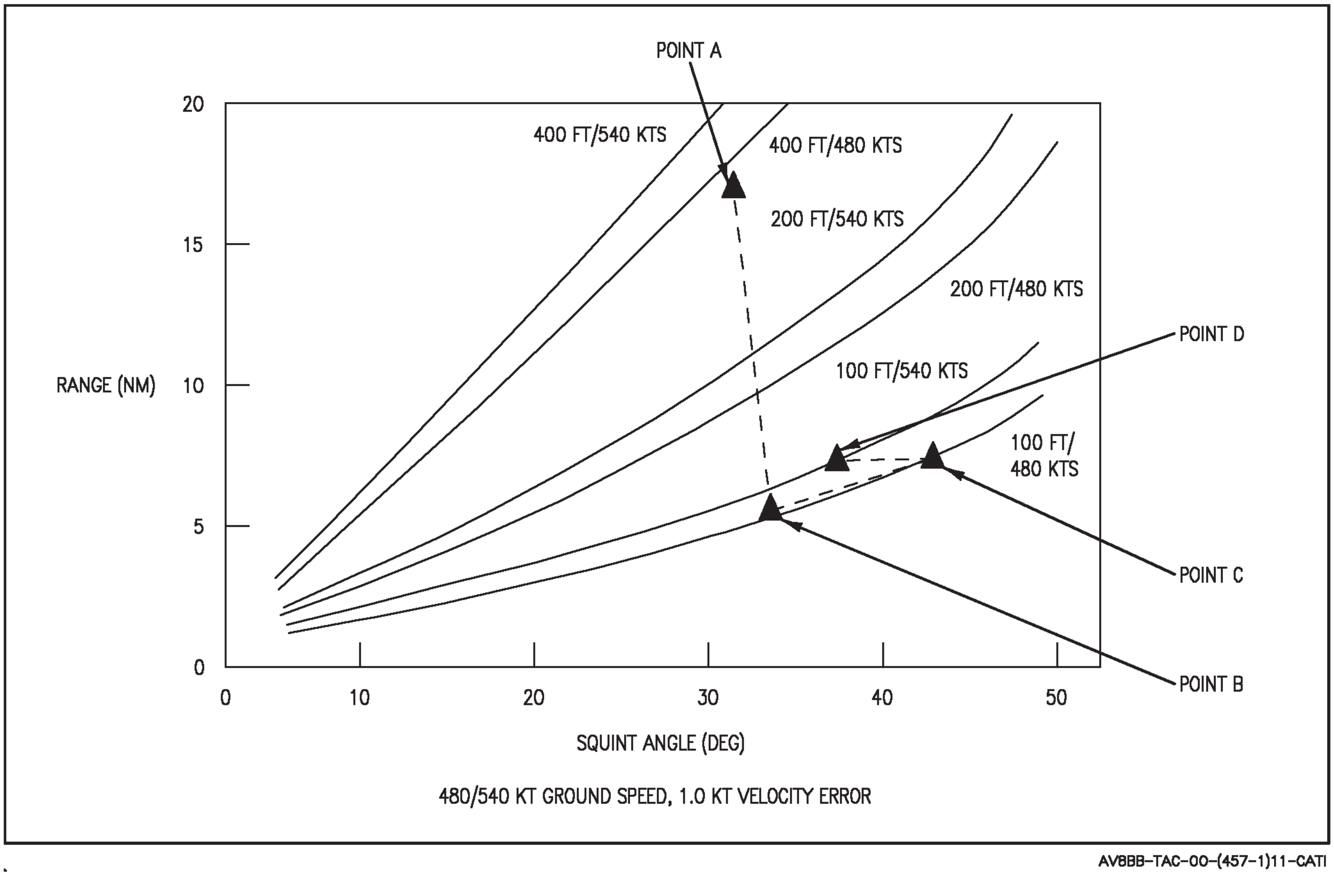


Figure 2-77. Constant Mapping Error

(g) Fly to a 45° angle off position by holding a slight angle of bank as required

(h) Freeze the map 1 to 2 nm prior to the ACD and refine designation

(j) Select AGR

ACD:

(a) If *"tally"*, UNDESIG-AUTO, velocity vector designate and deliver

(b) If *"no-joy"*, remain designated - CCIP - roll in

(c) At breakout, deliver visually

(d) If breakout does not occur by checkpoint, select AUTO and dive toss *or* conduct an abort as required

If a low altitude expand map ingress is required, remasking will be necessary after an adequate expand map with designation is built. The pilot must select "Freeze" option prior to the remask point.

This profile would change with the tactical scenario. Regardless of the selected profile, the principles of minimizing map shift and optimizing target stabilization remain the same. Figure 2-77 illustrates how you can vary the profile while holding a constant map shift. Point “A” represents the initial map made from a profile similar to the one described in the radar bombing attack. Designation accuracy is only slightly better than 400 feet with a 1 knot velocity error in the MC. Point “B” is the final map from the previous profile and is made at 5 nm. This map will produce a designation accuracy of 100 feet if made at 480 knots and a squint angle of 32°. If you were forced to change the profile so that the final map was made at 7 nm, Point “C” shows that you would have to increase squint angle to 42° in order to maintain the 100 feet designation accuracy. Finally, if you accelerated to 540 knots, at 7 nm, you would have 100 feet designation accuracy with a 39° squint angle, Point "D". The difference of only 3° in squint angle at 7 nm may be splitting hairs in practical terms of flying the aircraft, but it illustrates the effects of airspeed, squint angle, and range on map shift.

2.7.1.1 Summary. If the target has sufficient reflectivity and contrast from it surroundings, following these basic radar attack procedures should steer the aircraft close enough to the target for visual (unaided or aided) acquisition and weapon delivery. Monitoring system velocities and having a stable, tight INS is a requirement to optimizing the accuracy of the expand modes. Accurate hits will require additional preflight planning over and above what is required for other techniques (i.e., radar predictions), and they require dedicated practice runs before the pilot will feel confident he can execute his attack as planned.

2.8 DELIVERY TECHNIQUES (BOMBS, ROCKETS, GUN)

2.8.1 Weapon Independent Factors. Dive bombing is the accepted delivery method of conventional ordnance against a surface target. Even though a computed weapon system greatly expands tactical delivery parameters, it is important to remember that weapon arming time, terrain, enemy defenses, and safe escape distances must always be considered. Analysis of the computed weapon system requires a combination of skills. One is system management to ensure a high confidence level in the aiming solution. Also needed is a knowledge of the planned release parameters to check the system against incorrect data entry, system degradation, or poor sensor management. Height above target determination is critical to determining accurate weapons release solutions. Therefore, a thorough understanding of the various altitude sources as discussed in the initial part of this chapter is required in order to optimize the computed delivery system.

When using the noncomputed aiming system, weapon accuracy is directly related to the pilot's understanding of the delivery requirements and the magnitude of error induced by a deviation from the planned release parameters.

The required sight depression setting is obtained from the sight angle charts or the ballistics tables in NWP 3-22.5-AV8B, Vol. II, Chapter 2.

Whether using the noncomputed or the computed system, mission planning is essential to establish release parameters and safe escape from frag and terrain. For this reason the basic delivery and tracking techniques for bombing, rocketry, and strafing are covered first. This is because the basic airmanship of placing the aircraft at the desired point in space, in the proper flight parameters, at the time of weapons release, is required for all attacks.

2.8.1.1 Delivery Maneuver Selection. When selecting a delivery maneuver, start with maneuvers which provide the minimum slant range consistent with safety so that mil error characteristic of the weapon/delivery system has the least foot value. (Foot value decreases with slant range). Minimum slant range selection limitations include dive recovery for terrain avoidnance, weapon blast/frag envelope clearance, fuze arming time allowance, as well as threat avoidance and should be the minimum slant range that will allow you to comply with all four. Fuze arming time selection must allow the aircraft to clear before the fuze arms and allow the fuzes to arm before impact.

2.8.1.2 Dive Angle Selection. There is a firm relationship between dive angle and delivery accuracy based upon the pilot's ability to handle the aircraft smoothly and precisely.

The 10° dive delivery provides the best minimum slant range, but it doesn't give optimum mil accuracy, and more important, the aircraft cannot escape the weapon blast/frag envelope. The high drag finned bombs are designed to provide aircraft-weapon separation in the 10° dive delivery maneuver.

In comparing 30° and 45° dive deliveries, the 30° dive will involve larger slant ranges than the

45° dive for the same release altitudes. Trajectory drop will increase as will release error sensitivities with the 30° dive. Therefore, if working high angle, the 45° dive should be used unless forced shallower by weather.

2.8.1.3 Release Altitude Selection. The altitude chosen for weapon release is usually a compromise between survivability and weapons effectiveness. General Purpose bombs could be released from a shallow dive at 15,000 feet without assuming much risk from AAA and Manpads but the accuracy from this type of profile would not be adequate to have weapons effect on force structure targets sets. These same bombs could be released in a 30° dive at 3000 feet where accuracy would be optimized but the assumption of risk for this delivery may be perceived as prohibitive in certain circumstances. When choosing a release altitude first look at the accuracy level required to achieve the tasked damage criteria. Compare the relative weapons effect for different types of ordnance as they relate to a specific target's vulnerability. In other words choose the type of ordnance that will have the most effect on the particular target being attacked and determine what level of accuracy must be attained to ensure the damage criteria is met. Normally the level of accuracy required is directly related to the amount of ordnance expended. For instance if you drop one Mk 83 on an APC you are going to need to be much more accurate with your release to achieve the same level of destruction that four Mk 83's might achieve with a less accurate release.

This is where survivability comes into the release altitude equation. Assuming you have optimized the type of ordnance to be released, you can look at the cumulative ordnance requirement to achieve a damage criteria for different release profiles. You may find that you can achieve the same level of destruction by releasing four Mk 82's in a 45°/8000 feet delivery. Which delivery you choose will be determined by the allowable risk of your mission, the expected target area defenses, and the total amount of ordnance available.

2.8.1.4 Release Speed Selection. The airspeed you choose to release your ordnance could also be seen as a compromise. Obviously as you increase your delivery speed the time available to perform all the associated mission tasking goes down. If we were authorized to release ordnance at significantly high airspeeds then these temporal demands might become a factor. Currently the AV-8B is restricted to delivering ordnance between 450 KCAS and 550 KCAS with the majority of loads restricted to the lower side of this window. Therefore as a general rule we should plan on releasing ordnance as fast as is authorized in an effort to fly as survivable a profile as possible. It is essential that we maintain the highest energy level possible when transiting a threat envelope. More airspeed means less cumulative time in a threats envelope (both laterally and vertically) and more maneuvering potential. Speed is life. The gains realized by maximizing our airspeed far outweigh any perceived temporal demands. Any degradation in weapons delivery accuracy that is associated with higher release airspeeds are more likely a result of poor training habits.

2.8.1.5 Roll-in. Roll-in technique is totally dependent on aircraft flight characteristics. The following will cover only the general objective of the roll-in. The roll-in is the transition from essentially level flight to diving flight with a minimum loss of altitude and energy. Lost altitude is lost tracking time.

Remember, the HUD is a flight instrument to be looked through, not at. The roll-in is an "out the window" maneuver and the pilot should not attempt to use the velocity vector as an aid because it will be out to the side of the HUD away from where the pilot's attention should be, the target. This coupled with a slight lag of the velocity vector on roll-out prevents its optimum use in this case. The heading caret and the roll-stabilized sight or roll-stabilized aiming carets may be used as an excellent roll-out aid. An adaptive roll-in technique will allow you to compensate for errors in downrange distance. If the downrange distance appears excessive, initiate a level turn, allowing the nose to fall through as attack heading is approached. If the downrange distance appears minimal, initiate a nose low turn to obtain the desired dive angle. The nose

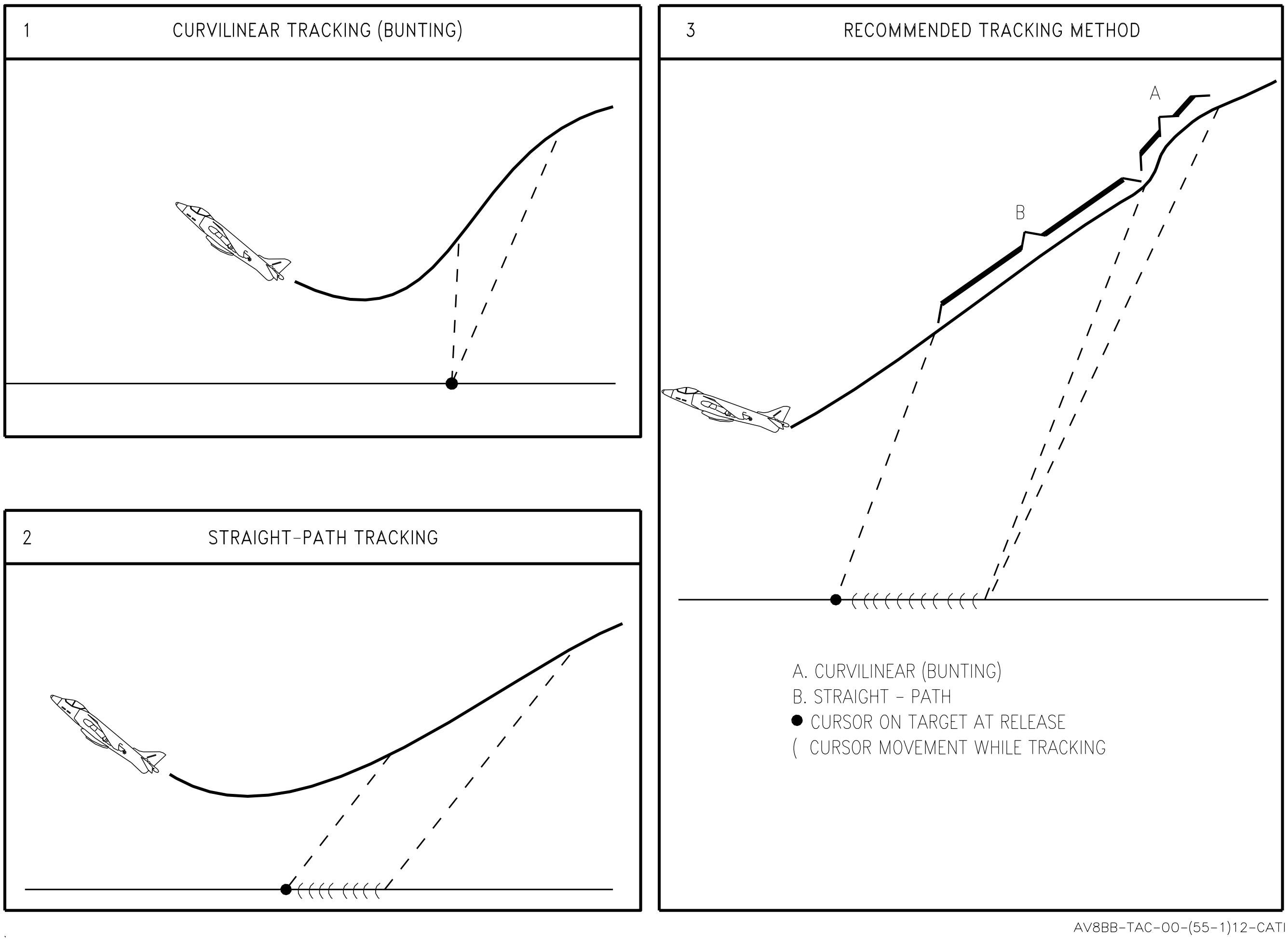


Figure 2-78. Tracking

level method dissipates more energy, and airspeed buildup must be faster to arrive at optimum release parameters.

2.8.1.6 Tracking. Tracking consists of acquiring the target (or aim point) in the sight and establishing a rate of aiming symbol movement that will place the symbol on the target at the instant the aircraft arrives at the release altitude, on the dive angle, and with the airspeed for which the sight setting was computed. Airspeed and dive angle control are achieved with relatively fewer problems than solving the problem of tracking to the release point. Tracking can be accomplished by placing the aiming symbol on the target immediately after target designation (curvilinear), or placing the symbol at the 6 o'clock position and allowing it to move to the target (straight path) as shown in Figure 2-78.

2.8.1.6.1 Curvilinear Tracking. Refer to Figure 2-78. Crosswind corrections during the run are difficult to apply. When the aiming symbol is held on the target during the dive, the aircraft flightpath becomes convex. The dive angle changes continuously since the aiming symbol is held on the target until weapon release.

2.8.1.6.2 Straight-path Tracking. Refer to Figure 2-78. The aircraft follows a straight line path during the dive while the cursor moves forward as the altitude is decreased. The g load becomes slightly less than 1g, but still affords good bomb-to-aircraft separation. The g load is 1g in level flight and approaches 1/2g in a 60° dive. The actual g load equals the cosine of the dive angle (less than 1g). During straight-path tracking, the dive angle remains constant as the cursor moves toward the target or offset aim point. Additionally, any ground reference that the velocity vector overlays will also remain constant if you are truely straight path tracking. As the dive progresses, two factors combine to produce symbol movement (four factors for computed deliveries). The first factor is aircraft travel across the ground which moves the cursor toward the target. The pipper moves as the foot value of the mil decreases (decreasing slant range and altitude). The second factor is fuselage angle of attack, which decreases as the aircraft accelerates in speed during the dive and tends to move the symbol toward the nose of the aircraft. When tracking while speed is accelerating, apparent cursor motion is rapid due to the decreasing angle of attack. When tracking while stabilized at the release speed, apparent symbol motion over the ground is slower.

NOTE

All sight angle charts and tables and the external stores limitations are based on the assumption that a straight-line flightpath is maintained during weapon release.

For computed deliveries the third factor is decreasing trajectory drop for close slant ranges and the fourth factor is external velocities (e.g. wind).

2.9 DIVE DELIVERY TECHNIQUES

2.9.1 Holding/Ingress (8 to 4 nm)

1. Fence checks complete.

2. Primary mode/sensor

   (a) DMT aircraft - AUTO/TV

   (b) Radar aircraft - CCIP/AGR/APS to sanitize

2.9.2 IP

1. WOF, or OVFLY update and select A/G master mode.

2. WINC/scroll to target or waypoint offset and ensure designated.

3. At action point ensure correct sensor/mode selected.

2.9.3 Designation. Begin geographic correlation using the INS, GPS, Radar TD box, the mark and/or your map. Begin associating the local terrain with your expected target position. Funnel your eyes from big to small in an attempt to achieve an early Tally. For DMT equipped aircraft use the TV to ″look″ at the designated point by selecting the INS sensor mode (rock forward on the sensor select switch).

If Tally the target -

1. DMT aircraft - AUTO/TV, maintain designation for ACD.

2. Radar aircraft - AUTO/AGR, maintain radar lock/INS designation for ACD.

If not Tally target prior to roll-in (4 to 2 nm) with INS diamond/mark in sight -

1. DMT aircraft - switch CCIP/TV, maintain INS designation, sensor select switch forward to look at target with TV, scan the area of the TD diamond.

2. Radar aircraft - CCIP/AGR, maintain INS designation/Radar lock, scan area of INS/ radar TD box or the mark.

3. Low angle entry remains the same except for primary mode/sensor:

   (a) DMT aircraft - CCIP/TV

2.9.4 Roll-In (3.0 to 1.5 nm). Fly parameters, utilize adaptive roll-in to achieve correct ITP off of INS/Radar TD diamond, mark or target if Tally.

If Tally at roll-in -

1. Maintain designation, rock forward on sensor select switch (if not already done) to look at what is designated (DMT aircraft). PID target.

2. As aircraft nose comes to target, assess the designation:

(a) AUTO mode - ensure designation on target.

(b) CCIP mode - designation places target within DDI/MPCD display for medium altitude deliveries (DMT aircraft), within wings of velocity vector (Radar aircraft). If the designation is within parameters consideration should be given to keeping the designation and slewing to sweeten as time permits. Upgrade to AUTO if slewing was successful.

3. If the designation is *not* within parameters for CCIP and time does not permit slewing or a redesignation attempt, rock forward on the sensor select switch to hand off to the INS. Maintain the most accurate target altitude and deliver in BCIP (DMT aircraft). CCIP/AGR will not be affected since ranging is through the CCIP cross and is continuous.

4. If designation rejected and time permits a reattempt:

(a) DMT aircraft - undesignate, sensor select switch aft twice to command TV (dot in the velocity vector).

(b) Radar aircraft - undesignate, sensor select switch forward to command AGR (dot in the velocity vector). Maintain current mode until accurate designation achieved. Once designation achieved upgrade to AUTO mode if not already there.

5. Designation technique. If designation is required command dot in the velocity vector. Fly the velocity vector to pass close to the side of the target at approximately 135° overbank. Adjust rollout to wings level with velocity vector just below the target. *Stabilize.* Allow the velocity vector to track up and on the target. *Stabilize.* Designate with the TDC. Sweeten as required. If the velocity vector drifts, it will drift upward and in line with the tracking run. This is the classic "J-Hook" technique and will result in a higher percentage of first designation success and less uncontrolled velocity vector drift from the ASL or track line during designation sweetening.

If no Joy at roll-in -

1. Verify CCIP/TV or CCIP/AGR

2. Once proper ITP is established off the mark or INS/Radar TD box, hold proper ITP until the check point and then track CCIP cross to the TD diamond or to the FAC's correction off of the mark.

3. If Tally prior to check point altitude but after wings level in the dive, maintain delivery mode and attempt to sweeten designation. Do not undesignate and try to redesignate unless an unusually long tracking time permits.

4. After checkpoint altitude total attention should be given to steady tracking and accepting the current delivery mode, with the only exception being in the event of a Radar/TV break lock and run away. In this case a handoff to an INS designation should be commanded (rock forward on sensor select switch).

2.9.5 Tracking

1. Descending through altitude sanctuary, initiate "ALL" program, assess ITP.

2. Minor corrections for ITP can be made but should be terminated prior to reaching the checkpoint altitude and attention devoted to setting the correct TPA.

3. Most tracking times do not allow for large corrections to the ITP. A good tracking run will begin with rolling in from the proper ACD and altitude.

4. AUTO/CCIP - Once correct ITP is established begin straight path tracking with velocity vector just slightly above target. Prior to checkpoint altitude, adjust the velocity vector to set the correct TPA and resume straight path tracking.

NOTE

Time from wings level in the dive to check point altitudes is usually relatively short. Allow the velocity vector to drift up while refining the designation. The velocity vector will usually reach the correct TPA just prior to the check point altitude without having to accelerate the aircraft and disturb the tracking loop. If TPA is established early, a bunt to curvilinear tracking can be done until check point altitude when straight path tracking can be resumed.

2.9.6 Pre-Release And Release

2.9.6.1 Pre-Release. The last seconds prior to release should be devoted to flying a steady state platform and accepting the parameters that have been achieved. AUTO releases should concentrate on smoothly flying the velocity vector onto the azimuth steering line and unless conducting dive toss releases, allow the release cue to come down to meet the velocity vector, vice accelerating the velocity vector into the release cue. For CCIP releases, line up and pipper placement are the critical variables to control.

2.9.7 Release. Pickle, expend, pull, full power immediately to minimize energy loss.

High Angle -

1. Pull aircraft at maximum ″g″ or limits of configured airframe (whichever is less) until the nose of the aircraft achieves a climb angle that is equal to the dive delivery angle (i.e., 45° dive = 45° climb). Once established, unload the aircraft for as long as possible to conserve energy prior to initiating a jink. Time to jink should be nearly equal to or just less than the time it would take for potentially the fastest AAA round to reach your altitude.

2. Re-initiate an ″ALL″ program no later than nose breaking the horizon (if not already done).

Low Angle -

1. Same as high angle except return to low altitude/lateral sanctuary if appropriate using dive recovery rules. Priority should be to exiting the target area laterally.

2.9.8 Egress. Reestablish relative sanctuary and egress target area or set up for reattack as required.

If decision to reattack is made -

1. Leave target designated.

2. Remain in AGR (Radar aircraft) or INS sensor mode (DMT aircraft).

If decision to egress is made -

1. Undesignate target.

2. WINC/scroll to egress waypoint.

3. Radar aircraft - select APS

4. DMT aircraft - select A/A master mode.

2.9.8.1 Weapon Jettison. As previously described the primary weapon release controls are on the master arm panel, DDI/ACP, and control stick. These controls provide an unarmed weapon jettison capability for all weapons aboard except the fuselage gun and Sidewinders or Sidearms on stations 1, 1A and 7, 7A. Five modes of jettison (emergency, combat, fuel tank, station, and stores) are provided and are summarized in Figure 2-79.

Jettison is accomplished via the emergency jettison button or the selective jettison button on the ACP. The applicable jettison button must be held pressed until the release sequence is completed. Each release pulse on-time is 40 milliseconds and the release interval is 50 milliseconds. Stations 1, 4, and 7 receive the first release pulse, stations 2 and 6 receive the second release pulse, and stations 3 and 5 receive the third release pulse. Stores on stations 1A and 7A cannot be jettisoned.

WARNING

Although bombs are released safe and will theoretically dud at impact, a high-order detonation is possible. Therefore, all normal release restrictions (minimum release altitudes, safe separation, etc.) must be observed when jettisoning.

If either store or station jettison is selected via the ACP, the A/G weapon select pushbutton legends on the DDI will be removed and their selection inhibited (does not apply to fuselage gun). Combat and fuel jettison does not affect the weapon select function.

In the event of the SMC or generator failure, the only method available for jettison is emergency jettison.

2.10 BOMBING

2.10.1 Considerations and Restrictions

2.10.1.1 Safe Escape Considerations. Release parameters must be selected to enable the aircraft to avoid the weapon fragmentation and to recover above the terrain and avoid the threat.

2.10.1.2 Multiple Release. In the computed delivery modes (AUTO and CCIP), the computer spaces the weapon impacts at specified down range intervals. In the manual delivery modes (DSL and DIR), the pilot selects the weapon release interval which will approximate the desired impact pattern. To accurately perform a multiple weapons release maneuver, the single release maneuver is used with the following modifications.

1. In delivery of a stick of weapons, safety depends upon the release altitude of the last weapon off. Use the safe escape tables (NWP 3-22.5-AV8B, Vol. II, Chapter 2) to determine if the planned release altitude for the last weapon off is greater than or equal to the minimum safe release altitude. The altitude of the first weapon off can then be determined by using the aircraft down range travel and altitude loss chart (NWP 3-22.5-AV8B, Vol. II, Chapter 2).

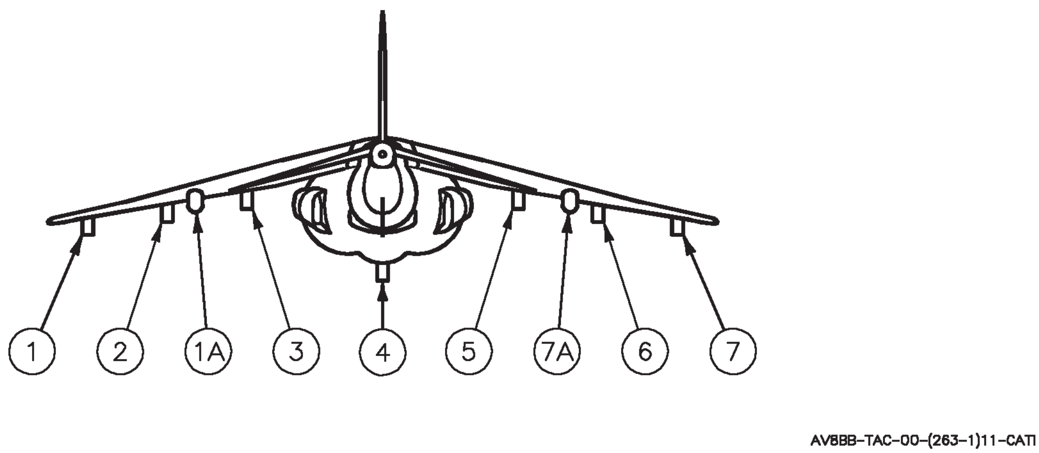
2. Adjust sight angle setting to place the center of the pattern on target.

3. Maintain a straight line flightpath during multiple release.

4. Press and hold the bomb pickle button for the duration of the ripple release.

This procedure should also be performed for AUTO and CCIP deliveries to ensure the aircraft does not enter the last weapon frag pattern, and all weapons have sufficient arming time. If altitude becomes a major factor, an AUTO mode dive toss maneuver should be utilized.

2.10.1.3 Release Restrictions. Release restrictions to ensure safe escape and terrain avoidance are given in the safe escape tables and sight angle charts for each weapon. A detailed description of the application of this data and the assumptions used in their preparation are provided under the heading "Chart Description" in NWP 3-22.5-AV8B, Vol. II, Chapter 2. Also, refer to safe escape tables, sight angle charts, ballistic tables, and dive recovery charts. Thorough consideration should be given to the trade-off necessary between accuracy and avoidance of enemy defenses.



EXTERNAL STATION(S) (STORES JETTISONED)	INTERLOCKS	JETTISON CONTROLS	JETTISON PROCEDURE
All Stations (Emergency Mode) (All stores and suspension equipment on BRU-36 bomb racks. AIM-9s suspended from LAU-7 launchers on stations 1, 1A, 7 and 7A are retained).	Gear handle UP or aircraft weight off wheels 1	Emergency Jettison Button	Emergency Jettison Button - PUSH
All Stations (Combat Mode) (All stores and suspension equipment on BRU-36 bomb racks, except all AIM-9s, TACTS, DECM, and cargo pods are retained).	Gear handle UP and aircraft weight off wheels	Selective Jettison Knob, Selective Jettison Pushbutton	Selective Jettison Knob - CMBT Selective Jettison Pushbutton - PUSH
2, 3, 5, 6 (Fuel Tank Mode) (Fuel tanks dropped in pairs from 2 and 6, then 3 and 5).	Same as above	Selective Jettison Knob, Selective Jettison Pushbutton	Selective jettison Knob - FUEL Station Select Buttons - PRESS APPROPRIATE BUTTON(S) Selective Jettison Pushbutton - PUSH
(Station Mode) All Selected Stations 1, 2, 3, 4, 5, 6, and/or 7 (All stores, including suspension equipment on BRU-36 bomb racks. AIM-9s suspended from LAU-7 launchers on stations 1, 1A, 7 and 7A are retained).	Same as above	Selective Jettison Knob, Station Select Buttons, Selective Jettison Pushbutton	Selective Jettison Knob - STA Station Select Buttons - PRESS APPROPRIATE BUTTON(S) Selective Jettison Pushbutton - PUSH
(Stores Mode) All Selected Stations 1, 2, 3, 4, 5, 6, and/or 7 (All stores and suspension equipment on BRU-36 bomb racks except: stores mounted on ITERs are jettisoned while retaining ITERs. AIM-9s suspended from LAU-7 launchers on stations 1, 1A, 7 and 7A, are retained).	Same as above	Selective Jettison knob, Station Select Buttons, Selective Jettison Pushbutton	Select Jettison - STOR Station Select Buttons - PRESS APPROPRIATE BUTTON(S) Selective Jettison Pushbutton - PUSH

WARNING: Although bombs are released safe and will theoretically dud at impact, a high-order detonation is possible. Therefore, all normal release restrictions (minimum release altitudes, safe separation, etc.) must be observed when jettisoning.

LEGEND:

1 A weight-on-wheels failure will inhibit jettison and prevent raising the gear handle. Emergency jettison can be enabled by using the DN LOCK OVRD to raise the gear handle.

2. Refer to NWP 3-22.5-AV8B, Vol. II, Chapter 5 for jettison limitations. All weapons are jettisoned unarmed.

3. Outrigger pylons (stations 1A and 7A) are not authorized for carriage, however, the capability exists on Night Attack aircraft.

Figure 2-79. External Stores Jettison Chart

2.10.1.4 Fuzing. Release restrictions may also be imposed by the weapon and/or the fuze. Refer to NWP 3-22.5-AV8B, Vol. II for external stores limitations in Chapter 5, and bomb fuzing and authorized fuze arming times in Chapter 3.

2.10.1.5 Aircraft-to-Bomb Collisions. Tracking during release must not be such as to reduce the prescribed aircraft-to-bomb separation. The component of gravity which is perpendicular to the flightpath of the aircraft must be within the release limitations listed for each weapon in NWP 3-22.5-AV8B, Vol. II, Chapter 5, external stores limitations. Also, refer to carriage equipment in Chapter 4.

2.10.1.6 Bomb-to-Bomb Collisions. Bomb-to-bomb collisions can occur and have occurred under certain combinations of release interval and weapon ejection angles. Proper planning and preflight caution can decrease this occurrence. Retarded weapons have a great tendency toward bomb-to-bomb collision caused by an aerodynamic phenomenon called tailgating. Fuze arming time should be carefully selected to provide maximum aircraft-weapon separation prior to arming. Refer to NWP 3-22.5-AV8B, Vol. II, Chapter 3 for authorized fuze arming times, and Chapter 2 for bomb spacing during multiple release charts description.

WARNING

The minimum authorized arming times and speeds must be observed and followed for each type of delivery as given in NWP 3-22.5-AV8B, Vol. II, Chapter 2. It is paramount that the pilots of all aircraft be aware of the probabilities of fragment hit in the event of an early burst when the arming time is less than the minimum authorized arming time prescribed for the delivery maneuver. This could conceivably occur when a dive delivery mission is diverted to a level delivery mission.

2.10.1.7 Section Bombing. Early bursts while section bombing and during other level delivery maneuvers inherently increase the danger of fragmentation damage to the delivery aircraft. The probability of an early burst from bomb-to-bomb collision is greater in a multiple aircraft release with aircraft in close proximity to one another and with reduced weapon release interval settings. With release conditions such as these, fuze arming time becomes critical to provide adequate bomb-to-aircraft separation before the fuze arms. Pilots must be aware of the minimum authorized arming time for the mode of delivery utilized. Violation of the minimum authorized fuze arming time typically occurs during divert missions where the preplanned delivery was dive bombing and the aircraft were diverted to section bombing, etc. Pilots should observe the following precautions to increase their margin of safety when performing section bombing and other level deliveries:

1. Observe the minimum authorized arming time and speeds for the type of delivery selected.

2. Maintain the maximum possible lateral and/or nose-to-tail (trail) aircraft separation within the confines of operational requirements.

3. Execute a positive, breakaway maneuver as soon after release as possible.

Some of these precautions are illustrated in Figure 2-80.

2.10.1.8 Safe Interval for Low Altitude Multiple Aircraft Attack. A safe release interval between the lead and trail aircraft provides a zero hit probability for the trail aircraft from fragments produced by the weapon released from the lead aircraft. The weapon dropped by the lead aircraft is assumed to be a ground-level detonation. The safe release interval can be determined by using the maximum fragment envelope charts, (NWP 3-22.5-AV8B, Vol. II, Chapter 2) for each weapon. To determine the safe release interval between the lead and trail aircraft, the following factors must be known:

1. The time of flight of the weapons delivered by the lead aircraft, obtained from the sight angle charts.

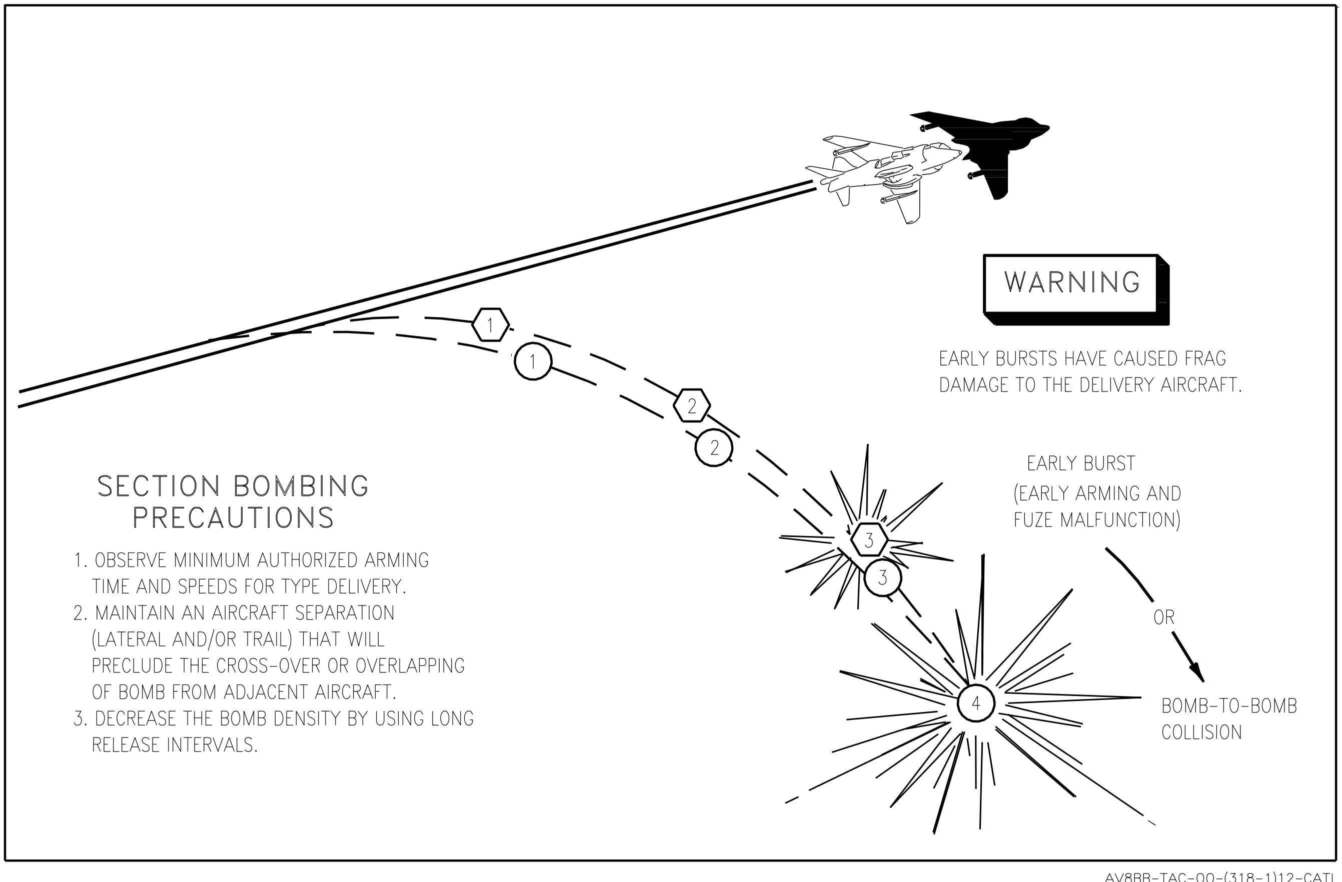


Figure 2-80. Fragment Envelope/Safe Release Interval

2. Recovery height above ground level of the trail aircraft. Use the dive recovery charts to determine the altitude lost during pullup.

3. Determine the time from burst through the maximum height of the fragment trajectory and down to the recovery height of the trail aircraft. Use the center vertical time curve on the maximum fragment envelope chart.

The safe release interval is the sum of the values obtained in preceding steps 1 and 3. If the recovery height in step 2 is greater than the maximum height obtained by the fragments, any release interval between aircraft will be safe. The safe release interval determined from the maximum fragment envelope charts is conservative and is applicable for all dive angles and varying release conditions between the lead and trail aircraft.

A more realistic safe release interval, one that is less conservative is illustrated for each type of ordnance in NWP 3-22.5-AV8B, Vol. II, Chapter 2. The safe release height of the trail aircraft assumes that the lead aircraft releases at the 0.000 fragment hit release height stated in the sight angle charts. These two charts are valid only when the lead and trailing aircraft have the same attack heading and are releasing the selected weapon in level flight and at the stated airspeed.

2.10.1.9 Coordinated Attacks. During attacks on a target complex in which more than one aircraft is involved careful consideration must be given to flying through fragmentation of weapons released from other aircraft. A general rule of thumb is to follow the first aircraft on the target simultaneously or with a delay of more than 30 seconds when delivery maneuvers carry the aircraft below the top of the fragmentation pattern.

2.10.1.10 Bomb Ricochet. When a projectile strikes a flat surface at a grazing angle it may rebound or ricochet from the surface. Ricochet from earth is usually accompanied by a furrow along the contact surface, or occasionally by a shallow underground hole which returns to the surface. Ricochet depends on many factors such as the density and hardness of the surface, the nose shape, and transverse moment of inertia of the projectile, as well as the angle of impact. For a given projectile and surface, there is a range of impact angles over which ricochet is uncertain. Within this range the impact angle at which ricochet occurs 50 percent of the time is called the critical angle. The critical angle usually increases with surface density and hardness. On the other hand, flat-nosed projectiles usually decrease the critical angle; i.e., they reduce the tendency to ricochet.

Ricochet is a problem in low, and minimum-altitude bombing since the safety of the pilot and aircraft may be endangered. The length and height of the ricochet trajectory as well as the bomb fuzing determine where the bomb will detonate with relation to the target and to the dropping aircraft.

Bombs tend to ricochet from water at angles of impact of 20° or less measured from the horizontal and from earth at somewhat larger angles. When impact is on rock or concrete, ricochet might occur at much larger angles of impact. Predictions of ricochet from rough water or from irregular ground are, of course, not accurate. Estimated ricochet height, length, and duration are shown in Figure 2-81 . The ricochet trajectory is roughly parabolic so that the bomb position at any time can be estimated once the length, height, and duration of the ricochet flight are known.

2.10.1.11 Factors Affecting Accuracy. One of the major advantages of a computed weapon delivery is that an accurate impact point is derived independent of the fixed release parameters imposed by an "iron sight" delivery. As long as the pilot meets the basic parameters of fuze arming, frag pattern, and terrain avoidance, the system will compute an accurate solution and ensure a reliable attack. Although the computed weapons delivery system is reliable, it is an inescapable fact that weapon impact error will occur. When the AV-8B releases a piece of ordnance, there are classically two main sources of error, the pilot and the system.

2.10.1.11.1 Pilot Errors. Pilot induced errors are strictly a function of proficiency. While they may be the largest single source of errors during initial training, they tend to decrease significantly as experience is gained with the aircraft and the system. They usually produce random impact errors as the result of:

1. Failure to precisely follow HUD steering commands.

2. Failure to stabilize symbology on the desired aim point during designation/weapon release.

3. Failure to understand and optimize the weapons delivery systems used for information input (i.e., radar, DMT, radar altimeter, barometric plane, etc.).

2.10.1.11.2 System Errors. The two major system errors are ranging errors caused by improper sensor management and INS drift.

a. Ranging errors. Ranging errors are generally caused by inaccurate aircraft altitude or target elevation measurements. They are usually the largest single source of system error. Factors affecting the accuracy of barometric, radar altimeter, or radar AGR ranging are as follows:

1. Barometric Ranging

   (a) ADC altitude sensitivity.

   (b) ADC derived Mach number.

   (c) Balanced flight - any sideslip induces some error.

   (d) Accurate barometric pressure setting for the target area.

   (e) Accurate target elevation entry into waypoint data.

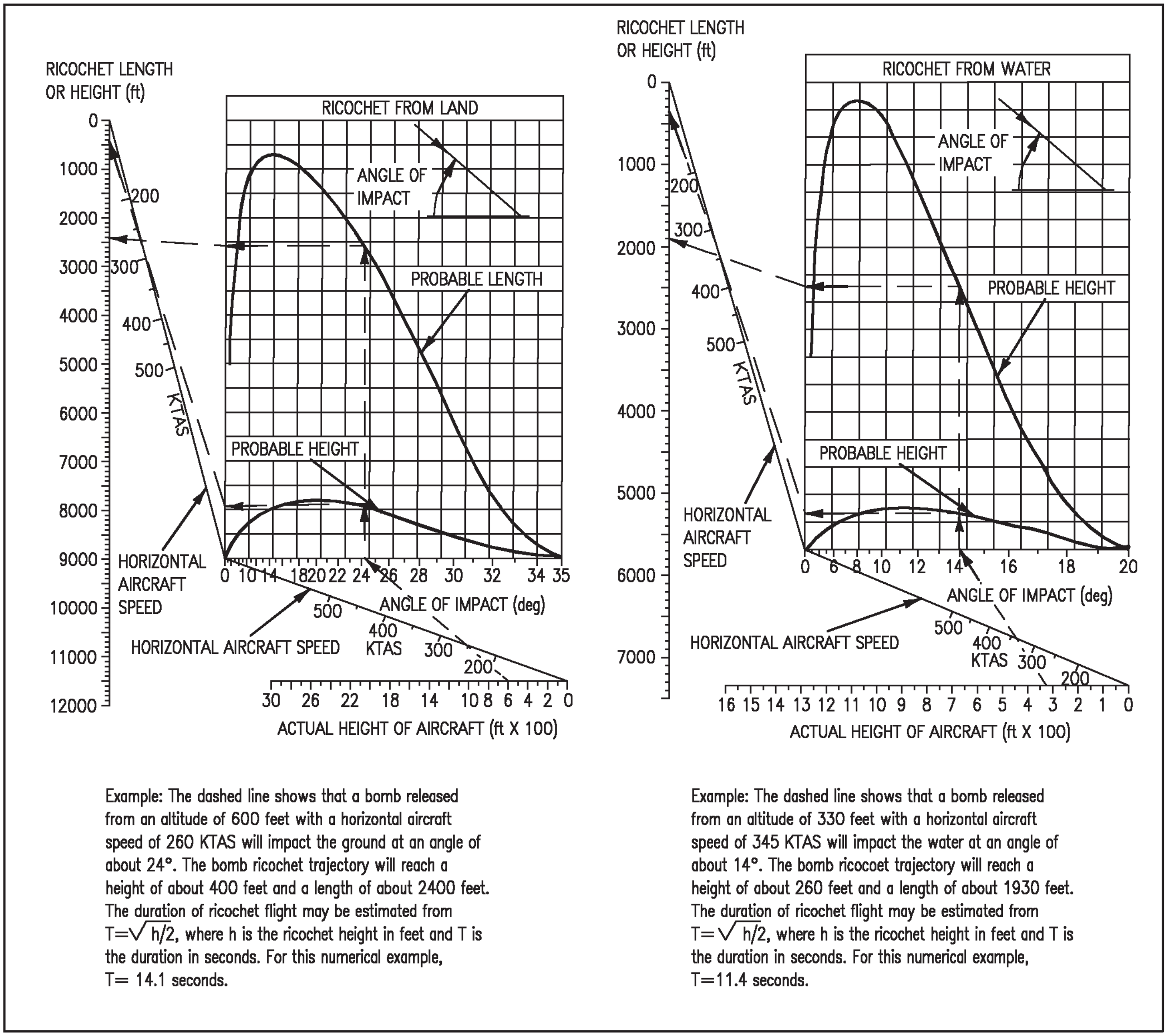


Figure 2-81. Bomb Ricochet Data

2. Radar Altimeter Ranging

   (a) Altitude error may be 4 percent of altitude.

   (b) Antenna limitations.

   (c) Not recommended when variations in terrain exceed 175 feet during the run-in.

   (d) More accurate than barometric ranging below about 2,000 feet AGL.

3. Radar AGR Ranging

   (a) Radar measured slant range.

   (b) Radar measured line-of-sight.

4. Radar FTT/GMTT

   (a) Radar measured slant range.

   (b) Radar measured line-of-sight.

   (c) Radar measured target velocity.

b. Velocity Errors. Inertial navigation systems tend to drift in a specific direction at a given velocity. This may be caused by a low quality alignment or by problems within the system. Whatever the source, its effect is like having a built-in wind in the INS.

Given the velocity error, the magnitude of the impact error can be computed by using the following equation:

Velocity Error (knots) × TOF (sec.) × 1.7 (ft./sec./kt.) = Impact Error (feet)

Example: a 5-knot velocity error with a 7-second TOF (time of fall) results in an impact error of: $5 \times 7 \times 1.7 = 59.5$ feet.

This INS drift can be judged by system management. The drift magnitude and direction can then be utilized to offset the aim point to produce an optimum solution based on system drift.

c. Miscellaneous Errors. The following system inputs can contribute fixed system errors. They are not detectable and cannot be corrected by the pilot.

1. Bomb dispersion (failure of the weapon to conform to its designed flight characteristics).

2. HUD boresight tolerance.

3. Weapon release delay and ejection velocity tolerances.

4. Angle of attack tolerances.

2.10.1.11.3 Error and Trend Analysis. Each squadron's WTI and maintenance department should together maintain a record of the past performances of each aircraft weapons delivery system. This record will include the following types of information:

1. The type, duration, and quality of INS ground alignments.

2. INS in-flight position update data (drift).

3. Duration of flight/total INS run time.

4. Bomb impact and aim point data ("spot" sheets).

5. Ranging methods used during delivery.

6. Groundspeed, check results.

7. Final/overran nm errors.

8. Remarks (for example, radar altimeter failed).

9. Record of changes of aircraft components/ computer reloads/INS gyro bias action.

From this performance history, a trend analysis can be established which will enable a prediction of the source and magnitude of significant system errors for each squadron aircraft. The WTI should use video debriefs to assist the maintenance department with fault analysis. Many system anomalies can only be detected by careful video debrief.

The trend analysis for ranging errors should be fairly constant from one flight to another for a given delivery maneuver. INS velocity errors will not be as predictable, however, because the quality of INS alignments and duration of flight vary from flight to flight.

a. Weapon Impact Analysis. Prior to actually dropping any ordnance, you should have some clue as to possible system deficiencies. Remember and anticipate what you learned from the maintenance trend analysis sheets, prelaunch checks and/or en route checks. This is what sensor and system management is all about. During early training, when you arrive at the range, make the first couple of passes "pipper-to-bull"; then:

1. Determine the source of error.

2. Calculate the magnitude of error.

3. Apply the proper type and magnitude of correction, or continue to analyze until the source of error is determined. As you have already learned, there are three main sources of error when the AV-8B drops a bomb: you,

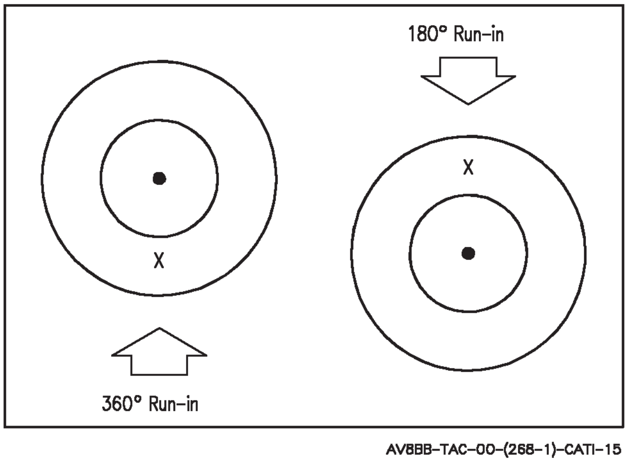


Figure 2-82. Ranging Error

the ranging, and the velocity. We will consider all three.

b. Pilot Error Analysis. Before you blame the system, ask yourself the following questions:

1. Did you really designate/pickle with the symbology stabilized on the desired aim point?

2. Were you pushing or pulling on the pole after designation?

3. Have your release parameters been consistent?

True, the system is supposed to take care of the ″ham fist″, but it can only do so much. So make sure you are not the primary problem before you delve further into the mystery of that ″150 feet at 12 o'clock″ bomb. Be smooth and be consistent on all your passes - the larger the deviations, the more meaningless the analysis!

Once satisfied that you are not the problem, there are some things you can do to determine whether the ranging or the velocity is at fault.

c. Ranging Error Analysis. Ranging errors result in impacts at the same relative clock code in relation to the aircraft.

1. Barometric Ranging. If the ADC computes an altitude differential greater than actual, long hits will result. Likewise, short hits will result if the ADC computes a lower altitude than actual (Figure 2-82).

(a) Detection Technique: Change the run-in heading by 90° or 180°. For example, on the first run-in heading of 360°, the bomb impacts 120 feet at 6 o'clock. On the next run-in heading of 180° the bomb impacts 125 feet at 6 o'clock. It therefore appears that a ranging error exists.

(b) Correction Techniques:

(1) Utilize ARBS/AGR tracking when available.

(2) Recheck the target elevation data.

(3) Use an offset aim point opposite to the direction of the error.

2. Radar Altimeter Ranging. Due to the constraints imposed by the radar altimeter antenna stabilization limits, radar altimeter ranging should be commonly used for low angle dives or level deliveries below 2,000 feet AGL.

(a) Detection Technique: Same as for barometric ranging.

(b) Correction Techniques:

(1) Utilize ARBS/AGR tracking when available.

(2) Use an offset aim point.

(3) Deselect the radar altimeter as primary height source.

d. Velocity Error Analysis. Velocity errors result in impacts in the same area on the ground, regardless of run-in heading (Figure 2-83).

1. Detection Techniques:

(a) Change the run-in heading by 90° or 180°. For example, on the first run-in heading of 360°, the bomb impacts 120 feet at 6 o'clock: On the next run-in heading of 180°, the bomb impacts 125 feet at 12 o'clock. It therefore appears that a velocity error exists.

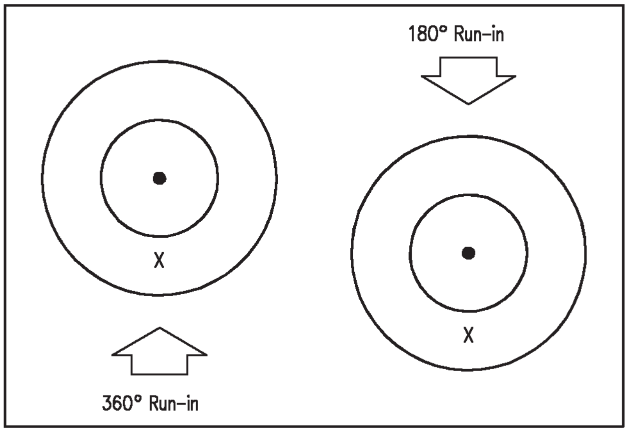


Figure 2-83. Velocity Error

(b) TD symbol drift is also indicative of INS velocity errors.

2. Correction Techniques:

(a) Use an offset aim point.

(b) If TD symbol drift is noticeable, use an offset aim point in the direction opposite the drift, so that at bomb impact (not at release), the TD symbol will be on target.

(c) If TD symbol drift makes aiming difficult, use CCIP, and offset the CCIP cross into direction of drift.

(d) If drift is significant, use DGD/ADC and pilot entered winds.

2.10.1.12 Backup Delivery Considerations. Depending on the failure situation, the only portion of the attack affected by using a noncomputed delivery is the final portion of the tracking solution. When possible the target should be EHSI/EHSD, WOF, or TOO designated to assist in locating and maintaining the target location for reattack. The TV sensor should be selected in the INS sensor mode to aid in early target identification. Once the target is acquired, the pilot should not waste any time slewing or sweetening since none of the sensor data affects an "iron sight" delivery. When the pilot must utilize the DIR or DSL(1) mode, care should be taken to ensure the delivery program is complete. This is due to the absence of the master arm safe indication (flashing mode) and the weapon release inhibit cue (weapon selected, fuzing SAFE).

The roll stabilized sight is the preferred noncomputed sight; however, it is not available with a HUD or INS failure.

After sight selection, the pilot maneuvers the aircraft to position the roll stabilized sight reticle or standby reticle cursor on target while meeting predetermined release conditions, and manually initiates weapon release. The HUD DSL mode symbology is shown in Figure 2-84. DIR and DSL(1) are the same except the DSL mode cue is removed.

2.10.1.13 Factors Affecting Dive Delivery Accuracy. The factors that affect the accuracy of the dive delivery are: dive angle, release height, airspeed, coordinated flight, wind, and target motion. The sight angle (reticle depression) set into the HUD is based on specified release conditions of dive angle, release height, and airspeed for a specified weapon. Corrections for deviations from these planned release conditions will be considered independently.

2.10.1.13.1 Dive Angle Error. Assuming that the weapon is released at the proper airspeed and release height, variation in dive angle would have the following effects: when the dive angle is steep, impact is long; when the dive angle is shallow, impact is short. Refer to Figure 2-85.

2.10.1.13.2 Release Height Error. Variation from the planned release height will produce the following effect, assuming that the weapon is released at the planned airspeed and dive angle: when the release height is high, impact is short; when the release height is low, impact is long. Refer to Figure 2-86.

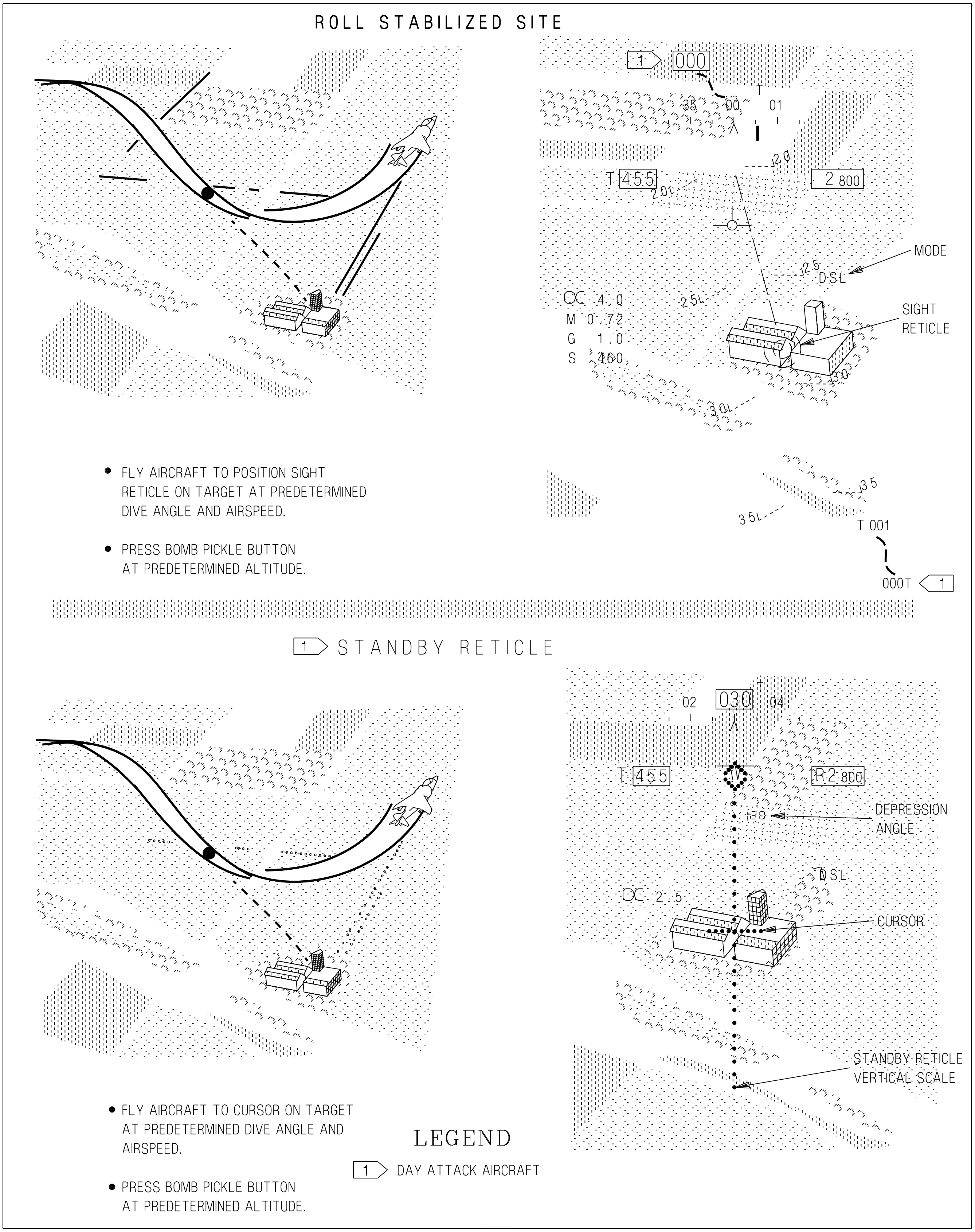


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Figure 2-84. DSL Weapon Delivery

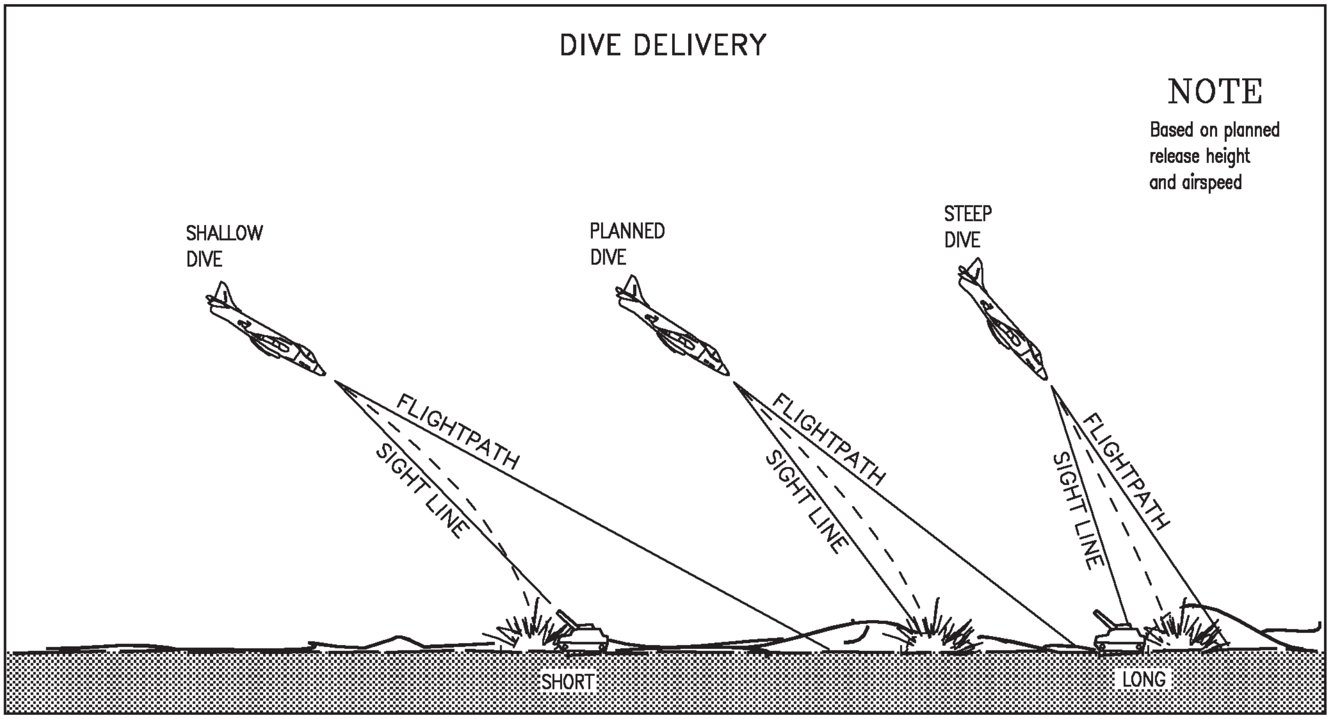


Figure 2-85. Dive Angle Error

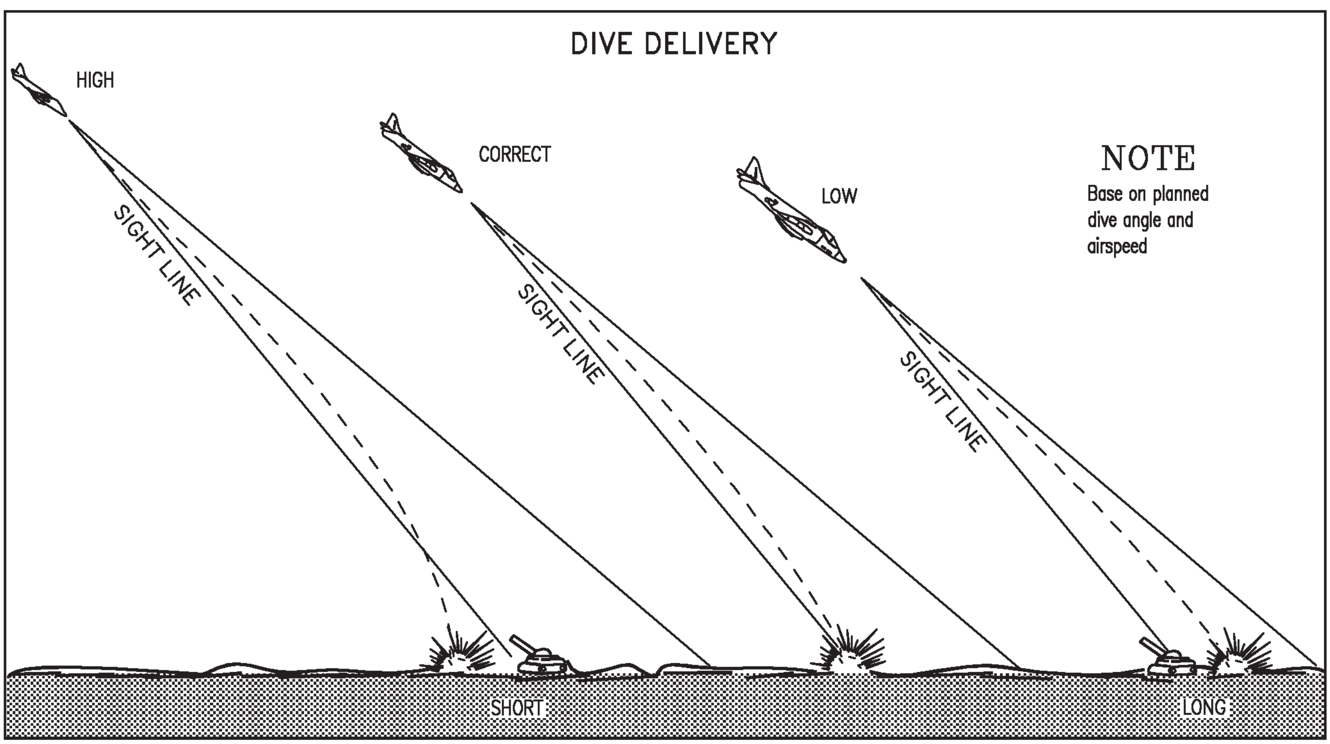


Figure 2-86. Release Height Error

2.10.1.13.3 Release Airspeed Error. When the weapon is released at the planned release height and dive angle, and the release airspeed is faster than planned, impact will be long. If the release airspeed is slower than planned, impact will be short. Refer to Figure 2-87.

2.10.1.13.4 Coordinated Flight. Even though the weapon is released at the planned airspeed, release height, and dive angle, uncoordinated flight at the time of release will produce an impact error. The most common delivery errors encountered are as follows:

1. Release in bank (Figure 2-88).

   (a) Right wing down, impact right and short (RSS errors are minimal).

   (b) Left wing down, impact left and short (RSS errors are minimal).

2. Skidding or sideslipping. Not keeping the ball centered is another tracking error. The pilot must keep the ball centered to be able to assess crosswind.

   (a) Ball out right, impact right.

   (b) Ball out left, impact left.

3. G-loading.

   (a) Positive g's, impact short.

   (b) Negative g's, impact long.

2.10.1.13.5 Wind Effects. A 10-knot wind shear acting only on the bomb after release would cause a 5.5-foot error. If the aircraft has been in the crosswind long enough to acquire the additional velocity, a 10-knot wind will cause a 120-foot error. Therefore, shear winds are ignored below the aircraft and only those winds acting on the aircraft at the point of weapon release are a factor. This is expressed as:

Error (feet) = Wind (knots × TOF (sec.) × 1.7 (ft./sec./kt.)

where: 1.7 is a units correction factor to change knots to feet/second.

Wind presents the pilot with the greatest uncontrolled variable in delivery.

Ballistic data is based on a wings level, balanced flight condition. The problem is complicated when attempting to conjure an offset aim point to compensate for the wind. If wind is unknown and conditions permit, assume zero wind, note leaders impact, and adjust. If conditions do not permit multiple runs, the wind must be assessed en route to the target by observation of smoke, wave action, tree bending, or blowing dust (only valid for low altitude bombing). This will only provide a crude assessment of wind direction and velocity. A common tendency is to yaw the aircraft to maintain track during crosswind conditions; however, yaw creates skid which will result in gross errors. Two methods of correction are discussed, first for a roll stabilized sight and second for a non-roll stabilized sight.

2.10.1.13.6 Wind Corrections with A Roll Stabilized Sight. When correcting for winds using the roll stabilized sight a wings level approach can be conducted using the available HUD symbology. Crosswinds and range winds are easily accounted for and unless winds are significant should still result in accurate hits. For some cross wind corrections the pilot need only to ensure the velocity vector remains over the target through the run. This will effectively offset the roll stabilized sight into the wind the proper amount. Assuming all parameters are met then the pilot would initiate weapons release when the roll stabilized sight is abeam the target.

For range winds the pilot is able to use error sensitivities to compute the mil correction required to offset the range winds. With this correction the pilot is able to add or subtract the mil correction from the sight setting or fly the roll stabilized sight long or short the appropriate number of mils in relation to the target and initiate weapons release.

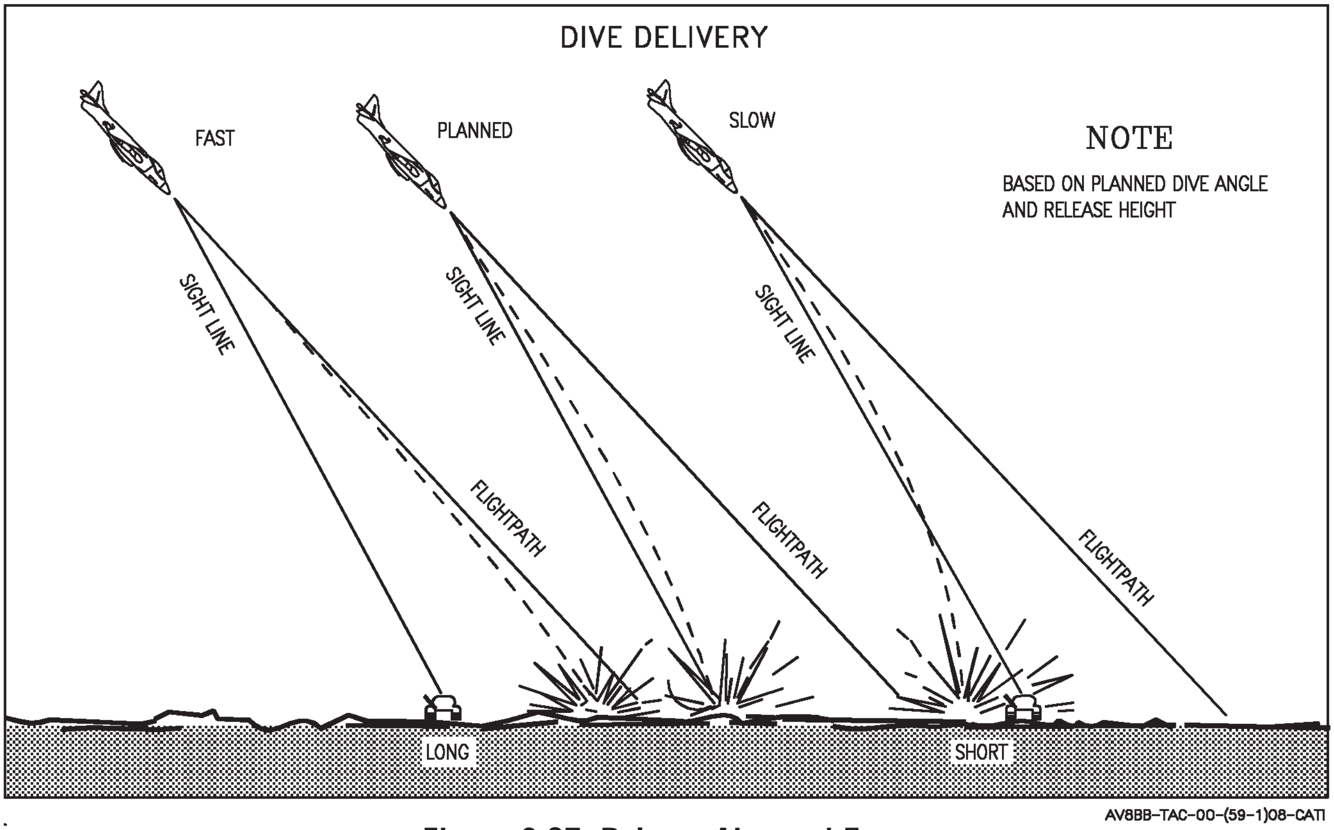


Figure 2-87. Release Airspeed Error

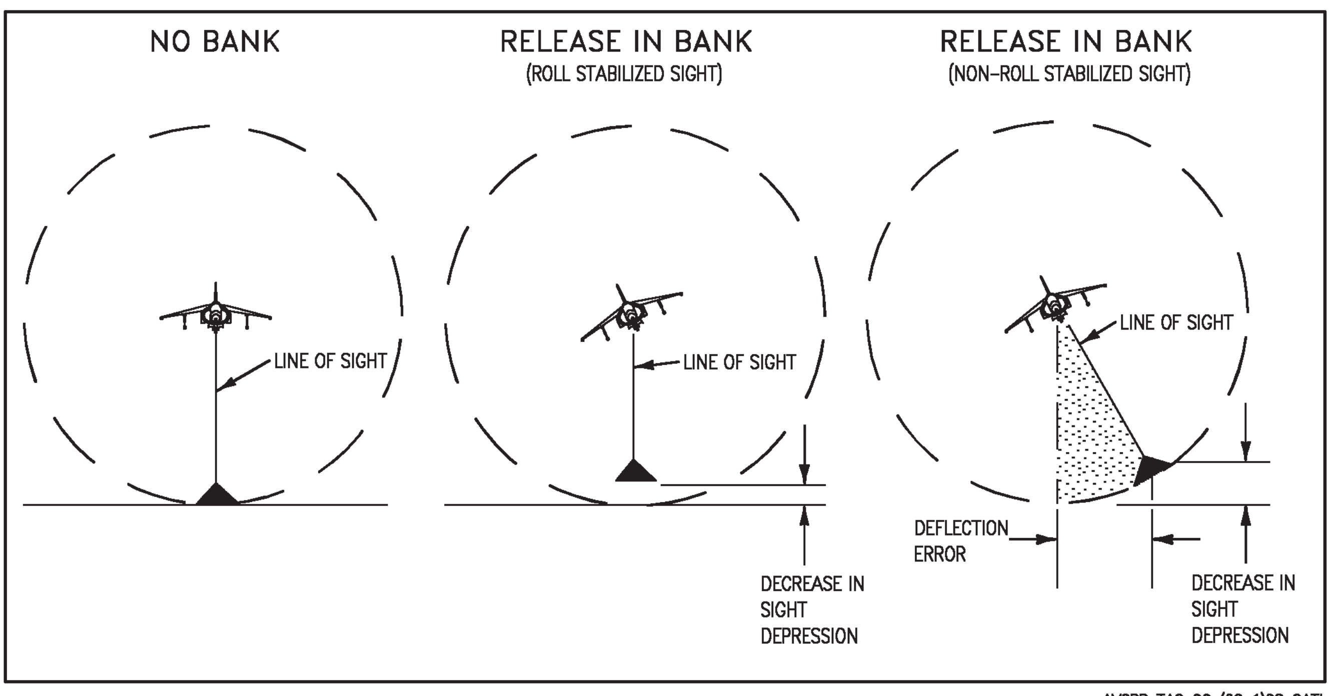


Figure 2-88. Effect of Releasing in a Bank

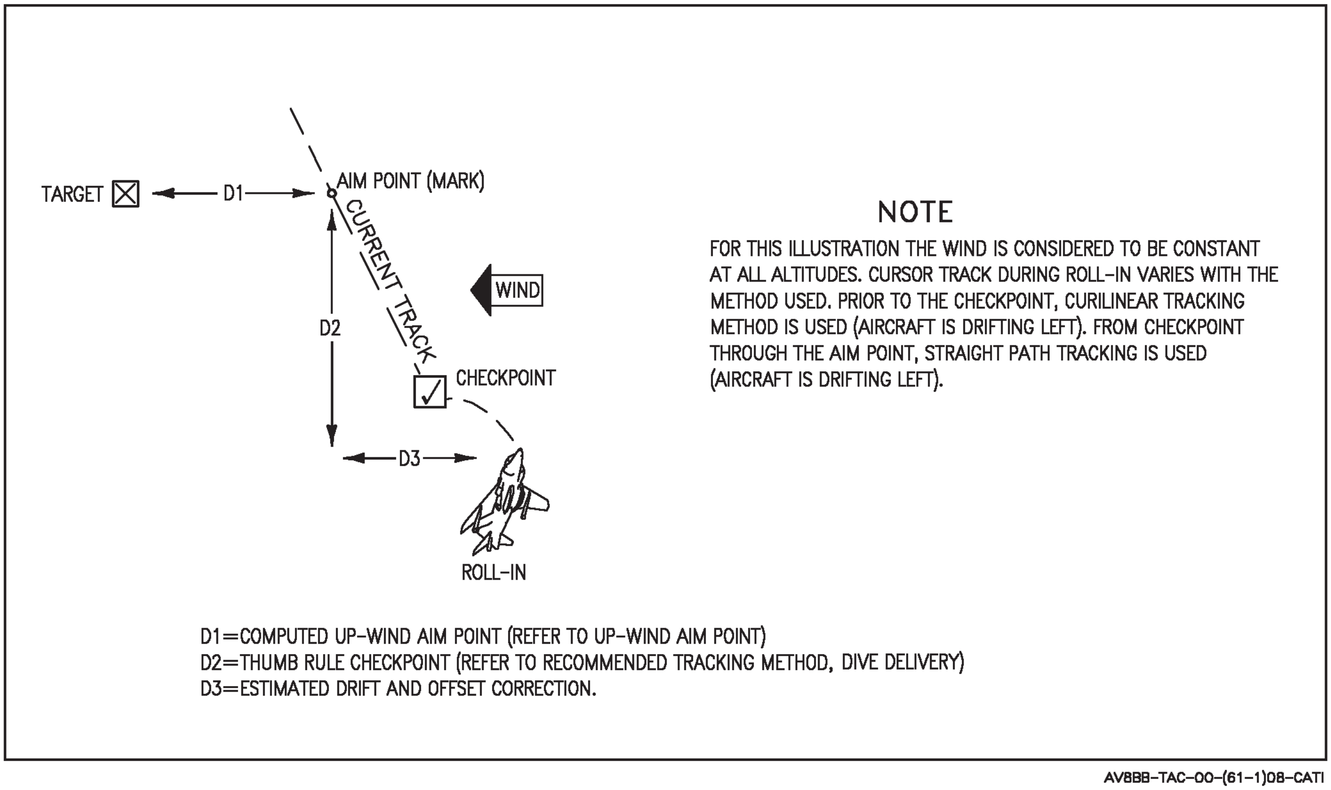


Figure 2-89. Cursor Tracking and Wind Effect

2.10.1.13.7 Wind Corrections With A Standby Reticle. The drift method of correction is best suited for dive bombing because a wings level condition is maintained throughout the attack run. Moving targets present essentially the same problem as wind, hence, corrections are similar. Wind effect on the aircraft while the pilot is tracking the cursor toward the aim point is as follows:

1. Right crosswind: aircraft drifts left, requiring right wing down correction to prevent overshoot.

2. Left crosswind: aircraft drifts right, requiring left wing down correction to prevent overshoot.

3. Headwind: tends to shallow dive.

4. Tailwind: tends to steepen dive.

The crosswind effects in the dive can be reduced by initially offsetting the cursor into the wind to minimize the correction required during tracking (Figure 2-89). The proper distance to offset is entirely pilot judgement based on experience. If the velocity vector is available then it can be used to compensate for crosswinds as in the discussion of crosswind compensation for the roll stabilized sight. For range winds the standby reticle can be used to place the pipper long or short the appropriate number of mils as determined by error sensitivities the same as was done with the roll stabilized sight. The advantages in estimating wind effects and offsetting the reticle cursor into the wind are as follows:

1. If the offset distance is accurately estimated, the entire dive can be performed wings level, thereby eliminating one variable to permit concentration on other factors.

2. Even too little offset in the right direction is beneficial in minimizing the error caused by wind.

NOTE

- Regardless of the drift corrections made during the dive, the wings must be level immediately before release to eliminate the bank error factor when using a non-roll stabilized sight.
- The computed delivery modes automatically account for wind effect at the release altitude.

2.10.1.13.8 Wind Correction and Computations. The Release Error Sensitivities and Wind Correction tables provide a relative wind correction value in feet per 10 knots of wind. Wind correction values may be calculated by multiplying the weapon time of flight (in seconds) times wind velocity (in knots) times 1.7 (knots to feet per second conversion factor). Thus, for a 10-knot wind and an 8-second weapon time of fall, the wind correction value is: 8-seconds times 10 knots times 1.7 = 136 feet. The relative wind value is used to relocate the aim point upwind from the target to correct for the total wind effect. Refer to Figure 2-90. For the higher release altitudes, the wind at the release altitude should be used since the wind at release will have the greatest effect on the impact accuracy. For the lower release altitudes, the surface wind can be used. The upwind aim point can be approached from any direction. This method of wind correction further assumes that the bomb is released at the planned release conditions and with the no-wind sight angle. The cursor should be on the upwind aim point when release occurs. The upwind aim point technique can be employed for dive bombing and level bombing with either high drag or low drag bombs, rockets, and guns.

2.10.1.13.9 Target Motion. Target travel is determined by estimating the speed and course of the target and predicting the position of the target at the time of weapon impact. The predicted target position then becomes the aim point.

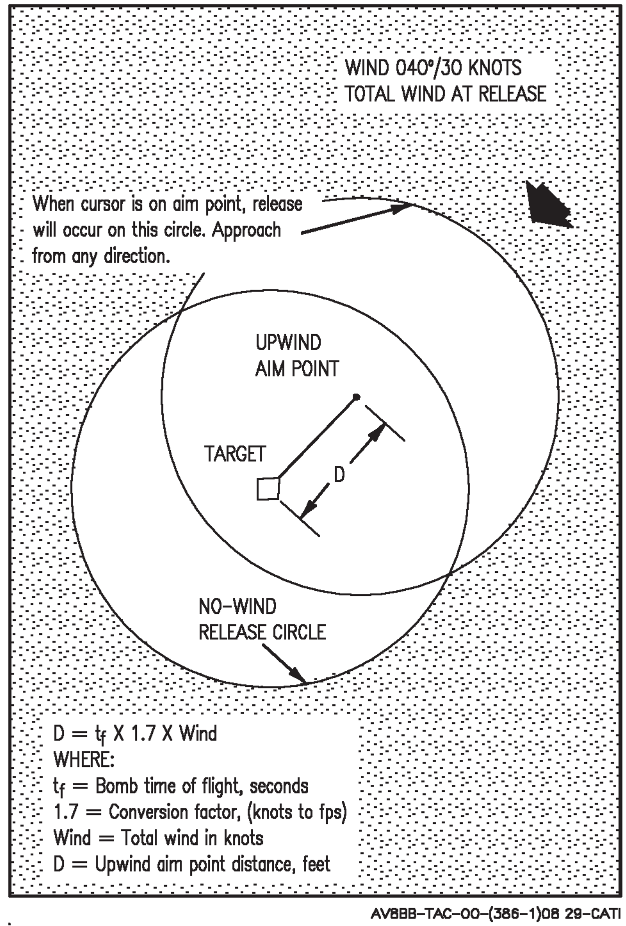


Figure 2-90. Upwind Aim Point

2.10.1.14 Factors Affecting Level Delivery Accuracy. The level delivery maneuver is a special case of the dive delivery maneuver where the dive angle is zero. The basic factors that affect the accuracy of the dive delivery also affect the level delivery accuracy. Refer to Figure 2-91 and 2-92 for errors produced by deviations in release airspeed and release height.

Since the velocity of the aircraft is imparted to the weapon at the time of release, it is of utmost importance that the planned release airspeed be achieved. All level releases must be accomplished in 1g level flight. Steady state tracking is an absolute requirement; however, as mentioned earlier, tracking time must be less than the time required by the enemy to bring effective fire to bear.

2.10.1.15 Conclusions. As can be seen from the factors covered, the complex nature of the

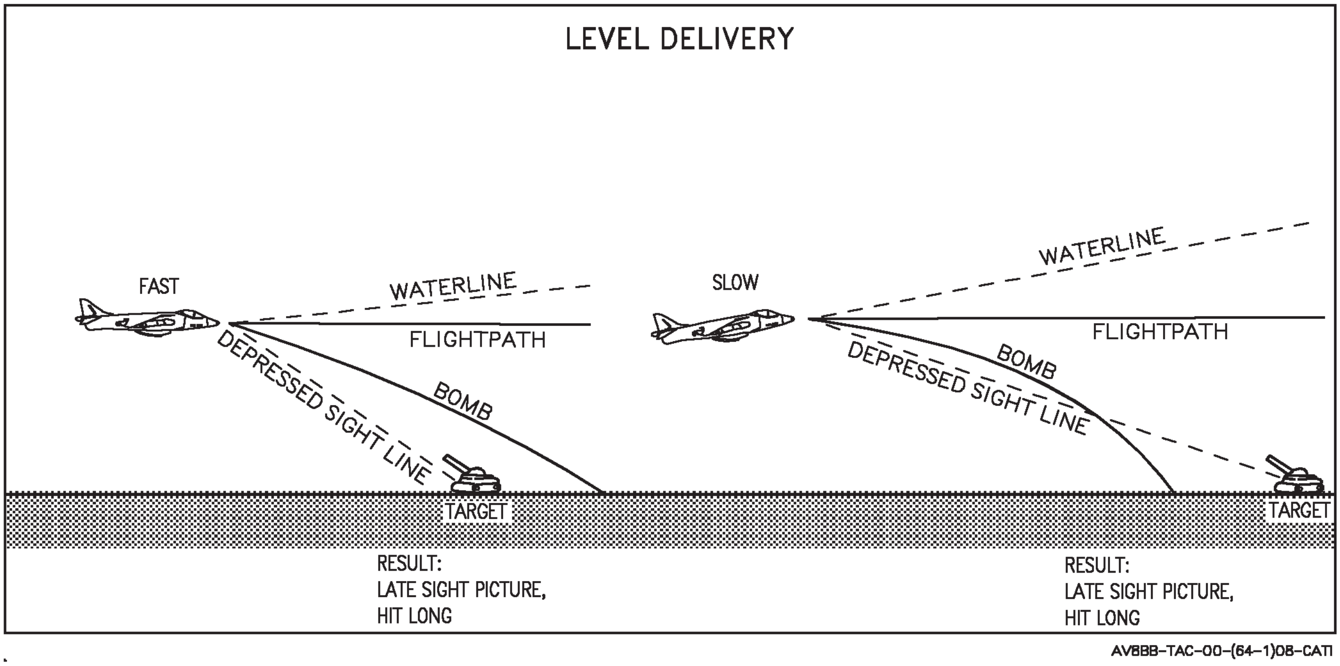


Figure 2-91. Release Airspeed Error

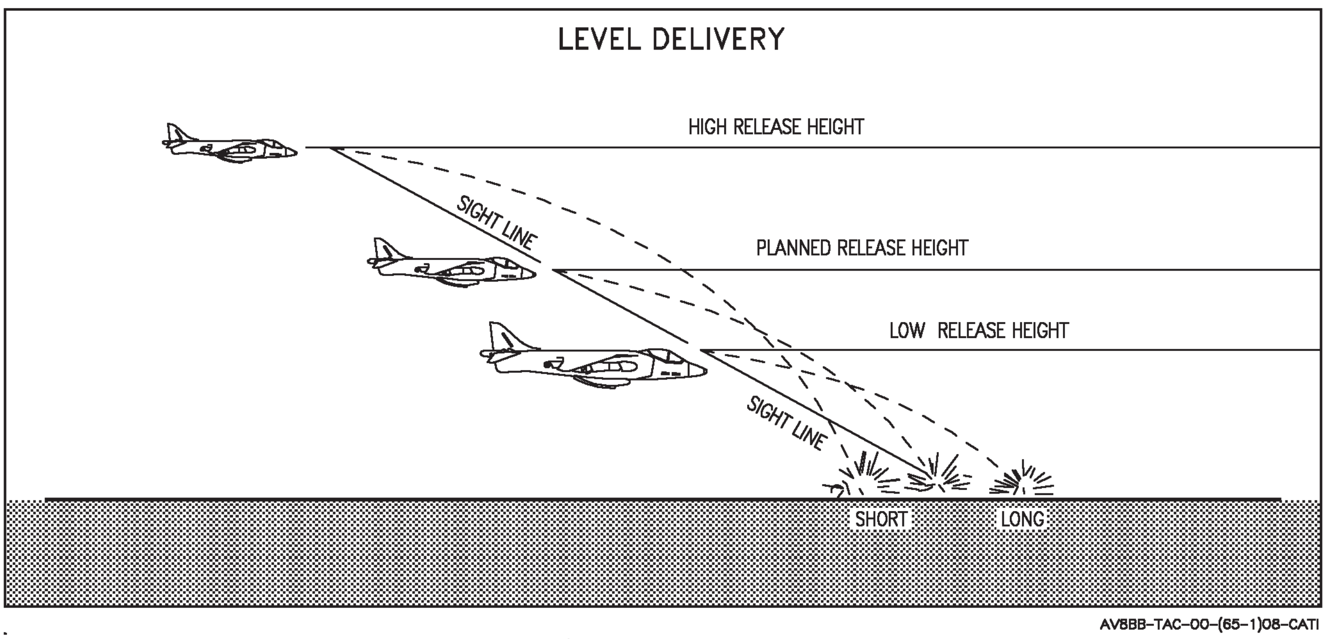


Figure 2-92. Release Height Error

manual delivery problem makes errors in delivery parameters unavoidable: dive angle, TAS, and release altitude AGL. Additional sources of manual delivery errors are: inaccurate mil setting computations (based on inaccurate gross weight, aircraft configuration, density altitude, etc.), imbalance flight, and, generally the largest error, pilot control of pipper position at release.

2.10.1.15.1 Bomb Error Sensitivities Relationship. To aid in DSL bombing the pilot must understand the relationship between bombing variables. The very complexity of the problem offers the means to improve accuracy through the following steps:

1. Learn the relationships between the effects of various delivery errors.

2. Develop procedures to make as many variables constant, where possible.

3. Calibrate your techniques and use standard consistent maneuvers so that you recognize errors in time to make corrections.

4. Practice until error analysis and corrective action become second nature.

5. Review HUD video.

2.11 ROCKETRY

Rockets are normally used on targets such as tanks, bunkers, buildings, railroads, and vessels. Since rockets are explosive missiles, the blast or fragmentation potential damage to the delivery aircraft during recovery necessitates that rockets be fired at relatively long slant ranges.

Rocket effectiveness is measured in terms of warhead effects, the type of target attacked, and the accuracy of the rockets as a function of slant range when they are fired. The warhead effects and specific target kill probabilities may be computed from Joint Munitions Effectiveness Manual, NAVAIR 00-130-ASR-2. Basically, the smaller the slant range at release, the greater will be the accuracy and, thus, the effectiveness. At slant ranges beyond 5,000 feet, the accuracy of all rockets starts degrading due to the 8 to 12-mil dispersion for all rockets, although the rocket impact velocity remains fairly constant.

Because the rocket CCIP symbology is generated by the same ballistic algorithm (different store codes merely account for mass differences) one delivery data table and one release error sensitivity table is provided for all rockets, 2.75 inch and 5.00 inch. Safe escape tables are provided for each warhead/motor configuration.

2.11.1 Entry for Rocket Delivery. The same entry maneuvers apply to rocketry as for strafing and bombing. The rocket attack is relatively easy to perform and may be initiated from almost any position with a minimum of preflight planning. However, for maximum effectiveness, the pilot should strive for consistent dive angles, slant ranges, and airspeeds. The drag from carrying many rocket pods requires a higher initial speed at entry and down to rocket release since the aircraft will accelerate slower, especially for low angle delivery.

2.11.2 Rocket Firing. Firing at the proper slant range is very important; therefore, the firing conditions of dive angle and release altitude are critical. For low angle rocket delivery (10° and below) as well as for strafing, slant range to the target is extremely difficult to estimate using dive angle and altitude, even with an accurate radar altimeter for altitude information. Therefore, low angle deliveries become accurate only with pilot proficiency in developing a sight picture, using target size to HUD symbol matching and outside-the-cockpit visual cues. If firing is commenced at a greater slant range than desired for a given dive angle, the impacts will be short of the target, unless an aiming correction was made. Additionally, pattern density is decreased due to increased dispersion, resulting in a larger impact area and reduced effectiveness. Firing at slant ranges below safe minimum slant range increases the probability of fragmentation hits from the rocket or target explosions, unless a breakaway maneuver is performed. Since rocket velocities leaving the launcher only slightly exceed aircraft velocity, rockets are highly sensitive to flightpath variations. A constant sight picture should, therefore, be maintained for a minimum of 0.5 second before release to ensure a steady flightpath. Gross errors can be expected if control inputs are made with insufficient time for flightpath response. Smooth steady control of the aircraft to maintain the sight picture prior to and during the firing sequence is vital to accurate rocketry. Rocket firing techniques are generally no different than those outlined for bombs or strafe except for the greater slant ranges in delivery. Rocket firing switchology is the same as for bomb deliveries.

WARNING

- Observe the minimum rocket firing speeds listed in NWP 3-22.5-AV8B, Vol. II, Chapter 5.

- Ingested rocket motor exhaust may cause engine compressor stall.

2.11.2.1 Indicated Minimum Open Fire Altitude. Since minimum release altitudes and mil settings are based on a single rocket launch, down range travel and altitude loss should be considered when determining pattern length and increased tracking timing for ripple firing an entire pod. Refer to NWP 3-22.5-AV8B, Vol. II Chapter 2 for corrections to sight angles when ripple firing a pod.

2.11.2.2 Minimum Cease Fire Altitude. Same as strafing.

2.11.2.3 Balanced Flight. When rockets are fired with the aircraft in a skid, the rockets will return to the flightpath by approximately 75 percent of the skid angle. Deflection errors should be multiplied by a factor of 4 to determine the correct skid angle to hold for the rounds to hit the target. For example, to correct for a 5-foot aim error to the left, sufficient rudder must be used to place the pipper 15 feet to the right of the target.

2.11.3 Recovery From Rocket Delivery. A pullup recovery should be initiated as soon as the last rocket is fired. If a 19-shot 2.75-inch pod or a Zuni pod is ripple fired, rocket impact may be seen before the aircraft nose blanks out view of the target. The recovery should be made by breaking away from the target, rather than over the target; this reduces the probability of damage from fragments or an exploding target. The breakaway type recovery can be commenced as soon as the rate of descent of the aircraft has been stopped. A maneuver similar to the Breakaway Escape Maneuver for PGU-23 should be adopted for recovery from rocket deliveries. See Figure 2-96. In addition, the breakaway recovery complicates the prediction problem for enemy ground fire.

Other items to consider which alter the dive recovery technique are: (1) possible foreign object damage to the aircraft from failures of the rocket and its components and (2) aircraft engine instability is possible due to rocket gas ingestion. To avoid possible foreign object damage (such as rocket fins, nose cone fragments and rocket igniter clips), pull up and away from the attack run as soon as the last rocket is observed to fire. Do not remain in a dive until rocket impact. The fragmentation pattern may be ahead of the aircraft.

2.11.4 Rocket Delivery Considerations. Wind and target movement corrections are virtually the same as for bombing and strafing. At the time of launch, the velocity of the rocket is only slightly greater than the velocity of the aircraft. After launch, the rocket rapidly accelerates to high velocity while gravity pulls it downward. The inherent long slant ranges involved with 2.75-inch FFAR and 5.0-inch Zuni rockets produce an 8 to 12-mil dispersion error, and an 18-mil CEP for all normal rocket delivery conditions. Tactically, this means that if the pilot is given a choice of making several runs or firing all out in one pass, make two runs and ripple two pods on each run. Although repeated runs do not improve weapons accuracy, there is a slight increase in target kill probability or weapon effectiveness. All factors considered, recommended tactics are to fire ripple with minimum number of runs.

2.11.5 Rocket Ricochets (Practice Warheads). Present safe escape tables for 2.75-inch rockets consider only the fragment envelopes of Mk 5 and Mk 151 service warheads.

The minimum release altitudes and slant ranges in the safe escape tables for service warheads are adequate for all dive angles to safely clear the target area when firing practice warhead Mk 5 and Mk 151 2.75-inch FFARs.

The ricocheting fragment envelope for practice 2.75-inch rockets will be similar to the envelope for 25 mm PGU-23/U target practice ammunition. The fragment charts that have been prepared for the 25 mm ammunition on sand, and earth range could be duplicated for the practice 2.75-inch FFAR.

WARNING

- Do not overfly the target area. Breakaway immediately after the last rocket is released.
- Do not fire practice FFARs at armor or other hard targets.

NOTE

The 30° half cone of safety behind the target area applies for rocket firing.

2.12 GUN STRAFING

The basic weapon of the AV-8B is the 25 mm GAU-12/U five-barrel Gatling gun, manufactured by General Electric Co. The weapon is highly effective against a wide variety of targets including medium armor. The ammunition family consists of the following rounds:

1. PGU-20 API (armor piercing incendiary)
2. PGU-22 HEI (high explosive incendiary)
3. PGU-23 TP (target practice)
4. PGU-25 HEI (high explosive incendiary)
5. PGU-32 SAPI (semi armor piercing incendiary)
6. PGU-33 TPF (target practice frangible)

All 25 mm rounds are a ″Ballistic Match″ by contract specification. The gun CCIP symbology is generated by the same ballistic algorithm regardless of which type round is used. One set of delivery data and release error sensitivity charts is used to complete weaponeering for all 25 mm rounds. The PGU-23 TP has a separate safe escape table due to its higher minimum release altitudes.

The three basic types of strafing are (1) area suppression, (2) line targets, and (3) point targets. Suppression fire is usually long-range area firing to ″keep their heads down″, where tracking is not of high priority. When strafing a line target, such as a truck convoy, the open fire slant range should be long to allow an extended burst or series of bursts and to make a safe escape maneuver away from the impact area of your first projectile impacts.

WARNING

PGU-23 TP ammunition tests have proven that ricochet or loose debris can be thrown 800 feet above and to either side of flat sand or earth impact areas. Refer to safe escape ballistic table in NWP 3-22.5-AV8B, Vol. II, Chapter 2.

When strafing a point target, the minimum slant ranges that permit a safe escape should be used. This will give the best accuracy and projectile effectiveness.

The choice of a delivery maneuver will depend on the target, on the enemy defenses, on weather conditions, and on terrain in the target area. For example, a steep dive coupled with high airspeed should be used in attacking ships; whereas, a shallow dive which is more likely to produce waterline hits, is more effective against small boats (or junks). Camouflaged targets are more easily seen when a low angle attack is conducted at a medium speed. Trenches or AAA positions should be strafed in a steeper dive in order to pinpoint the target. Recovery should be initiated as high as possible, consistent with the desired accuracy, in order to minimize the effectiveness of the enemy small arms and automatic weapons fire. Against ammunition dumps, the steeper dive maneuvers are recommended, with recovery being completed above 2,000 feet AGL in order to avoid explosion fragments.

The same basic delivery techniques and procedures for bombing and rocketry apply to strafing. A few exceptions are: reduced pendulum effect due to small sight depressions, small wind correction factors due to short time of flight of the projectile, minimum firing altitude based on firing time, altitude lost during recovery safe escape criteria (rather than fuze arming), and ease of obtaining improved accuracy through reduced projectile dispersion and short slant ranges.

2.12.1 Low Angle Strafing Techniques. The strafing attack is easily performed and may be initiated from almost any condition of flight with a minimum of preplanning. However, for consistency and effectiveness, the pilot should strive for optimum firing conditions: dive angle, slant range, and airspeed.

2.12.1.1 Entry. The low approach entry technique will depend on the target, terrain, weather conditions, and enemy defenses. For example, a low angle, high-speed evasive maneuver (jinking) approach should be made to a defended, armored target. Plan your final roll out such that you will not be straight and level over 3 seconds on your firing pass. Get your sight picture and fire a 0.5 to 0.75 second burst. Break away immediately. DO NOT WATCH FOR PROJECTILE STRIKES. Break line of sight with defenses if possible and if you re-enter, do so from another direction using different approach turns.

Low angle entries on undefended targets can be made more deliberate with preplanning of the approach and waiting for the desired sight picture. At cease fire, initiate an immediate breakaway clearing turn. DO NOT WATCH PROJECTILE STRIKES.

Low angle entries on softer targets that HEI ammunition can defeat can be at greater slant ranges with longer bursts for effectiveness. The same breakaway maneuver is necessary to avoid the pop-up debris and HEI fragments in the immediate target area. Don’t overfly the target unless there is no other escape route.

2.12.1.2 Firing. Firing should be initiated when you are satisfied with the sight picture.

On low angle close-in attacks using armor piercing ammunition, short bursts of 0.5 to 0.75-second should be used. Extensive hard data from over 600 antiarmor firing passes show that the most accurate rounds of a burst are made in the first 0.5-second when the sight picture is stable. Also, by firing short bursts you can push the attack closer for better impact velocities. On softer targets that HEI ammunition will defeat, you can fire from longer slant ranges and use longer bursts for more rounds on target.

Refer to safe escape ballistics table in NWP 3-22.5-AV8B, Vol. II, Chapter 2 for open fire and cease fire slant ranges.

2.12.1.3 Low Angle Strafe Recovery. Initiate a breakaway recovery as soon as the trigger is released. Any delay in initiating recovery will increase the chances of ricochet and exploding target damage. (See Figures 2-93 through 2-95.) The breakaway clearing maneuver is recommended because the density of fragments and debris is greater over the target. Also, a breaking recovery complicates the tracking solutions for enemy ground fire. After clearing the target, don’t fly straight and level. Fly evasive maneuvers (jinking), and break line of sight with ground defenses if possible.

WARNING

Stay clear of a 30° half-cone fragment area from the target to 15,000 feet downrange for a minimum of 45 seconds.

Due to clockwise spin of the projectile, the debris hemisphere is biased to the right, and a break to the left is recommended; however, don’t allow this to become a predictable habit.

2.12.1.4 Low Angle Strafe Ricochets. There are several hundred recorded incidents of aircraft strikes by fragments that have ricocheted off the target or by debris that has been thrown into the air by impacting projectiles. Reported strikes that the pilot was aware of at the time occurred either over the target or downrange from the impact area.

There are two options for safe escape from ricochets.

1. The best fragment avoidance maneuver is an immediate breakaway turn making sure

you stay clear of the 30° half-cone area behind the target (Figure 2-94).

2. When the situation prevents a breakaway escape, a straight ahead recovery can be made. To do this, you must cease fire sooner (longer slant range) to clear the higher fragments over the target. (See Figure 2-93 and 2-95) Further, you must continue to climb into the threat area, avoiding the 30° half-cone behind the target.

WARNING

Safe escape ballistics table and other data presented is valid only for breakaway maneuver.

2.12.1.4.1 Ricochet Envelope for 25 mm PGU-23/U Target Practice Round. The ricochet envelope for the PGU-23/U TP is shown in Figures 2-93 and 2-94.

The fragments will be more dense above and behind the target. Long-range fragments will be confined to a 30° half cone downrange from the impact area. The heights and range of ricochets for soft targets can be predicted (Figure 2-97). For downrange footprint of ricochets see Figure 2-93 and Figure 2-98.

WARNING

Do not fire PGU-23/U TP at hard targets.

2.12.2 High Angle Strafing Techniques. Establish the desired altitude and airspeed, and maneuver the aircraft to the proper roll-in position. Airspeed utilized should be the highest practical in order to impart maximum impact velocity on the rounds. Ensure sufficient fan speed to maintain air pressure to the gun (see Figure 2-68). During the final turn, maintain visual reference with the target. Don't attempt to fly the sight around to the desired aiming point. Roll out from the final turn in a slightly steeper dive than desired and place the cursor/reticle just below the desired aiming point. Always check for balanced flight (with the aircraft in a wings-level attitude) prior to commencing a strafing attack. Allow the cursor/reticle to drift smoothly up to the aiming point. Control the drift rate to position the cursor/reticle on the aiming point just prior to attaining desired open fire conditions. The open fire altitude is determined by an altimeter reference. Stabilize the aircraft in wings-level coordinated flight and fire.

NOTE

Slant range measured along the depressed sight line is contained in the ballistic tables. Slant range from aircraft to impact can also be obtained from the error sensitivity tables by multiplying 1 mil left or right error in feet by 1,000.

2.12.2.1 Firing. Firing at the proper slant range, dive angle, and release altitude are critical. If firing is commenced at a greater range than desired, the initial impacts will be short of the target unless an aiming correction has been made. In addition, pattern density is decreased due to increased dispersion, which results in a larger impact area and reduced effectiveness. Firing at slant ranges below safe minimum slant range will increase chances of ricochet damage. At present, the best method for arriving at the proper firing slant range is to be on dive angle and fire at the proper altitude AGL as shown on the altimeter.

2.12.2.1.1 Indicated Minimum Open Fire Altitude. The indicated minimum open fire altitude in the ballistic charts is precomputed with the addition of two values: altitude loss during 1-second firing and minimum cease fire height. These charts include the minimum cease fire height (AGL) that ensures recovery above minimum recovery height.

2.12.2.1.2 Minimum Cease Fire Altitude. The minimum cease fire altitude must preclude aircraft entry into the fragment envelope and allow the delivery aircraft to recover above ground level. Cease fire altitudes for the longer bursts are greater than those for the shorter bursts due to the lower striking velocities of those projectiles fired at a greater slant range.

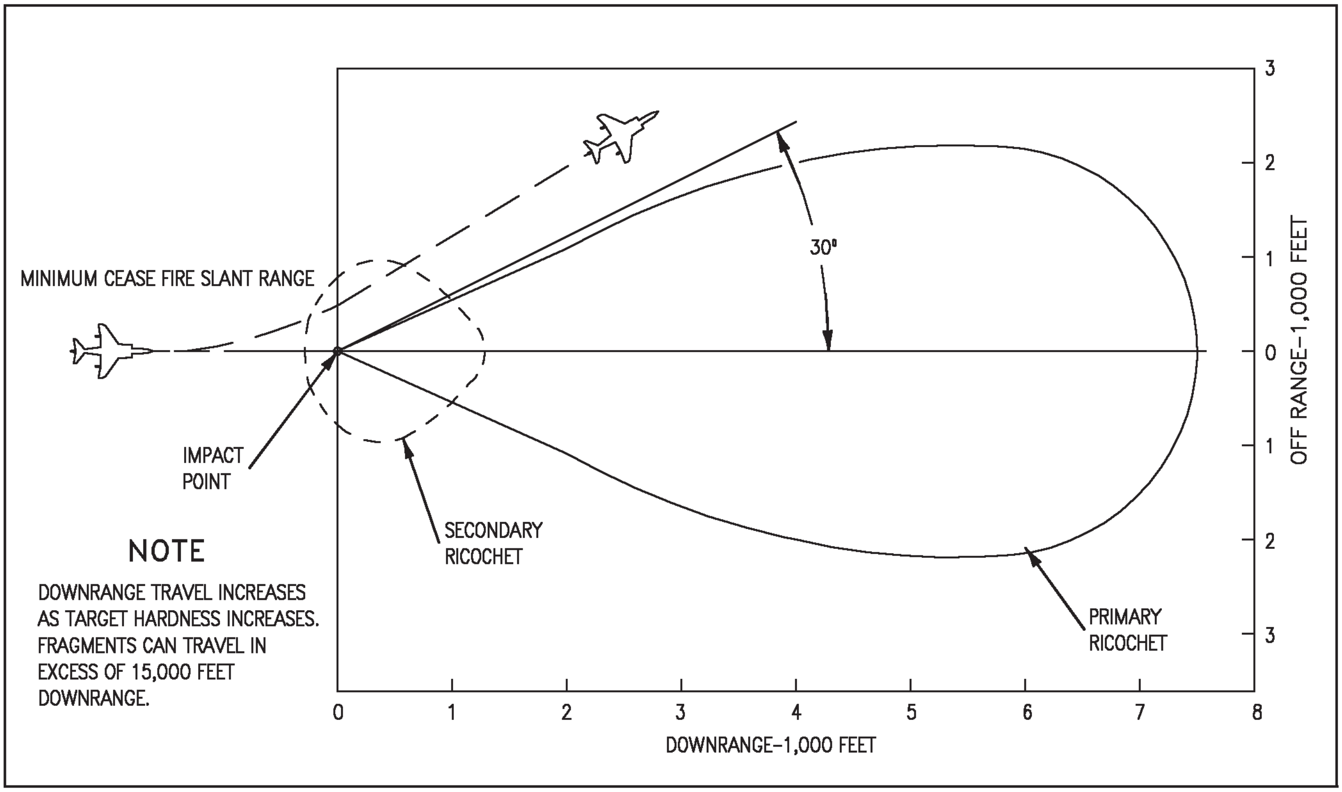
The lower striking velocities produce greater maximum altitude of the fragment trajectories. Bursts of approximately 1 second are computed in the ballistic tables. Bursts of 1 second allow greater accuracy due to the decreased slant range at cease fire compared to the longer bursts. The 2 to 3-second burst length will normally be the maximum. A typical strafing burst length is 1 second (50 rounds), which will give effective fire on target.

2.12.2.1.3 Balanced Flight. When guns are fired with the aircraft in a skid, the bullets will return to the flightpath by approximately 20 percent of the skid angle. Errors should be multiplied by 1.25 to determine the correct skid angle to put the rounds on target.

2.12.2.2 High Angle Strafe Recovery. The recovery should be initiated immediately after cease fire by making a smooth, wings-level pullup at planned g-load, normally 6g's in 1.75 seconds depending on aircraft capability. Assure the nose is well above the horizon before starting a reposition turn. If a long burst has been fired, bullet impact may be seen before the aircraft nose blanks out the target. The recovery should be made by breaking away from, instead of over the target, since this reduces the probability of damage from ricochets, fragments, or an exploding target. It also complicates the prediction problem for defensive ground fire. For undefended targets, reposition and reattack as desired. Evasive maneuvers (jinking) should be accomplished as necessary to negate enemy radar tracking or increase difficulty of manual tracking.

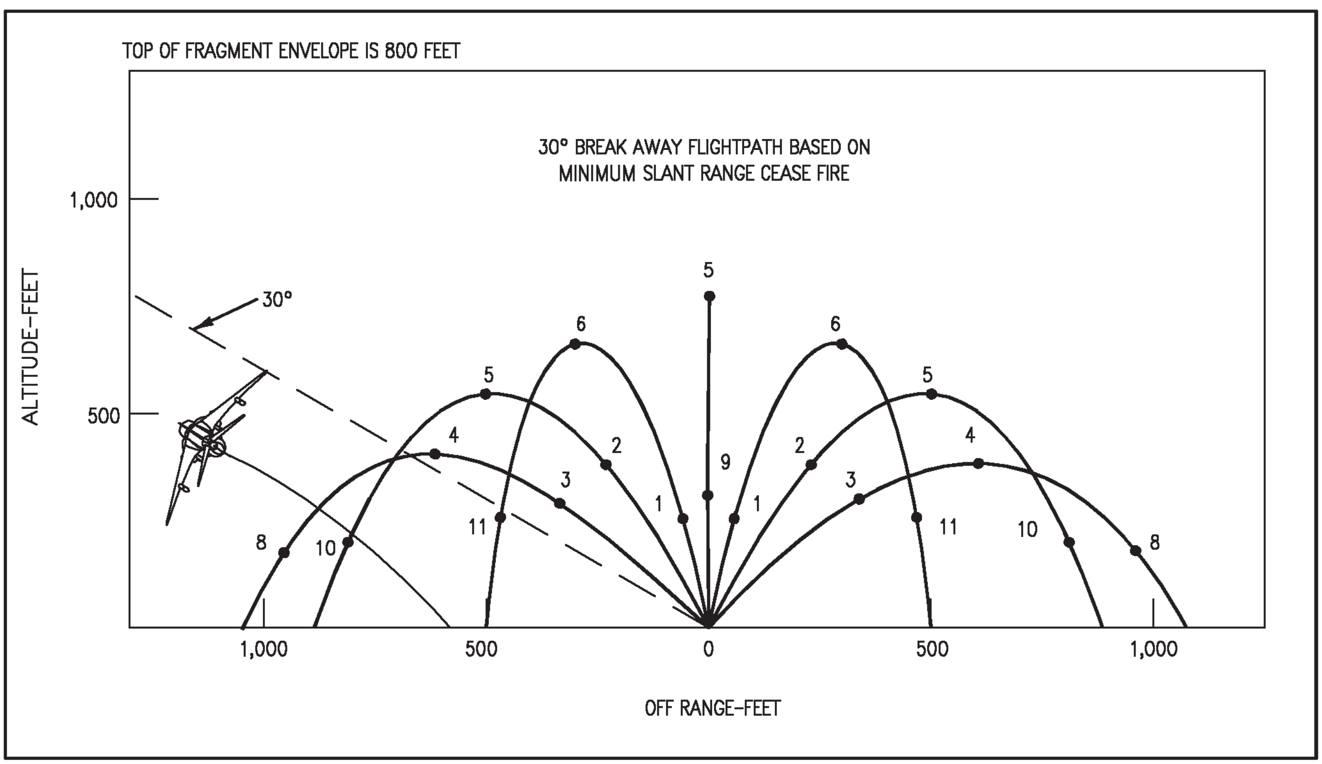
WARNING

Avoid the 30° half-cone fragment danger zone behind the target. (See Figure 2-94)



AV8BB–TAC–00–(271–1) CATI–27

Figure 2-93. PGU-23/U (TP) Ricochet Ground Fragment ''Footprint'' for Soft Target



AVBBB–TAC–00–(272–1)–CATI–25

Figure 2-94. Maximum Fragment Envelope, 25 mm PGU-23/U (TP); Pilot's View of Fragments in Target Area

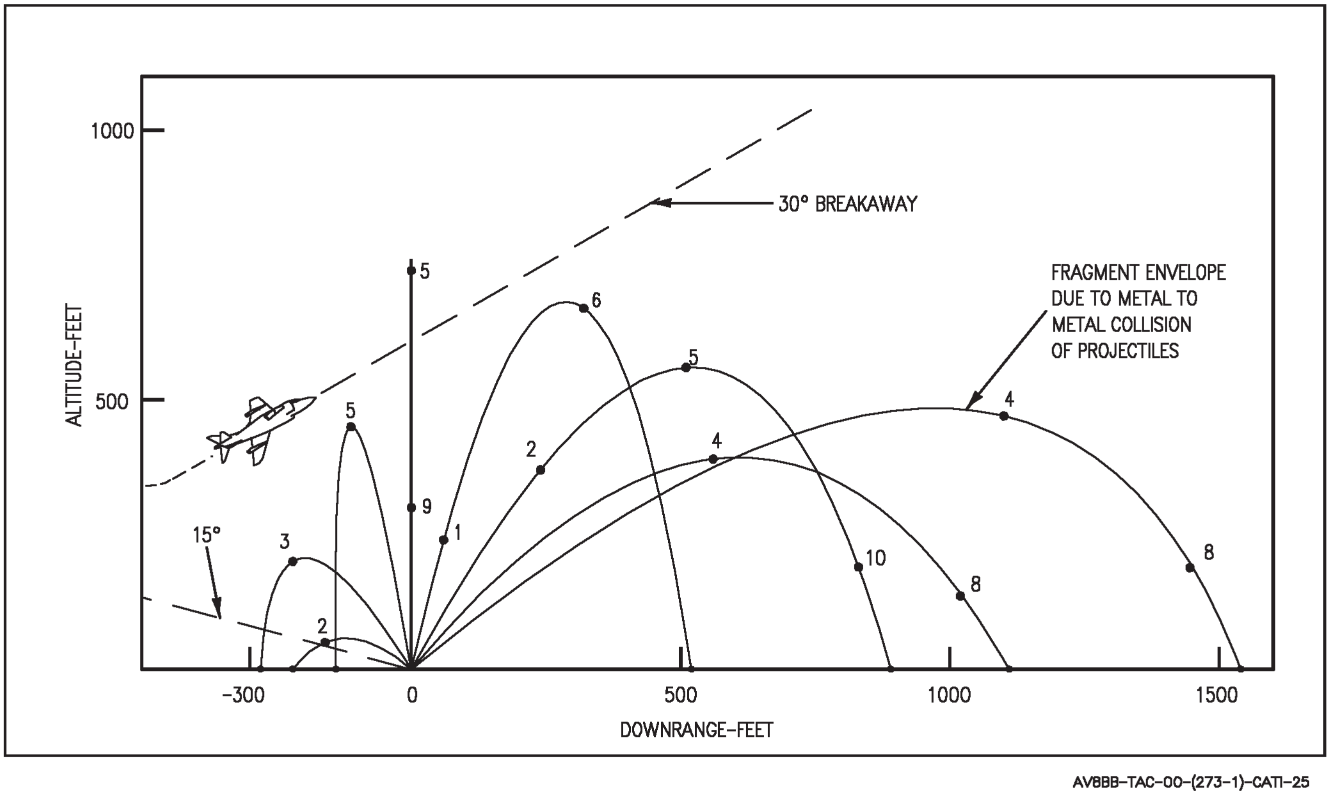


Figure 2-95. Maximum Fragment Envelope, 25 mm PGU-23/U (TP); Cross-Sectional View of Fragments in Target Area

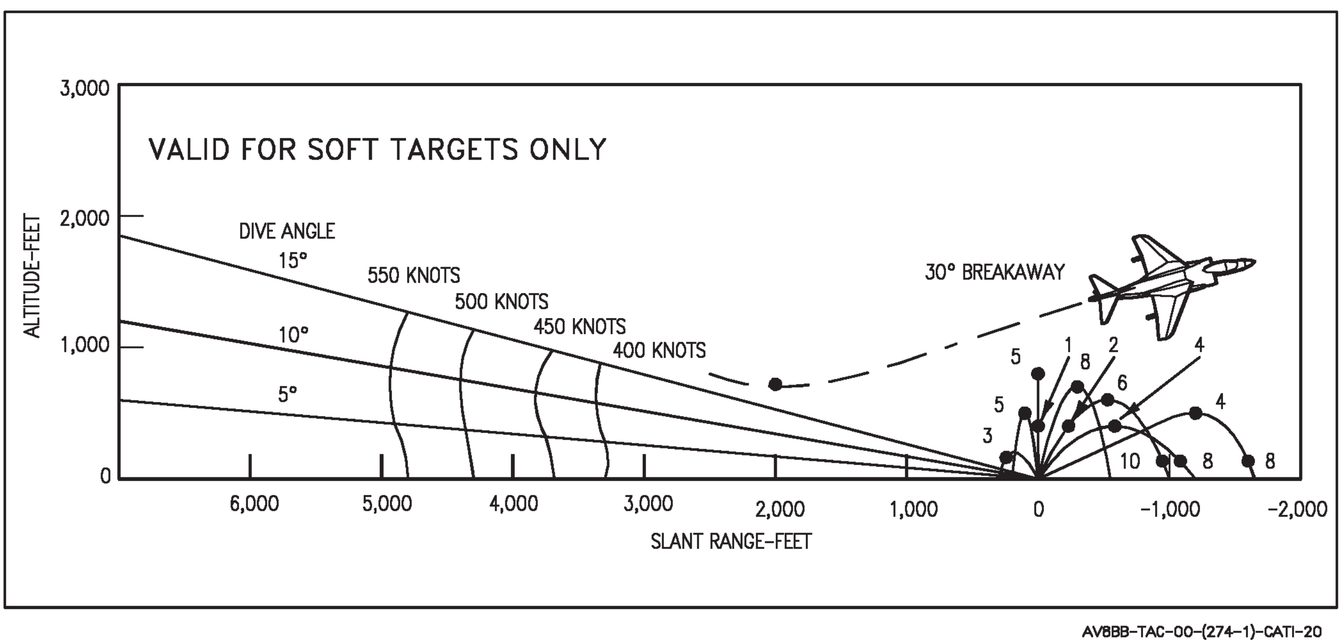
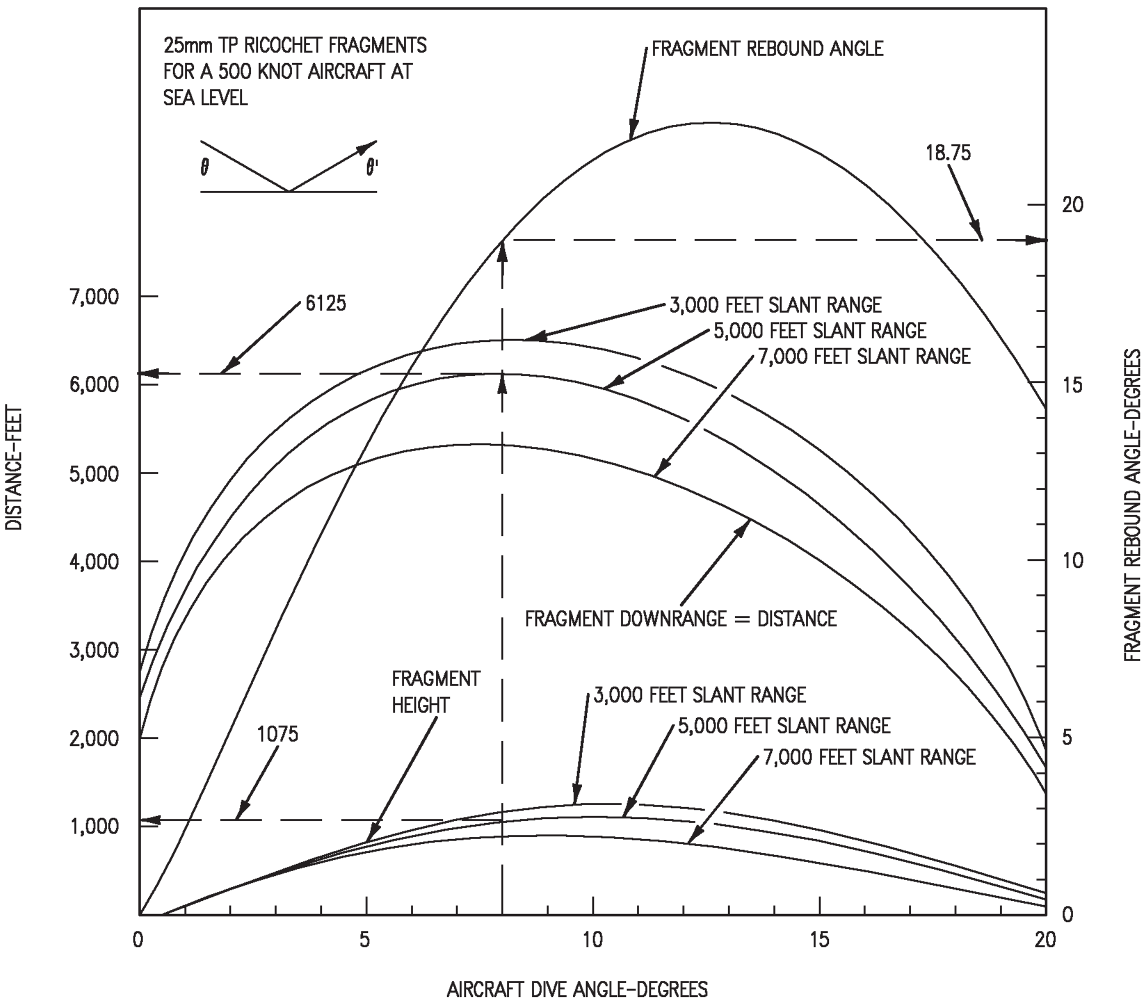


Figure 2-96. Breakaway Escape Maneuver for PGU-23/U (TP)



USE GUIDE

1. ENTER THE GRAPH ON BOTTOM SCALE AT YOUR INTENDED DIVE ANGLE. (THE SAMPLE IS FOR AN 8° DIVE ANGLE, DASHED LINE.)

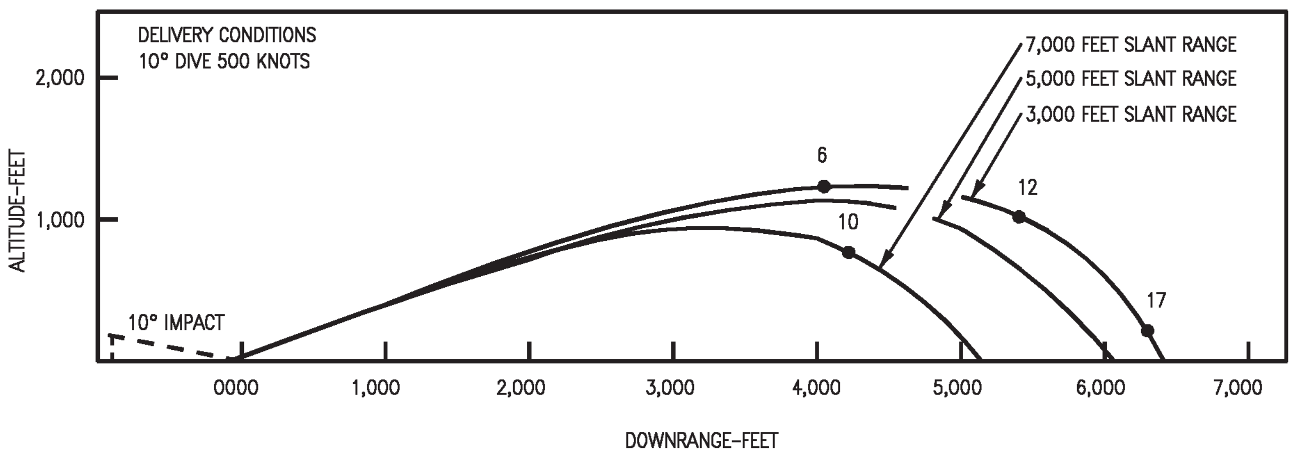
2. TRACK VERTICALLY TO THE LOWER CURVES, WHICH ARE FRAGMENT RICOCHET HEIGHTS FOR THREE CEASE FIRE SLANT RANGES. TRACK LEFT TO THE SCALE AND READ THE FRAGMENT HEIGHT IN FEET. (THE SAMPLE IS 1075 FEET FOR A 5000–FOOT CEASE FIRE SLANT RANGE.)

3. CONTINUE TO TRACK VERTICALLY TO THE UPPER SLANT RANGE CURVES. TRACK LEFT TO THE SCALE AND READ THE DOWNRANGE DISTANCE THE FRAGMENTS WILL TRAVEL. (THE SAMPLE IS 6125 FEET FOR A 5000–FOOT CEASE FIRE SLANT RANGE.)

4. CONTINUE TO THE INTERSECTION OF THE FRAGMENT REBOUND ANGLE CURVE. TRACK RIGHT TO THE SCALE AND READ THE REBOUND ANGLE IN DEGREES. (THE SAMPLE IS A REBOUND ANGLE OF 18.75° FOR A 5000–FOOT CEASE FIRE SLANG RANGE.)

AV8BB–TAC–00–(275–1)10–CATI

Figure 2-97. Ricochet Predictions



NOTE

- DOWNRANGE TRAVEL INCREASES AS TARGET HARDNESS INCREASES.
- DOWNRANGE TRAVEL CAN BE IN EXCESS OF 15,000 FEET.

AV8BB–TAC–00–(276–1)10–CATI–23

Figure 2-98. PGU-23/U (TP) Nominal Downrange Fragment Envelope for Soft Targets

2.12.3 Gun Firing Modes. Two modes are available for A/G gunnery: CCIP and DSL. Operation in these modes is very similar to operation in the CCIP and DSL modes for rocket delivery.

2.12.3.1 CCIP Mode. CCIP mode gun symbology is displayed on the HUD as shown in Figure 2-99. The gun reticle is a circle with range markings on the outside and a dot in the center. The pilot sets the maximum and minimum range cues and the tape around the reticle represents slant range to the impact point in feet. The center of the gun reticle denotes the computed bullet impact point on the earth surface. (Note that the velocity vector and/or any designation symbol is removed from the HUD when they touch the gun reticle. This is done to declutter the aiming point.) Maneuver the aircraft first using the velocity vector and/or pitch carets of the roll stabilized sight to establish tracking as if there were a BFL from the velocity vector to the reticle. Once track is established, position the reticle on the target.

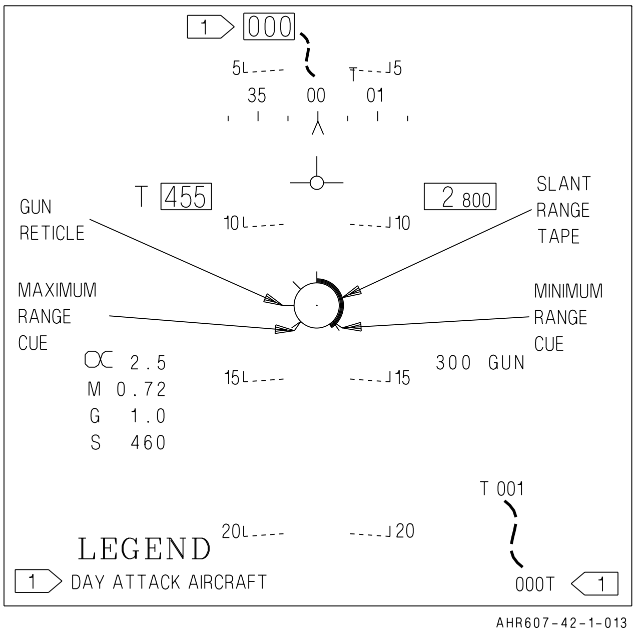


Figure 2-99. Gun Mode Symbology (A/G)

Squeeze the trigger to fire the gun when in range and stop firing when target is destroyed or minimum range is reached.

Radar altitude or barometric altitude may be used to obtain an aiming solution depending on the pilot selection of altitude source (BOMB option cued or not cued).

The SMC updates the rounds remaining status on the HUD and the stores display. If the gun rounds remaining indicator displays zero, the gun reticle is displayed with the weapon release inhibit cue; the gun can still be fired until no rounds remain.

2.12.3.2 DSL Mode. DSL mode HUD symbology for A/G strafing is the same as shown for bombing in Figure 2-84. Either the standby reticle or roll stabilized sight may be used in the DSL mode. Select the reticle cursor depression angle or roll stabilized sight depression angle based on the desired firing range for predetermined firing conditions. If the standby reticle is employed, the cursor depression angle is displayed just beneath the reticle diamond. If the roll stabilized sight is used, the depression angle is displayed on the scratch pad.

Maneuver the aircraft to position the reticle cursor on target or offset aim point and squeeze the trigger to fire the gun(s) when the estimated range to the target equals the desired firing range. The rounds count is updated on the display as previously described.

2.13 AGM-122A SIDEARM

The AGM-122A (Sidearm) is an air launched, air-to-ground, anti-radiation missile whose mission is to detect, home-on and destroy or disable enemy radar. The missile is authorized for carriage on Day and Night Attack aircraft. (See stores limitations in NWP 3-22.5-AV8B, Vol. II). The missile consists of a guidance and control section (GCS), target detecting device (TDD), warhead, rocket motor (MK 36 Mod 12), and wings.

The Sidearm is similar to the AIM-9 Sidewinder in that it is launched using the LAU-7 launcher and with the exception of the GCS, the other weapon components are functionally the same as those used on the Sidewinder.

The GCS (WGU-15/B) employs passive radar detection and tracking with proportional navigation to guide the missile to the target. For a description of the TDD, warhead, rocket motor, and wings, refer to NWP 3-22.5-AV8B, Vol. III.

2.13.1 Description. The Sidearms physical description is as follows:

length	117.95	inches
diameter	5.00	inches
span (wings attached, uncaged)	24.80	inches
weight	203.00	pounds
cg (inches from nose)	62.88	inches
GCS (WGU-15/B)		
length	29.25	inches
weight	42.11	pounds

2.13.2 Management. Initial weapon system management functions include establishing the initial number of missiles. The SMS uses the presence of the AGM-122/AIM-9 weapon identification signal from the stores station controllers at stations 1, 2, 6, and 7 and the weapon code (59) dialed in on the loadout panel (LOP) to determine which station(s) carry Sidearms. The presence of an identification signal and a non-AGM-122 or non-AIM-9 weapon code will result in a load fault (****) being displayed on the wing planform.

A mixed load of Sidearms and Sidewinders can be carried as long as the proper weapon code for each weapon is dialed in on the LOP for that station. The system will automatically select the priority station for the selected weapon. The station priority sequence is 1, 7, 2, 6.

Even though the Sidearm seeker head is not cooled, the coolant control switch (IR COOL on the ACP) affects both the Sidearm and the Sidewinder. Although the IR COOL switch can provide cooling for the Sidewinder, it causes a problem for the Sidearm.

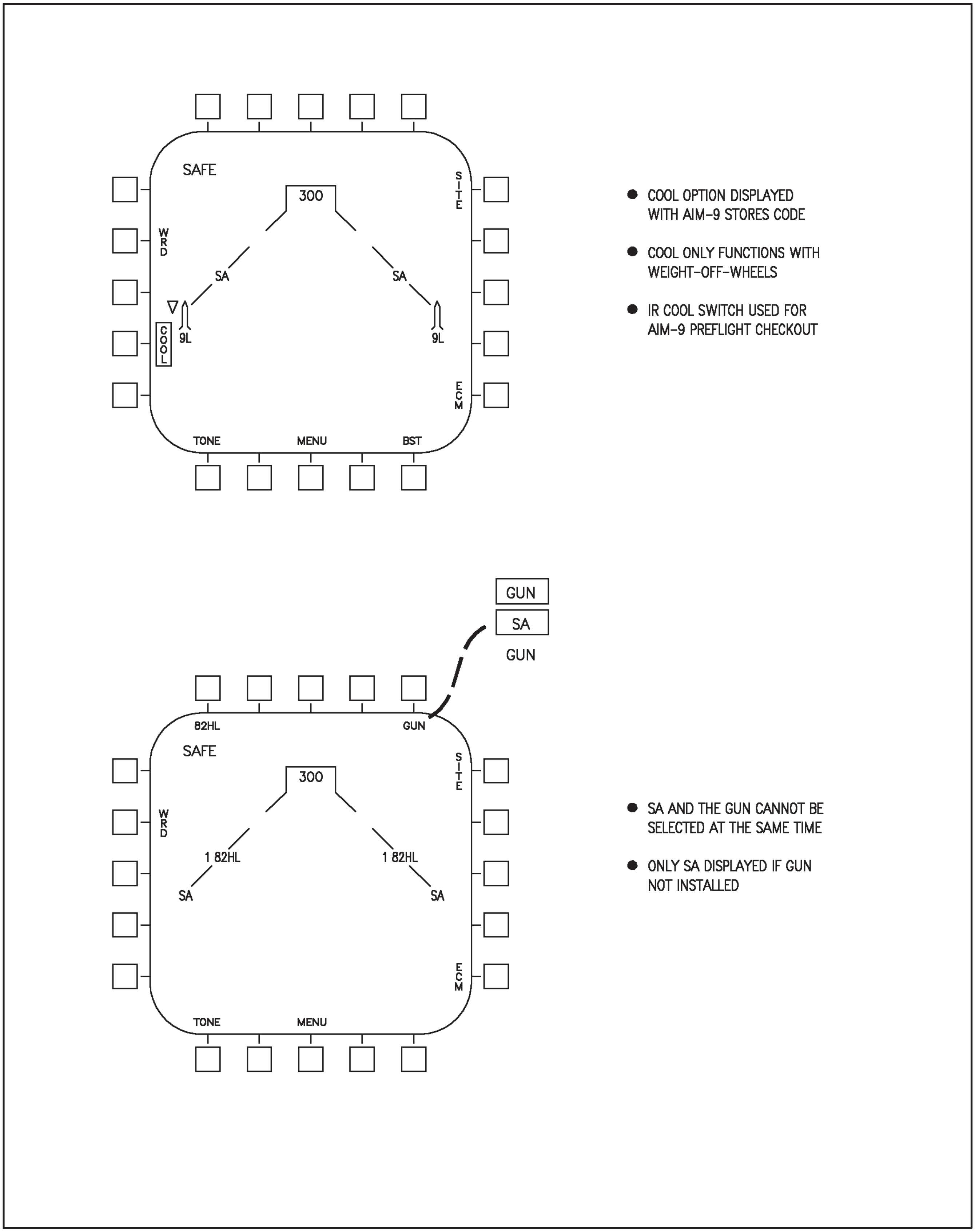
In A/G master mode with Sidearm selected, if IR COOL is selected and the Sidearm is uncaged (pilot actuates the cage/uncage button), the seeker is placed in the SLAVE mode. In the SLAVE mode, the seeker is awaiting head positioning commands that are not coming, thus the seeker is uncaged and will free float. ″Free float″ is defined as the lack of electronic restraint on or guidance to the seeker antenna such that the antenna is free to move where ever an external force directs it (i.e., dynamic flight loads). The movement will terminate at the gimbal stop. Excessive and uncontrolled contact with the gimbal stop can cause sever damage. With the IR COOL on there is *no* capability to command the missile back to the boresight (caged) position.

In non-A/G master modes (i.e., A/A), if the IR COOL position is selected, the Sidearm seeker will uncage and the seeker will free float. In this case, the pilot will have no indication of this (i.e., no Sidearm HUD symbology or missile tone). Due to the above conditions, the IR COOL switch should not be placed in the IR COOL position when Sidearm(s) is loaded on the aircraft.

When Sidewinders are loaded on the aircraft, a COOL option is displayed on the SMS stores display (Figure 2-100). This option is displayed when AIM-9 weapon codes are dialed in the SMS and allows IR COOL to be provided to all Sidewinder stations loaded with an AIM-9. The COOL option may be preselected (boxed) by the pilot while on the deck, however, IR COOL is not applied to the AIM-9 stations until weight off wheels occurs.

Even if the COOL option is not boxed, Sidewinder seeker cooling is automatically initiated to all Sidewinder stations with AIM-9 codes by the SMC when a Sidewinder is selected and the master arm switch is placed to ARM.

Since the COOL option does not function while on the deck, the IR COOL switch on the ACP must still be used when cooling is required on the deck. The IR coolant switch is a two-position switch with positions of OFF and IR COOL. The switch enables the pilot to manually apply IR detector cooling to the Sidewinder seekers for preflight operations. Placing the switch to IR COOL applies cooling to all Sidewinder stations. Placing the switch to OFF deselects IR cooling. The IR coolant switch must be returned to the OFF position prior to flight.



AV8BB-TAC-00-(406-1)10-CATI

Figure 2-100. Sidearm DDI Stores Display

2.13.3 Selection. The Sidearm is selected from either the DDI or ACP. The Sidearm is displayed on the HUD and DDI using the symbol SA.

Sidearm uses the same DDI option button as the GUN legend in a scrollable format when the fuselage gun is installed. When Sidearm is selected as the primary weapon, the STEP function is available on the stores display if the pilot desires to deviated from the normal launch sequence.

An ACP selection of a weapon station with a Sidearm overrides the normal launch sequence and the selected station will initialize as the priority Sidearm station when in A/G, NAV, or VSTOL master modes. Upon selection of A/G, NAV, or VSTOL master mode and Sidearm is selected as the primary weapon, the ACP will show AGM with dashed fuze codes. If any A/G ordnance besides Maverick or Gun is selected, the Sidearm will revert to the HOT sidearm mode.

The selection of Sidearm will automatically deselect Maverick or Gun if previously selected and the selection of Maverick or Gun will automatically deselect Sidearm. The selected Sidearm will be retained in memory when A/A master mode is selected. The Sidearm station will be automatically reselected upon reentry to the NAV, VSTOL, or A/G master modes.

2.13.4 Sidearm Operational Modes. The Sidearm has two operational modes, PRIMARY and HOT Sidearm modes. Both the PRIMARY and the HOT Sidearm modes are available in the AUTO, CCIP, and DSL deliver modes. Sidearm is also usable in some of the backup delivery modes, however, it is not available in the DIR mode (SMC inoperative). This is due to the inability to select any station with a Sidewinder/ Sidearm ID. In A/A master mode, when the SMC is operative, the Sidearm can be selected and fired as if it were a Sidewinder. The Sidearm station must be selected via the ACP in DSL(1) and launched by using the A/G weapon release button. In this mode, no automatic station selection or launch priority will take place.

Sidearm seeker head position is not displayed in the DSL(1) delivery modes. However, in all delivery modes the SMS sends the Sidearm audio from the priority missile station via the ACNIP to the pilots's headset. This is the same process as used for Sidewinder audio. Unlike Sidewinder audio, Sidearm audio is one half the PRF of the target with a 10 Hz modulation. The pilot can control the volume of Sidearm audio via the AUX VOL knob on the ACNIP.

2.13.4.1 Primary Mode. The primary mode is entered any time the Sidearm is the only weapon selected. With A/G master mode selected, the HUD will display the caged seeker symbol at the boresight position (2° below the waterline), SA, and the current quantity of missiles present. See Figure 2-101. The caged Sidearm symbol is an open circle consisting of a small dashed line on each side with ticks in the center of each dashed line.

The major feature of the primary mode is the assignment of the cage/uncage HOTAS function to the weapon. By uncaging the missile, the seeker is allowed to self track a target. The uncaged Sidearm symbol is a solid circle with sticks in the center of each side. The solid circle becomes dashed when the uncaged seeker symbol is HUD limited. The SMS receives head position data form all Sidearm stations via the slave reference and polar head position command signals and provides the information to the MC which then displays the seeker position. The Sidearm will remain uncaged until one of the following occurs:

1. Cage command from the cage/uncage button

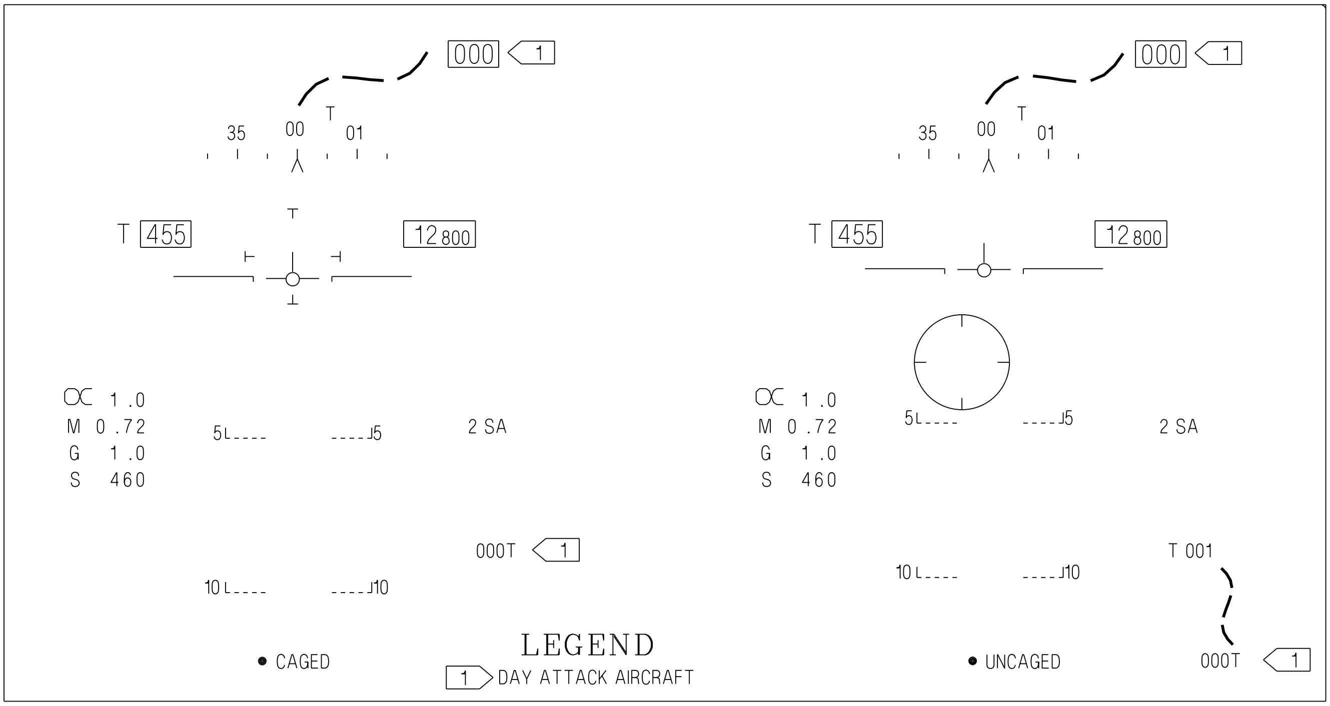
2. Selecting a different missile via the STEP option

3. Sidearm is deselected

4. Priority is advanced by ACP station select or launch

5. Selecting another A/G weapon

6. Selecting AGM-65 or 25mm gun



AHR607-432-1-013

Figure 2-101. Sidearm Primary Mode HUD Displays.

7. Changing master modes

8. Entering DIR or DSL(1) backup modes

9. SMS reset is received

10. SMS primary power is removed and reapplied

A 400 Hz noise on the polar head position command signal causes the HUD seeker position symbol to be jittery when the missile is uncaged and the position symbol is near the boresight position.

Care must be taken to prevent damage to the Sidearm guidance system when not tracking a target by keeping it caged. Anytime the seeker is caged by the SMS the MC displays the caged seeker symbology on the HUD.

2.13.4.2 Hot Mode. Hot Sidearm is entered when another A/G weapon except AGM-65 or 25mm gun is selected with Sidearm already selected, or Sidearm is selected with another A/G weapon selected. While in this mode, all the primary weapon delivery displays and the cage/uncage button are assigned to the other A/G weapon. The Sidearm seeker symbol is caged 2° below the waterline. See Figure 2-102.

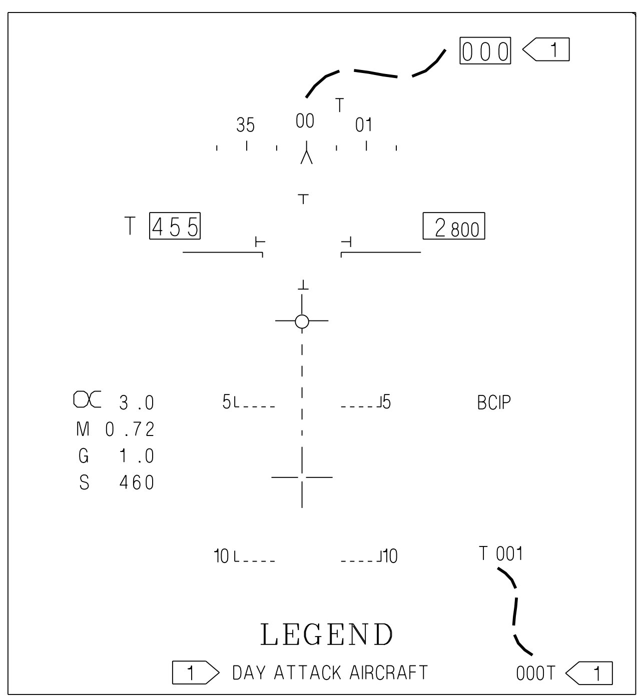


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Figure 2-102. Hot Sidearm HUD Display

2.13.4.3 Functional Operation. The Sidearm is a stand alone weapon and not connected with the ALR-67. Tactically, to determine the relative bearing of a threat the pilot must maneuver the aircraft to point the Sidearm seeker toward the threat.

The ability of a Sidearm to detect a threat is a function of the threat's operating frequency and strength. The Sidearm seeker is more sensitive when it is uncaged, therefore, if the seeker does not give a good tone when it is pointed at the threat, uncaging the missile will increase seeker sensitivity (PRIMARY mode only). If the HOT Sidearm mode is selected, all other weapons must be deselected before the missile can be uncaged. If the Sidearm does not self track the threat and provide a good tone, cage the seeker head to prevent seeker head damage during subsequent flight.

If a good tone is not received when the missile is pointed at the threat, uncage the seeker to command a target lock on. Target lock on is determined by the tone in the headset and observing that the Sidearm uncage symbol becomes stable as there is no special tone or symbol indicating lock on for the Sidearm. It is not necessary for the missile to be uncaged to fire as it can be launched when a tone is present in the headset whether the missile is caged or uncaged.

2.14 FLARES

2.14.1 LUU-2 Illumination. The LUU-2A/B and the LUU-2B/B aircraft Parachute Flares (APF's) are used for nighttime illumination of surface areas in search and attack operations. The differences between the two rounds are relatively minor. All planning and delivery assumptions along with the employment guidelines presented here may be considered valid for either round bearing in mind the following:

1. The LUU-2A/B APF is not authorized for shipboard operations.

2. The LUU-2A/B APF provides 300 seconds of 1,600,000 candle power illumination.

3. The LUU-2B/B APF provides 240 seconds of 2,000,000 candle power illumination.

4. The LUU-2B/B APF includes a 250 foot freefall setting for helicopter use.

2.14.1.1 Assumptions.

1. AV-8B flare aircraft are loaded with 16 LUU-2B/B APF's; 8 in each SUU-25F/A dispenser on stations 2 and 6.

2. The MAGTF commander has approved local use of illumination through the FSCC (DASC), FAC, or (for armed recce missions) on the ATO.

3. Three days notice is required for SUU-25F/A build-up: "Feet of Fall" fuze settings must be selected at this time.

4. Threat will allow flare and strike elements use of the medium altitude for at least one pass through the target area. More time is better for target detection and ordnance accuracy, and the night can offer inherent protection to strike assets.

5. If the threat drives strike aircraft to the low altitude environment (below 3000 feet AGL exclusively), consideration should be given to options for illumination provided by other agencies.

2.14.1.2 Illumination Placement. See Figure 2-104. When used by strike assets, battlefield illumination provides the lighting source that will fill one of two major functions: (1) target acquisition and/or (2) target area orientation. Under some lighting conditions (and with some sensors) placement of illumination in support of one function can have adverse effects on the other, so care must be taken to ensure placement with regard to intended purpose. For system deliveries with automatic target acquisition such as laser designated deliveries, illumination could be useful to the designation platform for target discrimination, but strike aircraft would only need the illumination for orientation. For visual deliveries, however, illumination is used to help

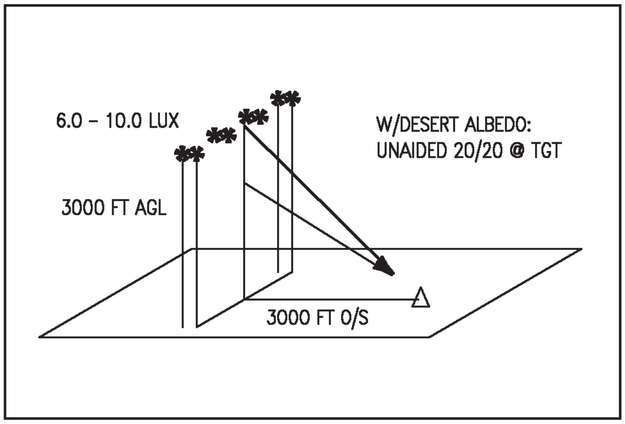


Figure 2-103. LUU-2 Multiple Illumination Pattern

find targets. Proper placement of the illumination is critical to its effectiveness as a target acquisition aid. In this case, when placing illumination the objective is to create a lighting condition that mimics optimum natural conditions for target acquisition. The following criteria describe conditions that will create maximum shadowing and contrast at the target for increased probability of detection and acquisition:

1. Defined SOURCE axis. Best acquisition bearing will be at 90° ±20° and perpendicular to the illumination bearing. This bearing provides maximum environmental contrast.

2. Defined SOURCE at between 30° and 45° elevation relative to projected target locations. Light sources that illuminate from directly over a target will ″wash-out″ the environment and create a bland scene. At grazing angles below 20°, long shadows begin to distort the environment. Plan for ignition at 3000 feet AGL. A 3000 foot lateral offset gives 45° of elevation. Given a 500 fpm rate of descent, the LUU-2B/B will then extinguish at 1000 feet AGL and 33° of elevation. These vertical parameters support either low or high angle attacks.

3. As much light as possible within sensor capability to resolve that light. Bright light too close to a target (within sensor field of view) will compete with target acquisition by dominating the sensor. Example: ″Lost sight″ on a 1v1 as the target flies through the sun.

2.14.1.3 Patterns of Multiple Illumination. Multiple or ″pattern″ releases can be of benefit by providing illumination for both target acquisition and for target area orientation. Additional pattern benefits include:

1. More total light available for target acquisition.

2. More stable and uniform light under windy conditions.

3. Visual Attack pattern orientation line for multiple element coordination, (Run-in headings of up to 40° to 60° variation are still possible if pre-planned, with negligible reduction in ideal acquisition bearing: #1 take 20 left, #2 has 20 right, and reciprocal run-ins are available.)

4. A pattern can reduce the incidence of ineffective illumination placements associated with long or short releases.

5. Depending on threat location and pattern orientation, a pattern provides significantly enhanced direct and indirect masking vs the IR threat.

6. Patterns cover adverse DUD effects.

2.14.1.4 Interval. If available release a string of four flares at 1500 foot interval parallel to the planned or anticipated attack run-in. Optimum lateral offset is somewhat dependent on planned visual acquisition sensor:

1. Unaided visual deliveries. Offset the string laterally by 3000 feet from the target. This will provide approximately 3.0 to 5.0 LUX at the target - equal to twilight conditions 22 minutes following sunset on a clear day.

2. NVG with ambient light conditions (above 0.0022 LUX). A lateral offset of 3000 feet should be used here as well, although NVG

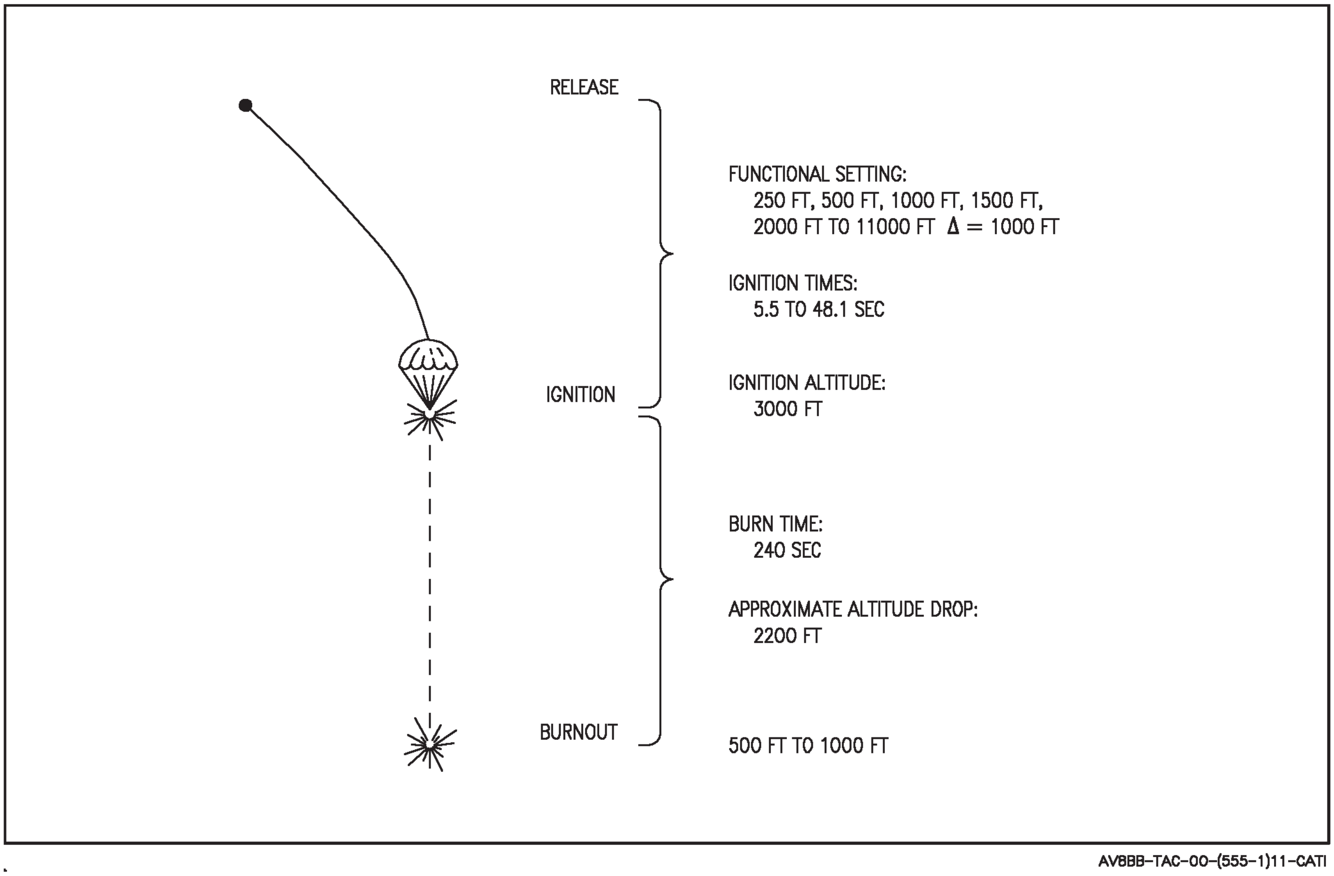


Figure 2-104. LUU-2B/B Flare Functioning Diagram

resolution will be driven to between 70 and 90 percent capable. The price paid in resolution is not necessarily bad: the light string will be removed from direct NVG amplification during target run-in, and an unaided visual cross check beneath the combiners for a specific aim point is possible. Alternatively, maximum resolution occurs at and below approximately 1.7nm lateral offset. Bear in mind that the further the illumination gets from the target, the lower becomes the grazing angle: at 1.7nm offset, ignition occurs at 17° elevation, and extinguish occurs at 11°. Even with 100 percent NVG capable resolution, 20/40 vision is the best we get; and since the NVGs will perform at this standard down to nearly starlight conditions, placement of the flares at 1.7 nm offset has done very little to aid target acquisition. This placement may, however, be useful for target area orientation and navigation. It is worth mentioning that placement of the APF at 3000 feet of offset (as recommended for target acquisition) will be an annoyance to NVG navigation scan any time the flares are in the 30° FOV.

3. NVG low light (less than 0.0022). APF brightness will be a distraction to NVG navigation if placed near the target under low light conditions. Even so, if target acquisition aid is the primary function of illumination, then APFs should be placed accordingly as in #2 above.

2.14.1.5 Flare Fuze Settings. See Figure 2-104. Options are: 0.5, 1, 1.5, 2, 3, 4, 5, 6, 7, 8, 9, 10, or 11 thousand feet of fall. Fuze function delays are selected by positioning the timer knob at the back of the flare to the appropriate setting. If the flares were accessible, this delay could be selected on preflight. For SUU-25F pod loaded flares, function delays will normally be selected and set during SUU-25 build up. Winds and APF TOF are critical placement considerations; placement accuracy does not readily lend itself to in-flight or preflight flexing: delay and delivery parameters with generic applicability are required so that valid wind projections and predictable releases can be planned. APFs should be set for 5000 feet of fall before parachute deployment and flare ignition. This setting provides stand-off, pattern flexibility, and weather capability. (If a low altitude Night System INS update can be performed, the flares may be delivered IMC reference the INS.) For a 3000 foot AGL opening, the APF delivery is level (only authorized FPA) at 8000 feet AGL. TOF for this fuze setting is 28 seconds. Given 28 seconds before the first flare ignition, there is time for the flare delivery aircraft to cycle back into the pattern for bomb drops.

2.14.1.6 Delivery

2.14.1.6.1 Parameters. APF delivery speed is 450 knots assuming the 5000 foot fuze setting. This is an achievable airspeed on the medium altitude, high drag, level delivery. 450 knots also provides adequate reactive capability given the excellent stand-off feature of a level 8000 foot release. Note also that the non-computed release and timing calculations are based on a 450 knots assumption. (TACMAN delivery parameters for a 3000 foot AGL ignition over a sea level target at 450 knots are release at 7624 feet with 3706 feet of DRT.)

2.14.1.6.2 Flare Ignition Timing. The 28 second TOF for 5000 foot of drop is significant, and must be considered in the target area plan. Normally, the aim is to provide illumination at least 30 seconds, but no more than 45 seconds prior to introducing strike aircraft into the target area. This allows time to build a picture prior to attack, while conserving illumination time for follow-on attack. The Command Speed/Time (CS/T) clock function does not include TOF calculations for ″Bombs on Target″ timing cues, so this has to be accounted for with an adjusted system entry for TOT. Enter a TOT that is 1 MINUTE ahead of universal TOT. Fly the timing cue to the target, and expect to reach the first release point of the multi-weapon release 6 to 8 seconds prior to entered TOT.

2.14.1.6.3 Techniques. Depending on aircraft software version, delivery of the LUU-2 APF can be BAUT or DSL. Selected run-in orientation and target area winds can affect the choice of both delivery mode and technique. Run-in geometry will be discussed first, and rules of thumb for wind will be covered in the next section.

2.14.1.6.4 Day and Night Attack Aircraft. Enter target elevation, and program QTY-4, MULT-1, INTV-1500 (150 in the ACP interval windows). If available and APF conservation is not required, QTY-8, and MULT-2 may be used instead. This increases total light while providing insurance against ″duds″ in the string. Enter TOT 1+00 ahead of universal TOT.

2.14.1.6.5 Radar Aircraft. Computed releases are not available, so the string must be built from multiple DSL releases. (If the APF's are loaded on two stations, the ″Multiple 2″ program option is still possible for two flares per release.) Enter the TOT 1+00 ahead of universal TOT. At 450 knots, the aircraft travels over the ground at 759 ft/sec, so actuate the pickle four times: once every 2 seconds for 1500 foot spacing. Count slowly from ″1″ to ″7″, with a pickle at each odd number.

2.14.1.7 Offset Steering. There are three primary methods for placing flares at the desired 3000 foot offset point, and at least 4 miles of run-in is recommended to set them up.

1. The first method is a simple offset; at 3 miles from the target, check-turn to place the ground track BUG 10° left or right as appropriate. Hold this heading until and through the release. The ASL will probably be driven out of the HUD FOV on run-in, so select DSL mode, and eject flares according to the release timeline above.

2. The second method also references the target for offset during run-in to DSL release: dial a course line through the target and overlay it with one-half of the DDI aircraft wing (10 nm scale) throughout the run-in. (This takes the delivery aircraft to 0.5 nm on the HUD WYPT DME.)

3. The third method provides a direct steering reference with HUD steering cues to the laterally offset pattern center point (more accurate), but this method requires more system manipulation:

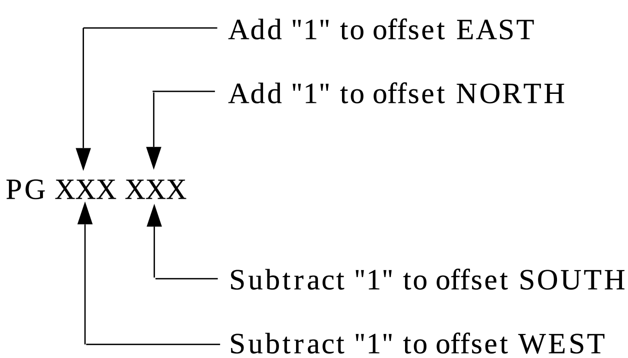
(a) Enter target data as an offset from assigned IP.

(b) Enter illumination point data as an offset on an adjacent WYPT/IP; adjust TGT grid coordinates by 1000m (3280 ft) for specific and accurate illumination coordinates.

(c) For N-S run-ins, add or subtract ″1″ to the middle digit of first grid group to offset release East or West by 3000 feet. For example: TGT coordinate - 345 678. For N-S run-in, we want illumination offset to the East by 3000 feet, enter 355 678.

For E-W run-ins, add or subtract ″1″ to the middle digit of second grid group to offset release North or South by 3000 feet. For example: TGT coordinate 345 678. For E-W run-in, we want illumination offset to the North 3000 feet: enter coordinate 345 688.

4. A ″gouge″ matrix can help with this data manipulation:



5. An adjacent IP is used to load specific illumination coordinates so that the assigned target is available for transition to attack following APF release. Ensure that the ″Pickle″ is held throughout the entire release which will last for approximately 7 seconds. Steering to the target may then be selected on the DDI/MPCD by scrolling up/down to the target WO/S.

2.14.1.8 Release Timing. Proper offset from the target to the illumination point may be generated by any method described above, but use of adjusted illumination coordinates is recommended. Initiate the release string beginning at 1.0 nm from the illumination coordinate for even pattern spacing abeam the target. For either target offset steering method, initiate release at 1.1 nm DME from the target:

APF RUN-IN: 090°

Pickle Point	APF 1	APF 2	APF 3	APF 4
	3,706 ft	1500 ft	1500 ft	1500 ft
↑		▲	↑	
5,956 ft.			3,000 ft lateral O/S TGT	

Note: Distance from illumination coordinate (1.0 to 1.1 nm)

2.14.1.9 Release Winds. Now that methods for very accurate flare placement have been developed, techniques for dealing with release and ignition winds are required. Wind effects are quite significant. Release winds will be covered first. Lateral drift for various winds from release to ignition point are listed in Figure 2-105; the 5000 foot fuze setting is assumed.

WIND	DRIFT	ROT	O/S CORRECTION
10kts	476 ft	500 ft	0.1 DME
20kts	952 ft	1000 ft	0.2 DME
30kts	1428 ft	1500 ft	0.3 DME
40kts	1904 ft	2000 ft	0.3 DME
50kts	2380 ft	2500 ft	0.4 DME

Figure 2-105. Release Winds

WIND	DRIFT (4 min)	X-WIND CORRECTION	RANGE CORRECTION
10 kts	4,080 (0.7 nm)	NONE	0.3 nm
20 kts	8,160 (1.4 nm)	NONE	0.6 nm
30 kts	12,240 (2.0 nm)	+3000 (enter 2000m)	0.9 nm
40 kts	16,320 (2.7 nm)	+3000 (enter 2000m)	1.2 nm

Figure 2-106. Winds at 3000 Foot AGL

The computed release accounts for these winds to place the flares properly at release - no correction is necessary when using specific illumination coordinates. Non-computed releases require pilot induced corrections. If at all possible, lay the flare string into the wind as a RANGE correction. It is easily made by anticipating or delaying the release point by 0.1 DME for each 10 knots of range wind. Cross winds are less exact. If the run-in geometry drives a cross wind situation, increase the 3.0 nm check turn by 1° for each 10 knots, or overlay more of the DDI aircraft wing on the courseline (up to ″wing tip-on″ at 60 knots) for the target referenced offset methods.

2.14.1.10 Winds at 3000 Foot AGL The winds at parachute deployment have a tremendous effect on the APF during the 4 minutes of burn. The parachute achieves same speed and direction of winds at altitude almost immediately for a drift rate of 1.7 ft/sec for every knot of wind. See Figure 2-106. Given the rapid drift associated with even relatively light wind, ideal or optimum lighting conditions cannot be expected throughout the burn of the flares. With only 10 knots of cross wind, the flares will drift over and past the target before they burn out. With 20 knots of cross wind, they will drift all the way to optimum on the other side. Therefore, once again if at all possible, deflect the flare release point into the wind, as RANGE wind. Range wind causes the string to drift past the target at a constant distance abeam for maximum useful illumination and attack time potential. If forced to work with cross winds, make no correction for winds up to 20 knots. As long as the flares are drifting toward the target, and as long as target acquisition functions are performed in the early stages of burn when delivery technique has provided optimum placement, then even direct overhead lighting will allow flares to drift past the target. For over 20 knots of cross wind, offset the illumination coordinate by 2000m vice 1000m on the opposite side.

2.14.1.11 Delivery Pattern. Flow flare aircraft into, through, and out of the target area in the same manner as for strike aircraft. In order to enjoy the maximum benefit of IR blanking offered by the APF string, orient aircraft orbit patterns on the same side of the target as the flare pattern. When NVDs are being used in a high angle pattern, orient the orbit to the opposite side; away from the flares. Although not critical, this can make NVD navigation more comfortable.

The flare delivery aircraft should start a stopwatch following release of the final flare in his string. He should then give a ″1 Minute″ remaining warning so that appropriate target area plans may be made.

2.15 MAVERICK DELIVERY MODE

The Maverick delivery mode is basically a non-computed delivery mode, but the MC does provide steering to the target if it is designated. The AV-8B is capable of carrying both the AGM-65E laser guided missile and the AGM-65F imaging infrared guided missile; however, Day Attack aircraft are limited to carriage of the AGM-65E.

The AGM-65 missile utilizes the LAU-117A(V)/A launcher. Both the missile and launcher can be carried on aircraft weapon stations 2, 3, 5 and 6. The missile and launcher are capable of carriage, launch (missile only), and jettison (launcher plus missile) from the aircraft. The normal launch sequence is station 2, 6, 3, and 5 unless a weapon is degraded. Dome cover jettison (if installed), missile control, and missile launch are accomplished via HOTAS control.

2.15.1 AGM-65E Laser Maverick Missile

2.15.1.1 Description. The AGM-65E missile is a laser guided, rocket propelled, air-to-ground missile. Guidance is provided through automatic terminal homing on coded laser energy reflecting from the target. The missile requires continuous laser designation of the target from missile seeker acquisition until weapon impact. The laser designator may be a ground device, either hand held or tripod mounted, or it may be a stabilized airborne device. Propulsion is provided by a solid propellant, dual thrust (boost sustain) rocket motor. The AGM-65E employs a 300 pound blast-fragmentation warhead with a selectable delay fuze, and is designed primarily for use against hardened targets requiring delayed fuzing such as ships, bunkers, fortified structures, and armored vehicles. The missile may be employed against stationary and mobile land and sea targets, day and night, with sufficient standoff range to permit limited exposure to target area terminal defenses. Refer to NWP 3-22.5-AV8B, Vol. II, Chapter 2 for more detail information.

2.15.1.2 Weapon Selection. The Laser Maverick weapon is selected by pressing the MAV (Day Attack aircraft) or LMAV (Night Attack and Radar aircraft) option on the DDI stores display. The legend is boxed when the missile is selected. When selected, the SMCS unlocks all missile restraint devices and commands gyro spinup of all missiles. The SMCS then selects the first available (not failed or hung) weapon in the station priority sequence. The SMCS provides laser code data to all Laser Mavericks aboard. The selected weapon is initially caged (align mode). The weapon station selected is displayed in the lower left corner of the DDI/MPCD. The STEP option is provided to permit selection of station(s) other than the priority station if desired. STBY is displayed below the station selected legend until the missile selected reports it has completed gyro spinup cycle time (30 seconds) when it is replaced by RDY legend. Figure 2-107, sheet 1 is representative of the Laser Maverick display at initial selection.

2.15.1.3 Laser Energy. The Laser Maverick acquires, locks-on, and guides to a target using laser energy reflected from a target being illuminated by a laser designator. Laser designators/rangefinders emit discrete pulses of infrared energy which are invisible to the naked eye. The characteristics of these pulses are determined by the pulse repetition frequency (PRF) code of the laser energy beam which can be set by a series of PRF switches on the equipment. To be employed together, designators and seekers must use the same PRF code. Since seekers have limited FOV to see the laser energy reflected from a target, their LOS must be toward the target and also must be within the field of energy.

2.15.1.4 Laser Designator Types. The AGM-65E missile is compatible with standard military ground and airborne designators. The military laser is the Neodymium Yttrium Aluminum Garnet (Nd; YAG) laser which radiates in the invisible near infrared region at 1.064 microns. The most common U.S. designators that USMC AV-8B pilots may encounter are the MULE, G/VLLD, AH-1W, F/A-18 LDT/R, and the AH-64. The most desired designators offer the smallest beam divergence and the largest power out. A small beam divergence will allow for a smaller laser ″spot size″ at a given range. A rule of thumb to use regarding spot size is that your spot size should never exceed 1/2 your target size. This will greatly reduce any spillover problems.

2.15.1.5 Laser Acquisition Range Predictions. Determination of expected laser acquisition ranges can be essential to achieving maximum launch ranges and minimizing exposure times. Those conditions which affect target area visibility (weather and atmospheric conditions) will also affect laser acquisition ranges. The maximum acquisition range will be a function of launch aircraft altitude, target area absolute humidity and visibility, designator output power, target reflectivity, and total range from designator to target and from target to launch aircraft.

NOTE

It is absolute humidity rather than relative humidity that contributes to the atmospheric attenuation of laser energy. A 85 percent relative humidity January night in central Europe will allow longer range lock-ons than a 55 percent relative humidity July day in the Indian Ocean.

The pilot can learn the seeker performance characteristics when flying training sorties with the TGM by noting the absolute humidity in the target area on different days and comparing this information to achieved correlation and lock-on ranges. Night operations will be affected by the same factors as daylight operations except that the pilot will not be able to assess target area visibility as easily. A knowledge of the procedures and techniques for working with laser designators in the offensive air support environment is also important to achieving maximum acquisition and launch ranges.

2.15.1.6 Laser Code Entry. The display is initialized with the CODE option selected (boxed) and the UFCS is enabled for code entry. If a code was not previously entered the default code (four ones) is displayed. The laser code is displayed across the top of the Laser Maverick display and appears approximately five seconds after it is entered. A different code (other than the stored code or default code) may be entered at this time.

Although a code has been entered in the display shown on Figure 2-107, sheet 1 the CODE legend still initializes selected (boxed), and the UFCS is automatically enabled to permit immediate code change. If the WPN button was not pressed, the C-mode (counter-countermeasures) option is displayed in option window 1. Pressing the adjacent option pushbutton selects the CCM mode, indicated by the colon displayed next to the C in option window 1. Pressing the pushbutton again deselects the CCM option and the colon is removed. If the code is not changed the 30-second time out feature will disable the UFCS for code entry.

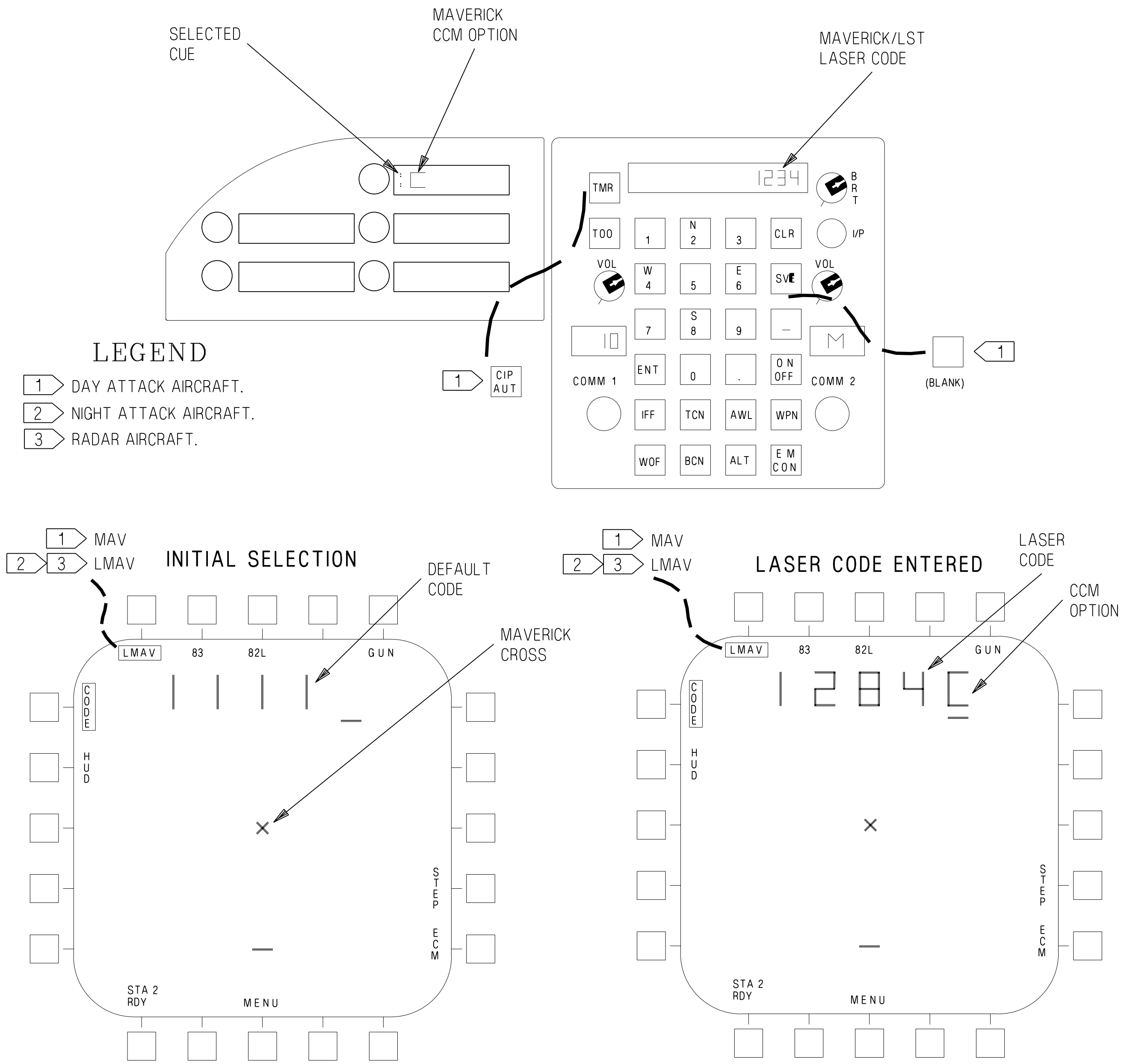
On Day Attack and Night Attack aircraft the Laser code is the same as the ARBS/LST laser code; therefore, the UFCS can be enabled for laser code entry by selecting the CODE option on the DMT display. See ARBS preflight management, Chapter 1.

After landing the laser code is set to the default code (1111). This occurs five seconds after a weight-on-wheels transition is detected.

NOTE

Weight must be on wheels for five continuous seconds.

Laser Maverick selection is indicated on the HUD by the AGM or LMAV legend and the stationary Laser Maverick cross. See Figure 2-107, sheet 2. Actuating the cage/uncage button on the throttle uncages the missile seeker enabling it to search (following the MC scan pattern) for a properly coded laser illuminated target. Actuating the cage/uncaged button a second time causes the seeker to return to boresight (electrically caged 2° below waterline). Successive actuation of the cage/uncaged button repeats the preceding sequence. When uncage is commanded the Laser Maverick cross and the 15° launch constraint circle are displayed on the DDI/MPCD as shown in Figure 2-107, sheet 2. If



- MAV/LMAV LEGEND BOXED INDICATING MAVERICK SELECTION.
- CAGED MODE IS INDICATED BY FIXED GIMBAL POSITION (MAVERICK CROSS) AT DISPLAY CENTER.
- ON INITIALIZATON THE CODE OPTION IS BOXED.
- LAST SELECTED SCAN MODE (NAR, WIDE, OR HUD) DISPLAYED.
- LAST ENTERED LASER CODE IS DISPLAYED. AN INVALID DEFAULT CODE OF FOUR ONES IS DISPLAYED IF NO CODE HAS BEEN ENTERED.

- MAVERICK IS CAGED, INDICATED BY FIXED GIMBAL POSITION (MAVERICK CROSS) AT DISPLAY CENTER.
- CURRENT LASER CODE IS DISPLAYED.
- CODE LEGEND IS BOXED ENABLING A CODE CHANGE ON UFCS.
- CCM OPTION SELECTED.

AV8BB-TAC-00_323-1-12

Figure 2-107. Laser Maverick Displays (Sheet 1 of 2)

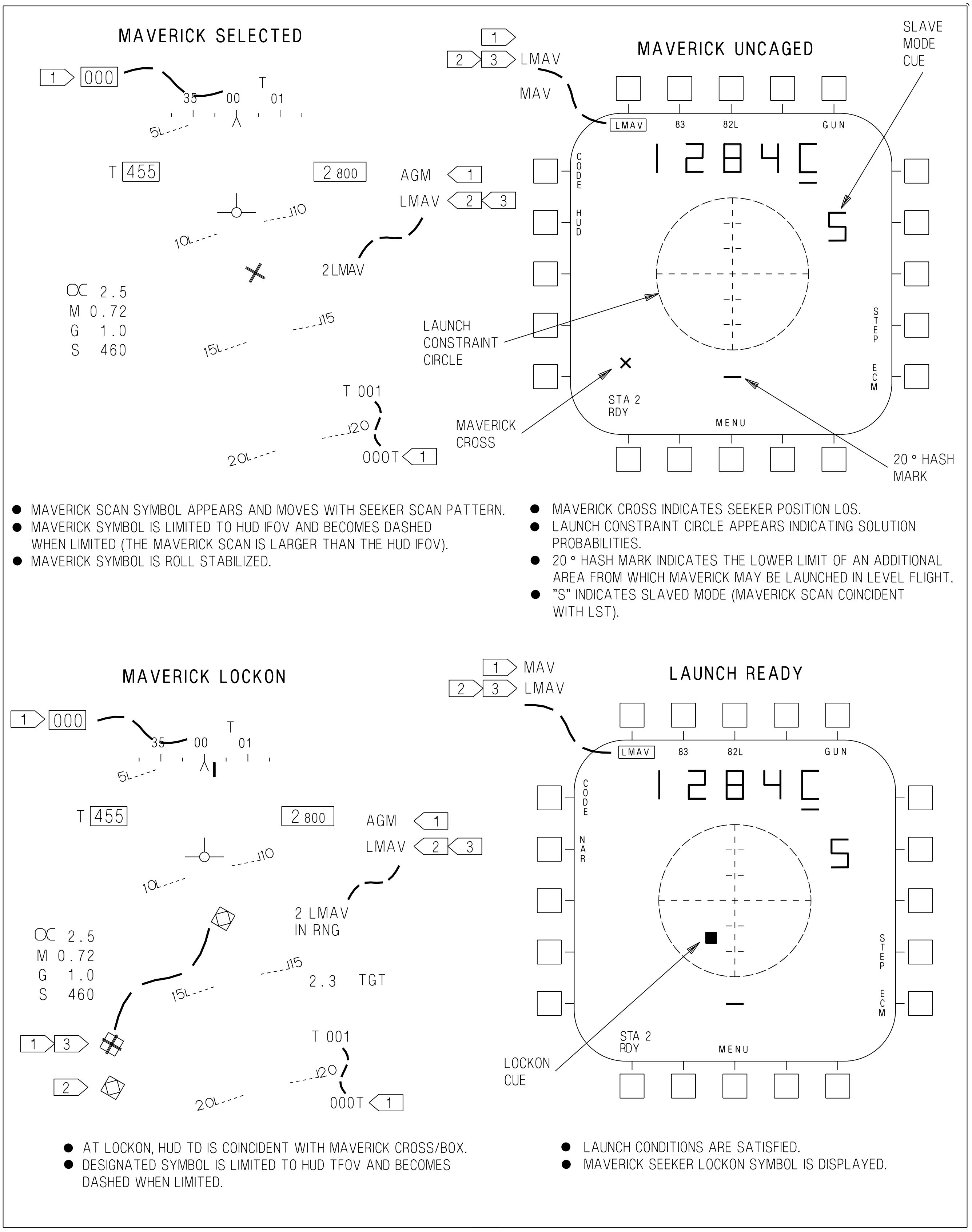


Figure 2-107. Laser Maverick Displays (Sheet 2 of 2)

a target is designated via another sensor (radar, LST, etc.) the slave mode cue (S) is displayed to the right of the launch constraint circle.

2.15.1.7 Scan Patterns. The Laser Maverick missile has three scan patterns: narrow, wide, and HUD. The scan pattern initially used when the missile seeker is uncaged is automatically selected by the MC. If a target is not designated when the seeker is uncaged, the missile begins searching using the HUD scan pattern. When a target is designated with the TDC and the missile seeker is not locked on to a target, the missile searches using the last selected scan pattern (narrow, wide, or HUD) or upon first initialization, the HUD scan pattern. The scan option scrolls between WIDE, NAR, and HUD when the pushbutton is pressed. The scan pattern elevation can be adjusted using the TDC in no action slew to speed lock on. If the slaved mode cue (S) is displayed, the Laser Maverick searches using a circular scan pattern about the designated target until it also locks on. The circular scan pattern is not pilot selectable.

2.15.1.8 Target Designation. If a target is designated by any means other than LST and the missile seeker locks on more than 20 milliradians from that TD location, the designation will not automatically transfer. The range displayed on the HUD in this instance is the range to the designated point. If the designated point is then slewed to within 20 mR of the Laser Maverick lock, the designation will transfer and the range will be to the Laser Maverick lock on point.

2.15.1.9 Missile Lock On. See Figure 2-107, sheet 2. At lock on, the Laser Maverick cross on the HUD overlays the target and the TD diamond appears. Target range is also displayed.

On the DDI the Laser Maverick cross is replaced by a solid square at lock on. Its position with respect to the launch constraint circle indicates probable success when fired. The pilot maneuvers the aircraft to satisfy launch constraint and in-range criteria. When the missile is within range of the target, the IN RNG cue is displayed just below the AGM or LMAV legend on the HUD. The Laser Maverick cross or box on the HUD flashes when the Laser Maverick seeker is looking outside the launch constraint circle limits to provide the pilot with a head-up indication. This flashing occurs whether or not lock on has been accomplished.

2.15.1.10 Weapon Release. When the bomb pickle button is pressed, the SMCS applies electrical fuzing control and a launch command to the weapon. The next highest priority missile is automatically selected when one Laser Maverick has been launched and a quantity of two or more has been selected. The normal Laser Maverick launch sequence is station 2, 6, 3, and 5. A Laser Maverick missile is automatically electrically caged when it is deselected.

When launched the missile accelerates away from the launch aircraft during the 4-second boost-sustain rocket motor burn. The missile gains about half a Mach number over its launch Mach, but it decelerates rapidly to subsonic speed shortly after the rocket motor burn ends. G-bias trades airspeed for altitude further slowing the speed of the missile, while the launch aircraft continues forward at a constant speed (sustained by constant thrust). At the higher launch Mach numbers and longer launch ranges, the launch aircraft may overfly the target before missile impact unless the aircraft turns away from the target.

2.15.1.11 Sensor Integration. On Day and Night Attack aircraft the ARBS/LST sensor mode can be integrated with the AGM-65E Laser Maverick to acquire a target at increased range and azimuth. The MC slaves the missile seeker to the LST LOS while searching for a target. If the LST has not acquired the target, the Laser Maverick scan pattern is similar to LST scan (NAR, WIDE, or HUD). Once the LST or Laser Maverick has locked on the target, however, the other seeker scans in a circular pattern to acquire the target. In this case, the Laser Maverick cross and LST cross coincide on the HUD most of the time as shown in Figure 2-108. The gimbal limits of the LST and Laser Maverick differ in both azimuth and elevation; therefore, the Laser Maverick will scan coincident with the LST only within the missile seeker gimbal limits. The TD diamond appears when the LST has locked on the target. At lock on, the

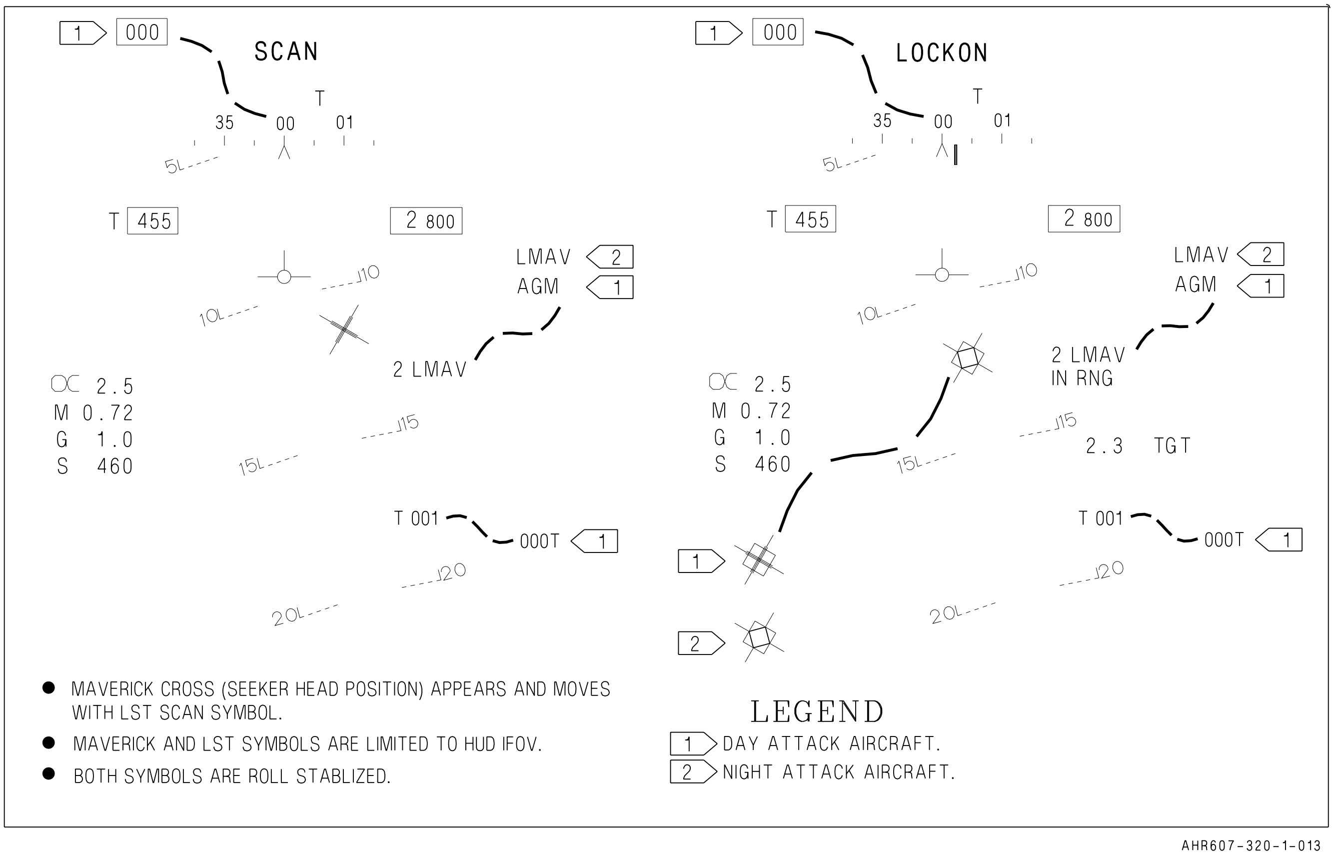


Figure 2-108. LST/Laser Maverick Scan and Lock On HUD Symbology

Laser Maverick cross (Day Attack aircraft) or Box (Night Attack aircraft), the LST cross, and the TD diamond are coincident as shown in Figure 2-108. When the Laser Maverick is within range of the target, the IN RNG cue is displayed just below the AGM or LMAV legend as applicable.

When MAV/IRMV is selected, LST correlated and Laser Maverick video displayed, pressing the target designate button replaces the Laser Maverick video with the DMT display. When MAV/IRMV is selected, LST correlated and DMT video displayed, pressing the target designate button replaces the DMT video with Laser Maverick video.

2.15.1.12 Mission Planning. Many factors must be considered in order to effectively employ the Laser Maverick missile. Of primary consideration are factors, described in the following paragraphs, which effect target acquisition ranges.

Laser Maverick missile post launch performance characteristics must be considered to maximize the effectiveness of the missile. Many of these characteristics such as warhead fuze delay selection, aerodynamic launch range envelopes/missile free flight parameters and splash patterns are essentially the same as for the IR Maverick missile.

2.15.1.13 Target Acquisition Factors. The Laser Maverick missile's designated target acquisition range is dependent upon variables such as atmospheric particulate content, object reflectivity, designator equipment output power, designator/pilot coordination and attack geometries.

2.15.1.13.1 Absolute Humidity. Absolute humidity rather than relative humidity is the contributing factor to atmospheric attenuation of laser energy. The pilot can become more familiar with seeker performance characteristics as a function of absolute humidity, when flying

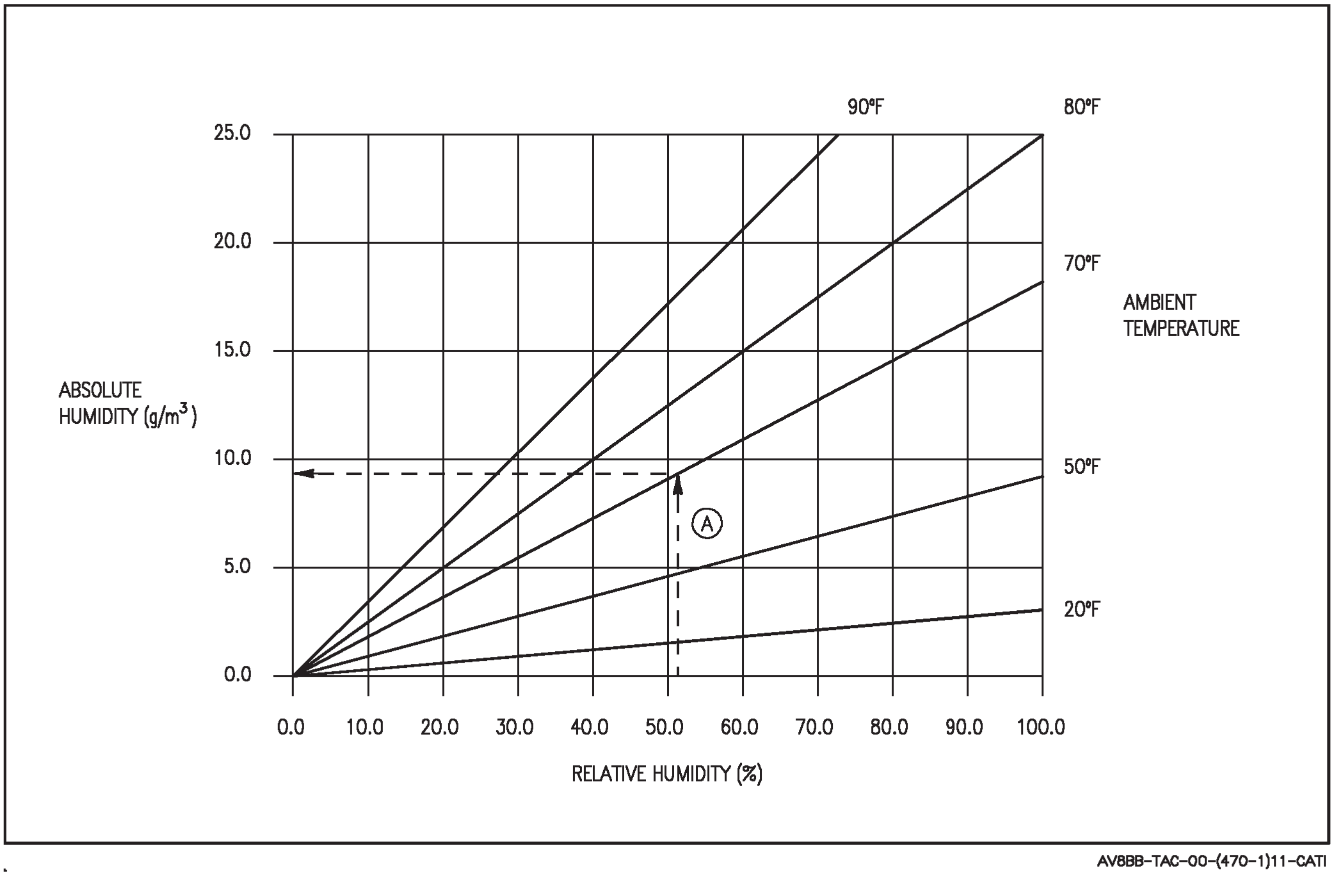


Figure 2-109. Absolute Humidity Versus Relative Humidity and Temperature (°F)

training sorties with the TGM by computing the absolute humidity in the target area on different days and comparing this information to achieved acquisition ranges. Figure 2-109 allows you to determine the absolute humidity, given a relative humidity and temperature. Absolute humidity is usually measured as grams of water contained in a cubic meter of air.

Example A in Figure 2-109 shows that about 9.7 grams of water per cubic meter of air can be measured given a 70°F temperature and a measure of 53 percent relative humidity.

2.15.1.13.2 Absolute Humidity Versus Visibility. Figure 2-110 provides the solution for maximum expected visibility dependent upon the given absolute humidity. Visibility is more important than absolute humidity when calculating acquisition ranges. Actual visibility will probably be lower than the graph represents due to the inherent particulates suspended in the air. With this in mind, the visibility plots on the designation versus acquisition graphs should receive greater attention than absolute humidity.

Example A in Figure 2-110 represents that a maximum visibility of approximately 23 nm can be expected to give an absolute humidity of 10 grams per cubic meter.

2.15.1.13.3 Target Reflectivity. Target reflectivity is another important factor for estimating target acquisition ranges. Because of the variance in reflectivity exhibited by a number of materials, predicting reflectivity for the purpose of determining acquisition ranges is difficult. Figure 1-123, Chapter 1, provides reflectivity range sampling for a number of materials.

a. Land vs Water Target Designation. Going back to the discussion earlier about diffuse reflection versus spectral reflection, water surfaces make excellent reflectors. If the target is a small boat, the laser energy that strikes the water around the boat is reflected away in a

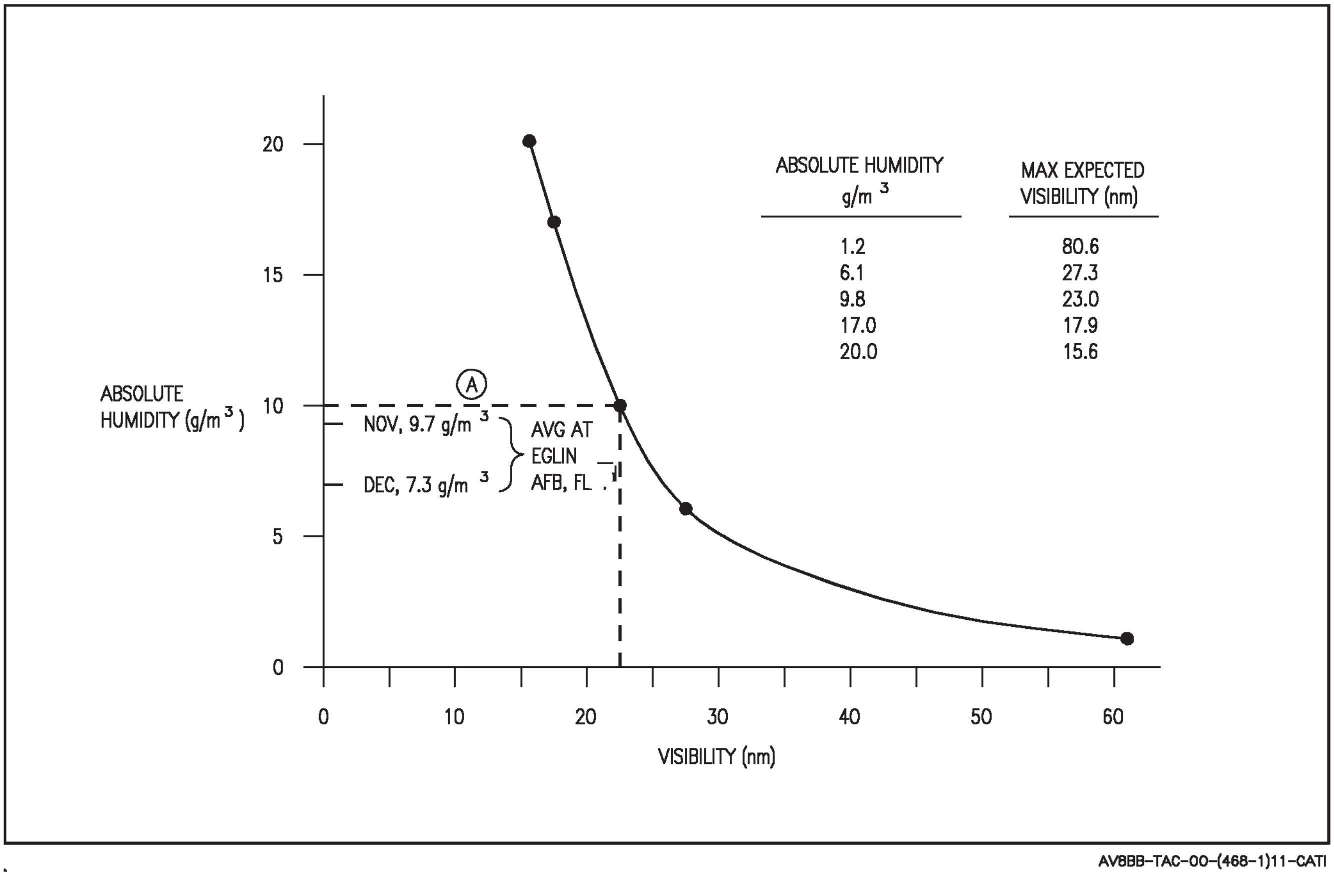


Figure 2-110. Absolute Humidity Versus Visibility

concentrated beam rather than being diffusely reflected (scattered in all directions) by the surface texture and features of the boat. Aiming error, that portion of the time that the laser beam is not striking the boat, will cause the majority of the laser energy to be reflected away and may cause the seeker to lose correlation. As long as the aiming error is random, and the laser beam is on the boat most of the time, it should not effect missile guidance. Against large ships, aiming error should not be a problem as the large surfaces area of the target will insure the laser energy will always be directed at some portion of the ship. Water can be a factor in the designation of land targets as well.

Bridges can produce the same effect as small boats. Energy that missed the bridge can be reflected by the water's surface either away from the target, or towards some other part of the bridge or the objects nearby. One technique is to lase the far end of the bridge along the axis of the roadway. Long or short aiming errors will still designate a portion of the bridge. If the desired impact point is one of the supports, low altitude designation should cause any spillover or aiming error laser energy to be reflected away from the bridge where it will not be seen by the missile.

Water is also present following recent rain showers, or when it is raining on the target, For a wet target, the decrease in laser energy is due to the absorption of energy by water resulting in an effective decrease in target reflectivity.

2.15.1.14 Predicted Acquisition Ranges (Laser)/PAR(L). One of the most important items in the Laser Maverick mission planning sequence is to obtain the predicted acquisition range of the Laser Maverick for that particular day and designator. The easiest way is to fill out a Laser Ops Worksheet and turn it in to your station weatherman. You will receive a detailed prediction sheet for your mission and predictions for the rest of the day as well. (This report is classified Confidential.) Refer to NWP 3-22.5-AV8B Vol. III (S), see applicable discussion regarding laser PAR. If the worksheet method is not available, you can use the charts to get a ″rough″ prediction of Laser Maverick lock-on ranges for certain fixed parameters. The charts will compute expected Maverick acquisition ranges versus designation range at various prevailing visibility. Refer to Figures 2-115 thru 2-117.

2.15.1.14.1 Designation/Pilot Coordination. In order to accomplish a successful target strike, the actions of the pilot delivering the weapon and the designator illuminating the target must be carefully executed. Designator location should be established in an area which will be conducive to laser actuation and transmission.

The proper PRF code with which the designator will be transmitting must be known before the mission actually occurs. The weapon must be programmed to look for and sense the correct PRF.

The designator operator must know whether the weapon deployed will be a laser guided missile or bomb. The operator must also be aware of battery life versus the time needed for acquisition and weapon time of flight.

2.15.1.14.2 Attack Geometry. The position of the aircraft relative to the designator is important in target acquisition and possible lock on range. The requirement is for the attack aircraft inbound to be situated behind the designator with an angle of approach within +45° from the designator to target line. For designator safety, direct overflight within +10° is prohibited. Therefore, the usable angles are from 10° to 45°. It is recommended that the aircraft run-in headings be planned to be in the middle of this cone. Therefore, inbound to the target, the delivery aircraft run-in heading should approach the target from behind the designator, at an angle of approximately 25° from the designator LOS to the target. See Figure 2-111. Also, Figure 2-112 shows the designator/aircraft geometry versus laser energy loss.

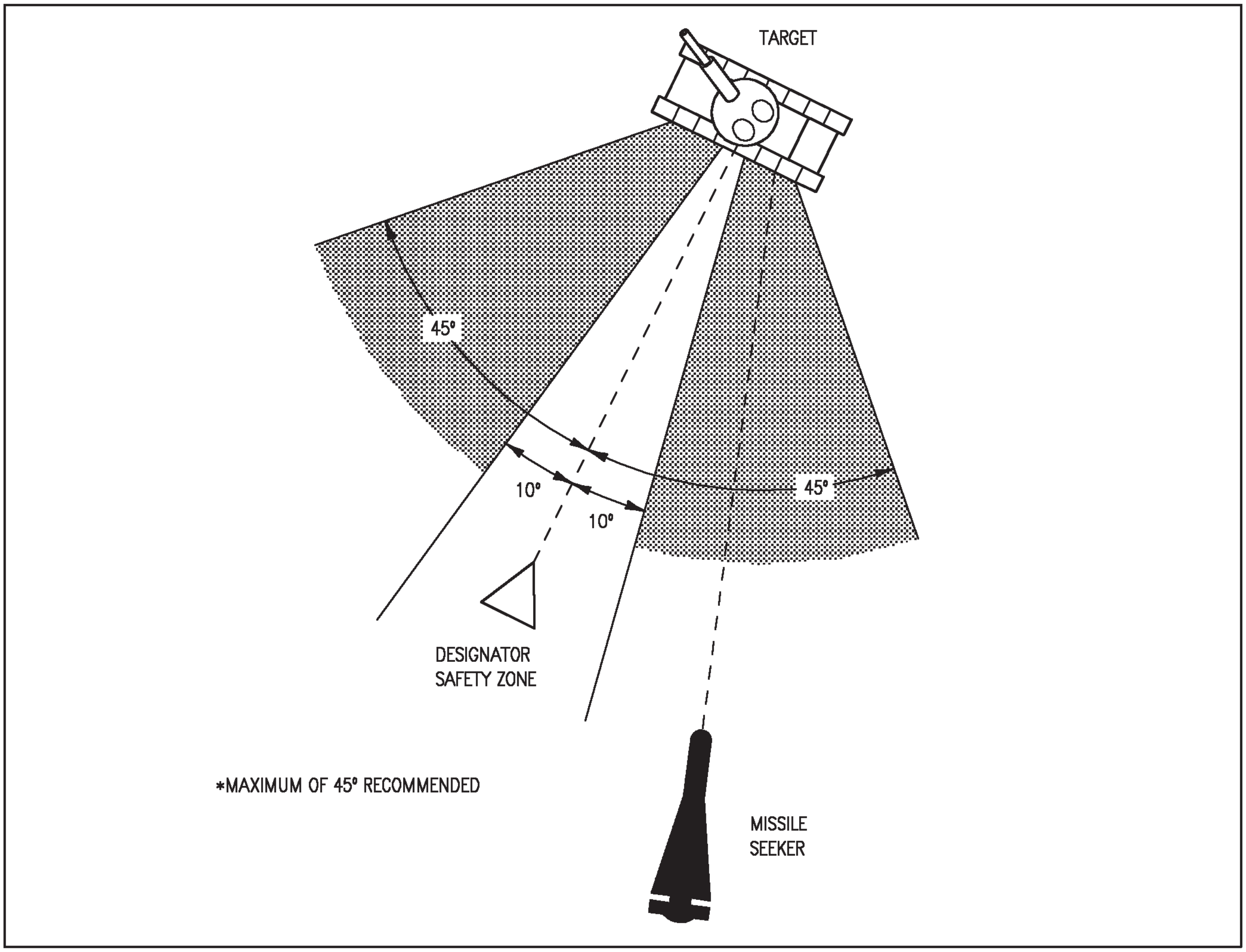


Figure 2-111. Designator to Aircraft/Missile Angles.

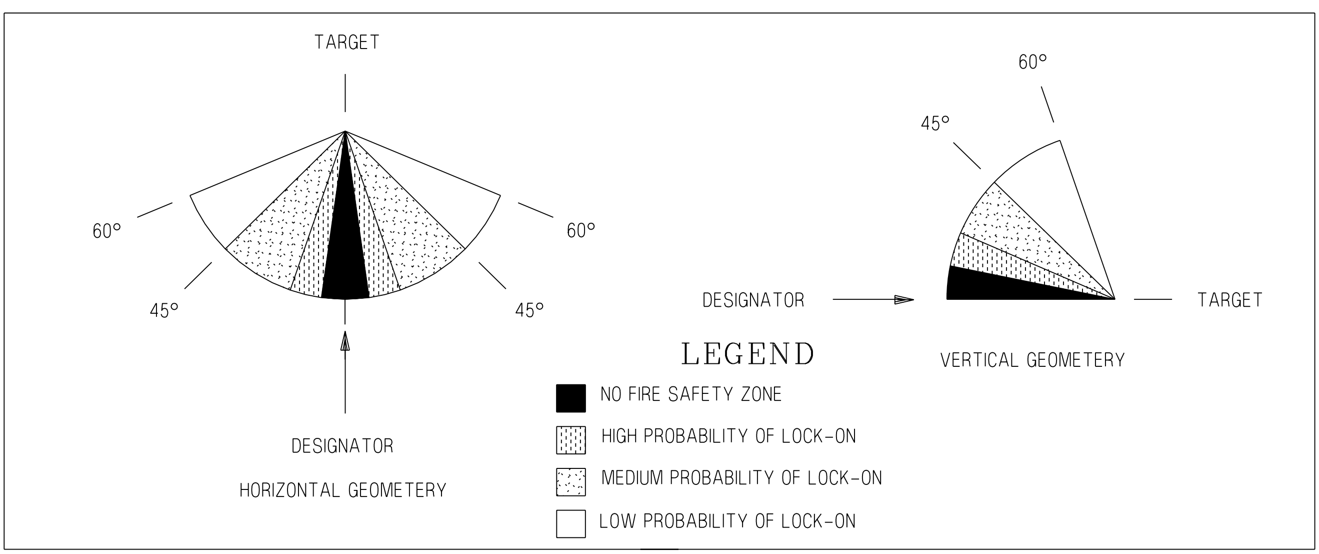


Figure 2-112. Approach Angle Versus Laser Energy Loss

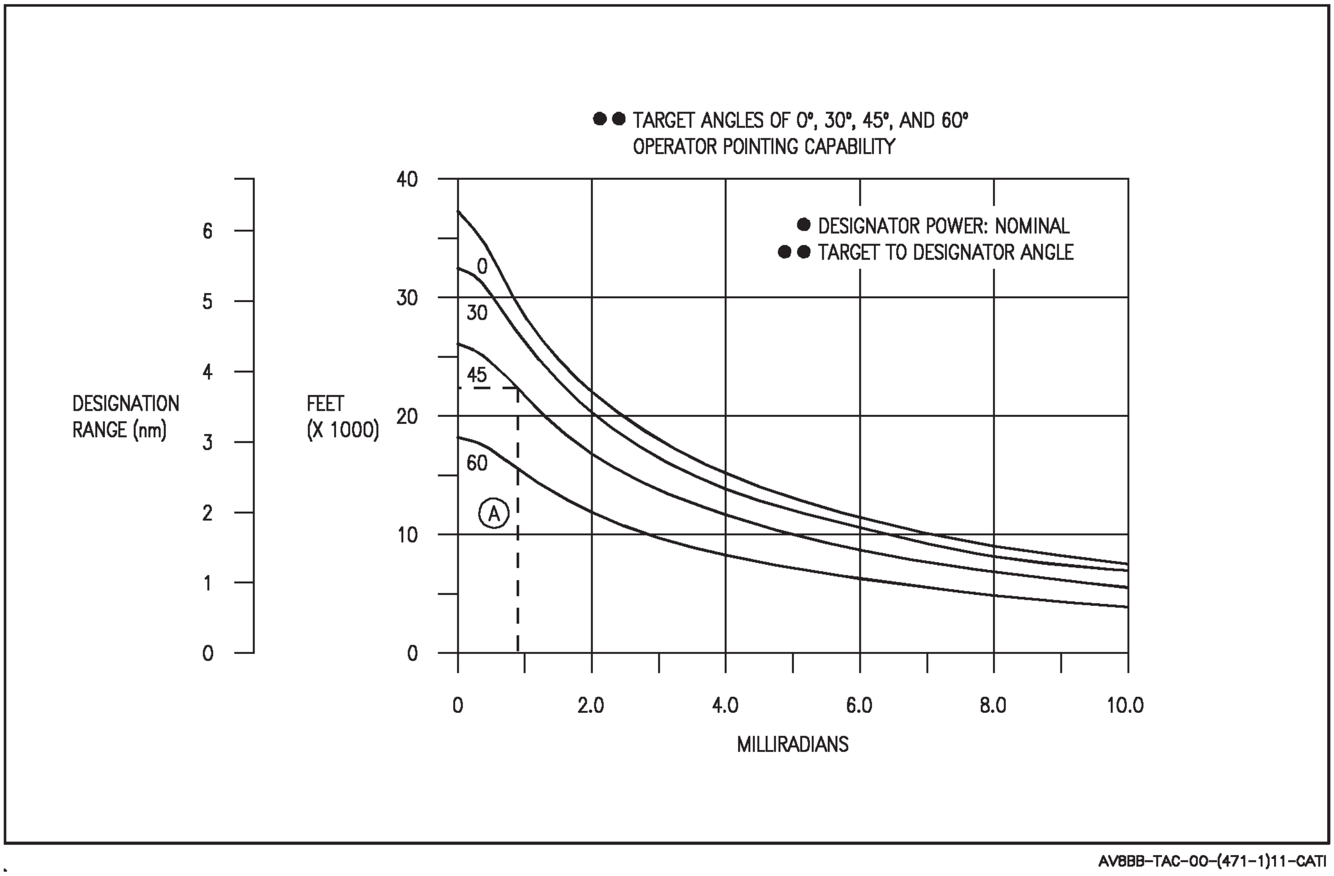


Figure 2-113. MULE Operator Pointing Capability (15 ft. × 15 ft. Target)

2.15.1.14.3 MULE Operator Pointing Capability (15 ft. × 15 ft. Target). Figure 2-113 indicates the maximum expected designation range for a tripod mounted MULE. The variables are designator to target angle and operator pointing capability. Note that with an increasing angle, the designator to target range must decrease in order to prevent spot spillover. The assumption of operator pointing capability is purely subjective: however, it is expected that an experienced MULE operator should be able to hold a tripod mounted MULE's laser spot to within 1.0 milliradian of a stationary target center and to within 2.0 radians of a moving target. Example 'A' of Figure 2-113 depicts that with a target to designator angle of 45°, a MULE operator could, in theory, designate a tank size target without laser spot spillover at a range of 22,000 feet.

2.15.1.14.4 Typical Airborne Designator Pointing Capability (50 ft. × 50 ft. Target). The plot in Figure 2-114 works the same as the MULE operator pointing capability plot. an experienced pilot can be expected to track a stationary target within 1.0 to 2.0 milliradians and a moving target within 2.0 to 3.0 milliradians.

2.15.1.14.5 Mule Designation Versus AGM-65E Missile Acquisition Range. See Figure 2-115.

2.15.1.14.6 Typical Airborne Designation Versus AGM-65E Missile Acquisition Range. Figures 2-116 and 2-117 provide the same information as shown in Figure 2-115 except that the designation is being performed by an airborne designator.

2.15.1.15 Enroute. The following paragraphs describe factors which should be taken into consideration while enroute to the target area. Situational factors that are dynamic are usually the rule rather than the exception, so be aware that cloud cover, target location (if mobile) are all subject to change while airborne. If the pilot is

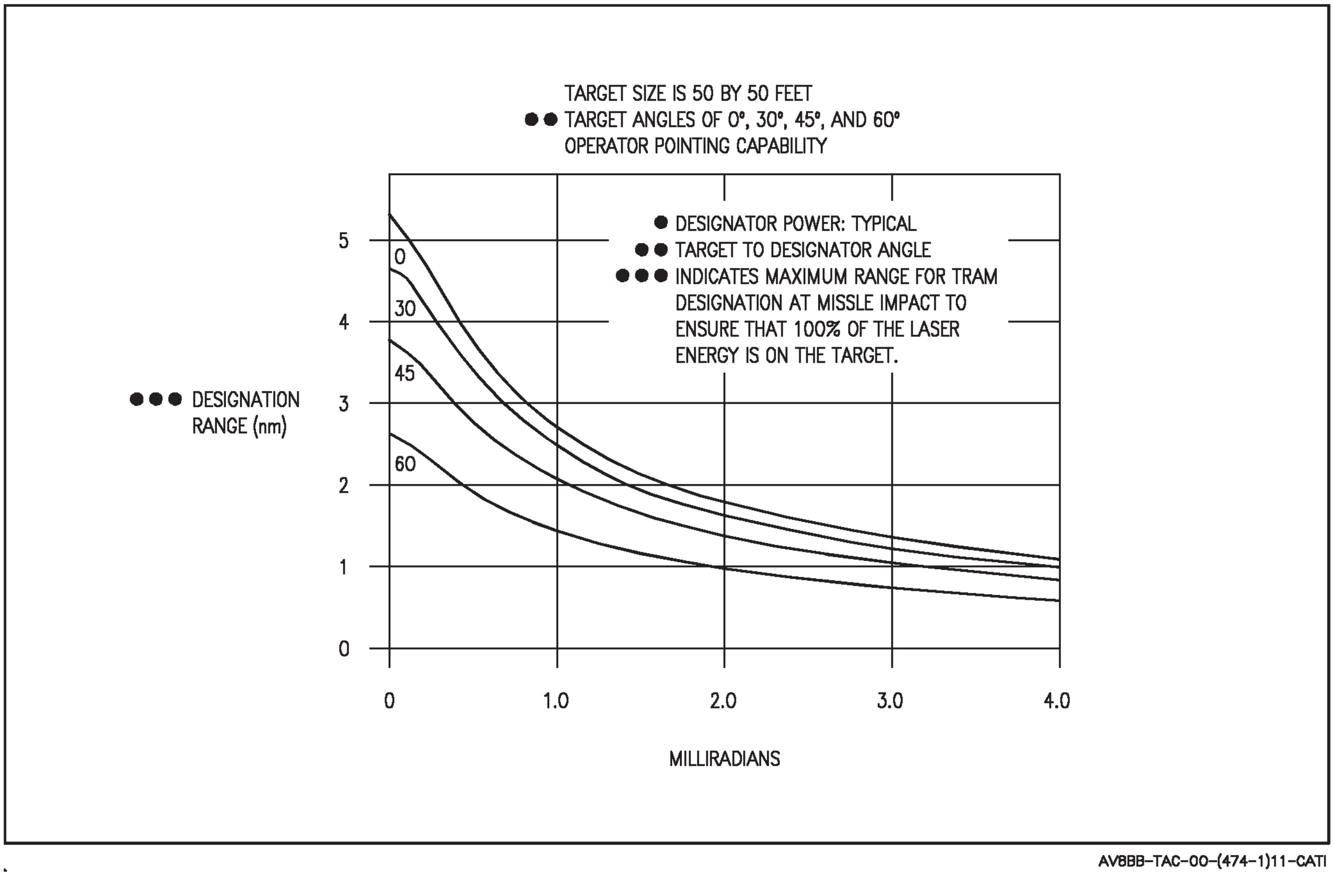
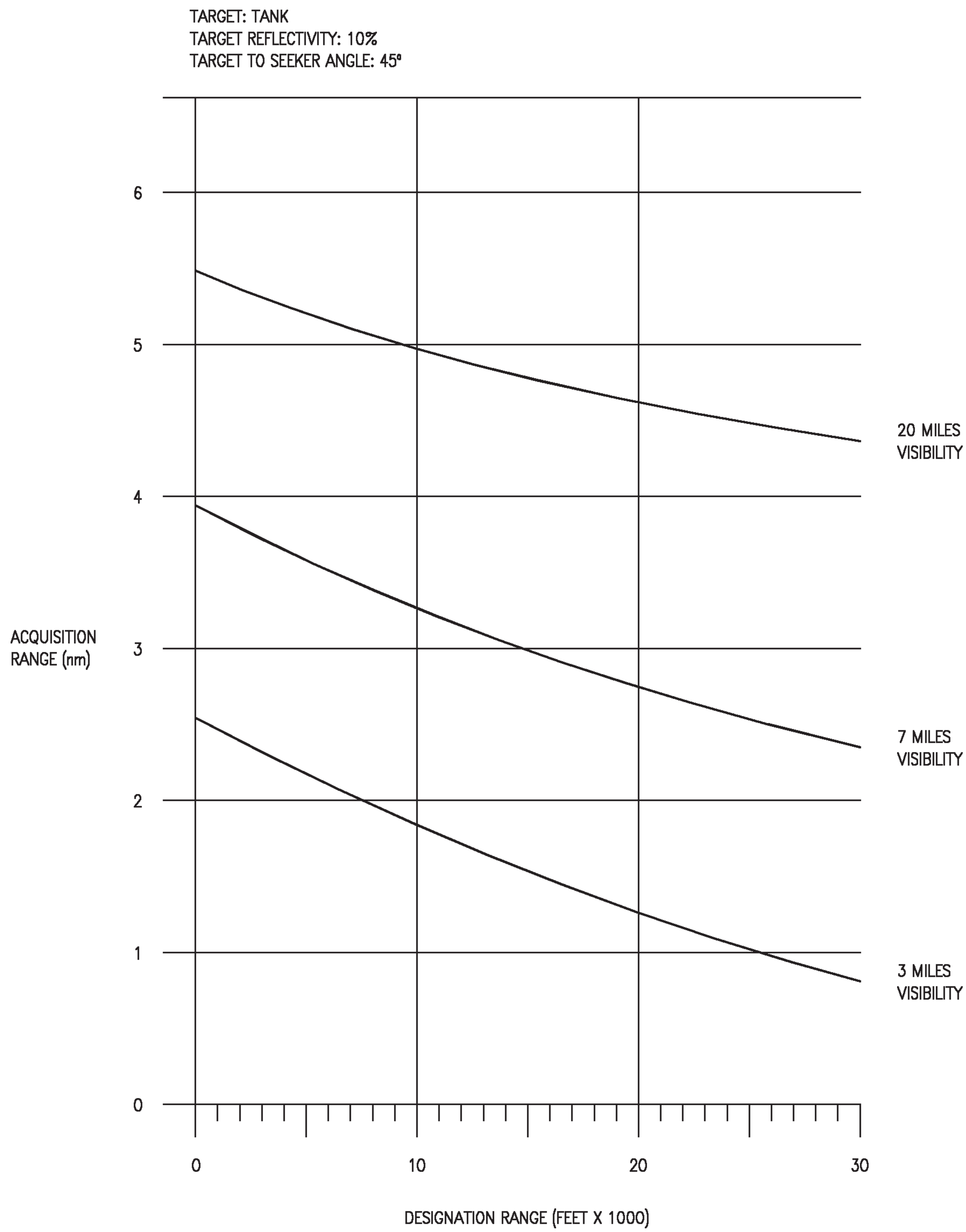


Figure 2-114. Typical Airborne Designator Operator Pointing Capability (Target Size 50' × 50')

aware of what could happen due to a change in weather and/or target parameter/location, they will be more capable of employing the best compensatory moves.

2.15.1.15.1 Preset Missile Functions. While enroute to the target area, time can be saved by preselection of certain missile function such as: appropriate scan or slave modes, warhead fuzing and PRF codes.

2.15.1.15.2 Missile Operating Time. The Laser Maverick missile should not be operated (missile ″on″) for more than 30 minutes continuously during a single mission. The missile is ″on″ (active mode) when selected and uncaged, and missile video is displayed on the DDI. Missile ″on time″ per mission also includes missile operation immediately prior to takeoff. More than 30 minutes total operating time (″on time″) during a single mission can be obtained if the missile is operated intermittently. Turning the missile off between operating periods of less than 30 minutes will allow the guidance unit to cool and will extend the cumulative operating time beyond 30 minutes in a single mission. The Laser Maverick missile is ″off″ when the missile station has been deselected and missile video in not displayed (ready mode). One additional minute of operating time is gained for every 2 minutes the missile is off. For instance, if the missile is on for 10 minutes, and then turned off for 10 minutes, 25 minutes continuous operating time is then available (30 − 10 + 5 = 25). If the missile on/off operating cycle described above is practiced throughout the mission, the 30 minutes continuous operating time limit should not be a constraint. If more than 30 minutes continuous missile operation is required, more than one missile should be carried and alternately activated. Continuous uninterrupted missile operation beyond 30 minutes may result in degradation of the guidance section sensitivity and overall picture quality. Extended continuous missile operation for longer than 1 hour, under



AV8BB-TAC-00-(472-1)11-CATI

Figure 2-115. MULE Versus AGM-65E Missile Acquisition Range (45° Target to Seeker Angle, Target Reflectivity 10%)

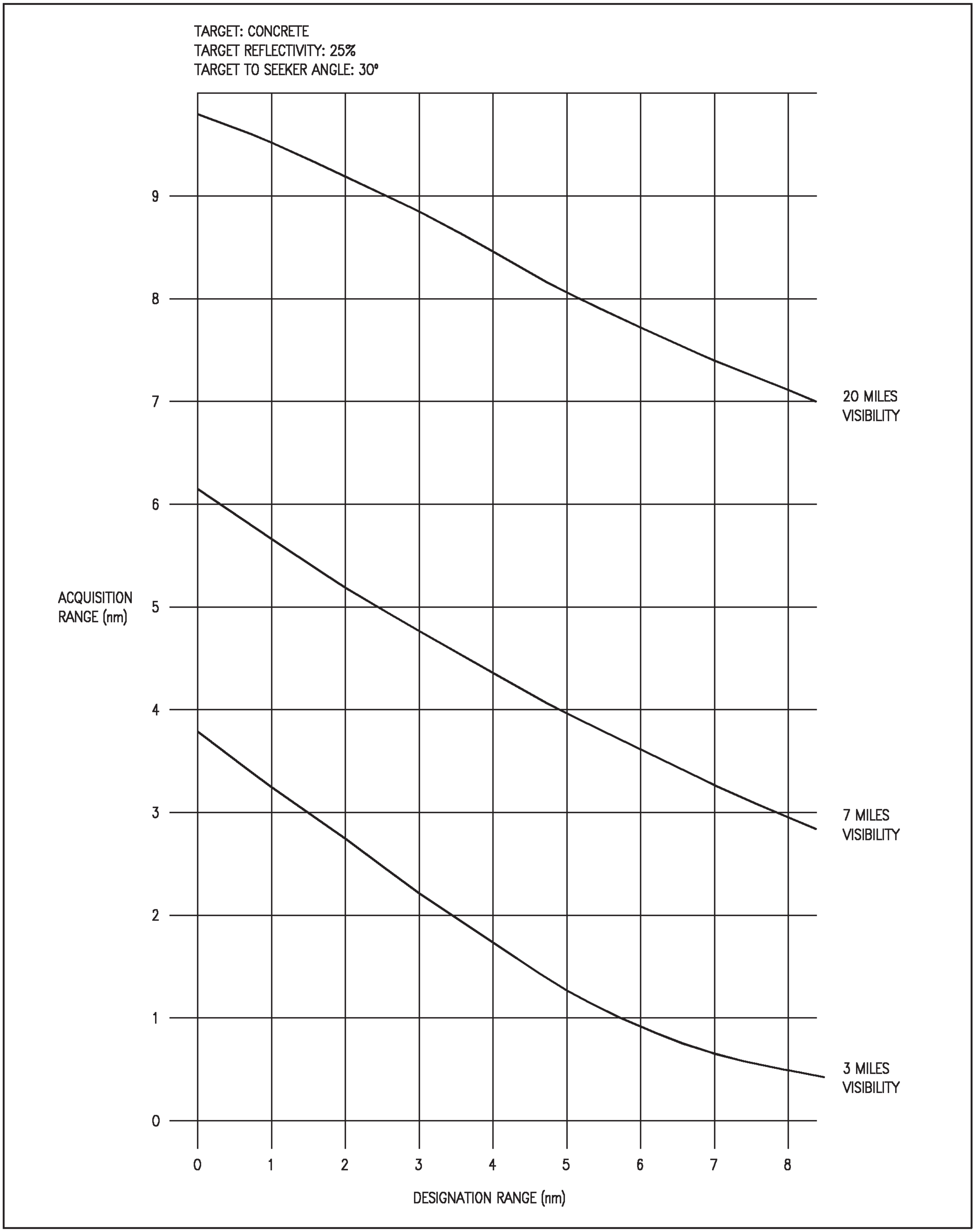


Figure 2-116. Typical Airborne Designation Versus AGM-65E Missile Acquisition (30° Target to Seeker Angle, Target Reflectivity 25%)

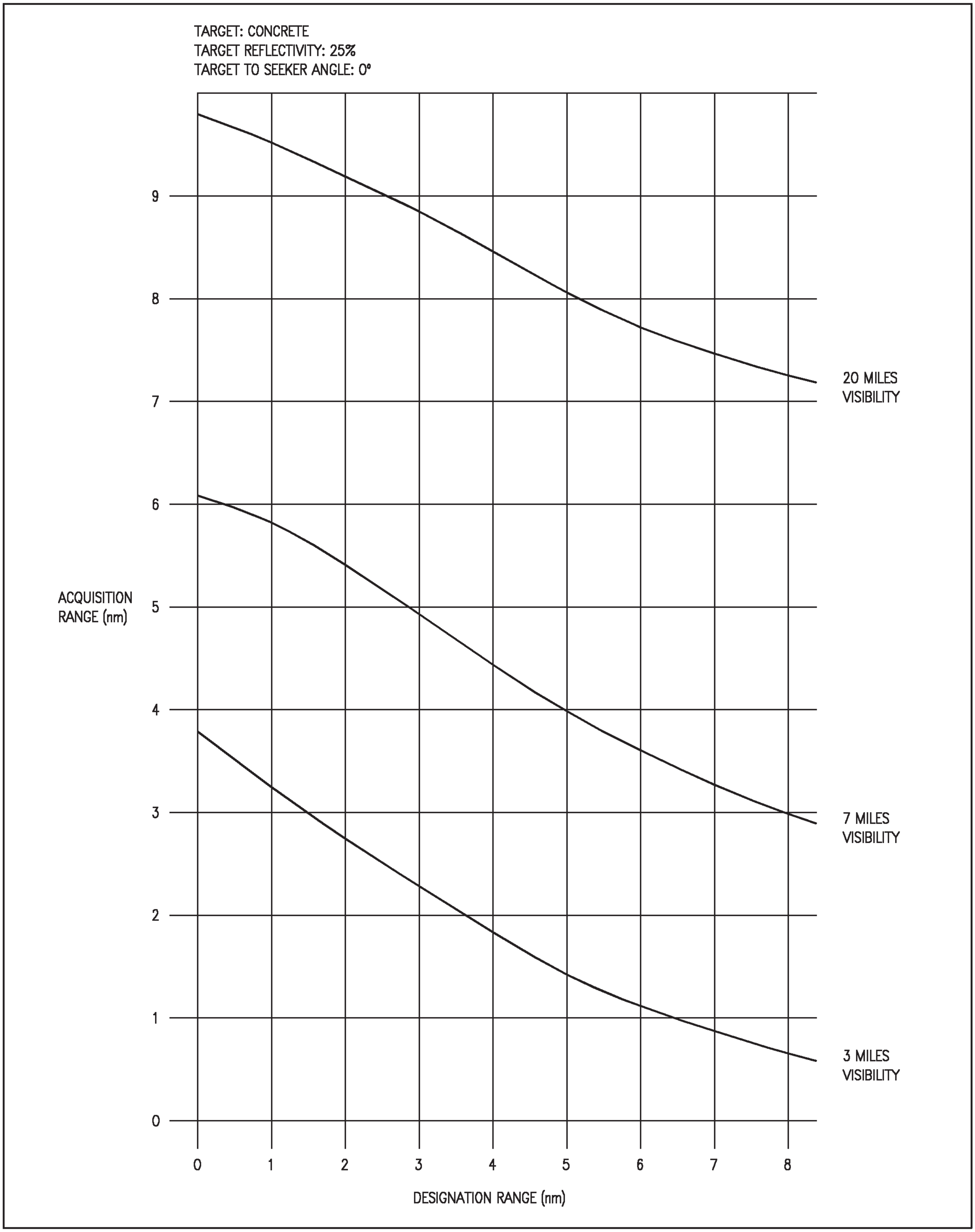


Figure 2-117. Typical Airborne Designation Versus AGM-65E Missile Acquisition (0° Target to Seeker Angle, Target Reflectivity 25%)

high temperature conditions, may result in damage to the missile guidance unit.

2.15.1.15.3 Optimum Target Acquisition Aid. The AGM-65E electronics have been designed to accept slaving signals from various aircraft acquisition aids. With the missile in the align mode, the pilot can locate the target with an aircraft acquisition aid. When the missile seeker is uncaged, it will be slaved to the same point as the acquisition aid. The seeker will accept slaving signals from the aid of up to 28° of the missile longitudinal axis (56° cone).

2.15.1.16 Target Area

2.15.1.16.1 Visual Target Area Procedures. When the target area is sighted visually, uncage to activate the Laser Maverick missile seeker. Fly the aircraft to place the head up aiming reference in the target area. The missile seeker will scan the target area for the designated target. Upon detection of the coded laser energy, the X will begin to flash, changing to a solid square when lock on occurs. Following lock on, it may be necessary to adjust the aircraft flight path to place the solid square within the launch constraint circle prior to launch.

2.15.1.16.2 Non-Visual Target Area Procedures. During the hours of darkness or during low visibility conditions, other aircraft aids may be used to acquire the target. Search, lock on and launch considerations would be the same as in a visual attack.

2.15.1.16.3 Laser Maverick Missile Flight Parameters. The following paragraphs address the operational considerations (missile flight parameters) which must be taken into consideration when target lock on and missile launch procedures are pending.

2.15.1.16.4 Seeker Alignment and Stabilization. When the missile is in the ready or align modes, the seeker assembly is electrically aligned to the longitudinal axis of the missile. Note that the seeker electrically aligns at the rate of 12° per second, and any aircraft turn rate in excess of that amount will cause the seeker to lag behind the aircraft; however, when the g-loading is reduced during rollout, the seeker will quickly realign to the missile axis.

2.15.1.16.5 Launch/Roll Quotient. The Laser Maverick missile must have a vertical reference established for proper roll control and missile trajectory (g-bias) after launch. The vertical reference is established at missile launch by assuring that the launching aircraft is within ±10° of wings level at missile launch. After launch the missile will maintain the vertical reference established at launch and will fly a lofting (g-bias) flight trajectory to the target. Optimum launch range performance will result when the aircraft bank angle is within ±10° with decreasing maximum launch range as the bank angle increases from ±10° out to the maximum of ±30°.

2.15.1.16.6 Laser Maverick Missile Launch Constraints. The following launch limitations apply to the Laser Maverick missile:

1. Launch load factor: 0.5 to +3.0g
2. Roll rate: ±30° per second
3. Dive angle: 60° maximum
4. Roll angle: ±30° maximum
5. Altitude: 33,000 feet maximum/150 feet minimum

2.15.1.16.7 Misfire and Hang Fire Procedures. If a missile rocket motor fails to ignite upon a firing attempt (misfire), the Laser Maverick missile should be deselected. The mission may be continued with other missiles on board. Standard procedures should be followed with the misfired missile. If brought back, the misfired missile may be safed after landing, but 1 hour must elapse between the firing attempt and missile downloading, to allow the missile battery to cool down.

2.15.1.17 Laser Maverick Missile Employment Guideline. Acquisition range prediction ability and familiarity with seeker performance characteristics can be developed by pilots while flying sorties with the TGM, by noting the absolute humidity in the target area under different conditions, and by comparing this information to achieved correlation and lock on ranges. Night operations are affected by the same factors as daylight operations except that the pilot will not be able to easily assess the target area visually. The effective use of the Laser Maverick missile depends in a large part on the training and skill of the personnel operating the various laser designators, the capabilities and material condition of the designating equipment, and careful attention to the characteristics and unique laser employment considerations during the mission planning phase.

2.15.1.18 Launch Range Determination. The Laser Maverick's capability to lock-on and track a target is dependent upon the amount of laser energy reaching the detector. This quantity is a function of the designator power, the distance travelled by the laser energy during the path from the designator to target to detector, the reflectance of the target, and prevailing atmospheric conditions. Under optimum atmosphereic conditions, the AGM-65E has the capability to correlate and lock onto reflected laser illumimation at slant ranges which exceed the aerodynamic capability of the missile.

The automatic lock-on symbology (solid square) does not consider target slant range as a parameter; therefore, the pilot must insure that launch slant range falls within the aerodynamic range of the missile (AGM in range). The missile will guide to and hit any correctly coded laser spot it locks onto and tracks.

The following list summarizes the major operational considerations of the Laser Maverick missile:

1. Visible light is not required for the Laser Maverick missile; therefore, day or night employment is equally feasible.

2. The Laser Maverick missile may not see through visible moisture (rain, fog, clouds) or smoke, dust, haze.

3. Be aware of the GPI after lock on. If the GPI is outside the launch constraint circle prior to launch, maneuver to place it within launch constraints.

4. Lock on is indicated by the GPI changing from an X to a solid square. Do not depress the A/G weapon release button until the solid square appears and the range to designated target is confirmed to be within the missiles aerodynamic capability.

5. Verify target by actuating target designator control between LMAV video and DMT video.

6. To prevent inadvertent eye injury, avoid looking directly at known or suspected ground or airborne designator positions.

2.15.2 AGM-65F IR Maverick Missile

2.15.2.1 Description. The AGM-65F IR Maverick Missile (IRMV) is an imaging infrared guided, rocket propelled, air-to-ground missile authorized for use on Radar and Night attack aircraft. It is authorized for carriage only (ferry) on Day Attack aircraft.

The IRMV is similar to the AGM-65E Laser Maverick (LMAV) in appearance, suspension, aerodynamics, handling and loading, electrical fuzing, rocket motor and warhead. The major difference between IRMV and LMAV is in the seeker, or guidance control section (GCS). Refer to NWP 3-22.5-AV8B, Vol. II, Chapter 2 for additional details on IRMV components. The IRMV seeker tracks infrared (IR) significant targets and provides the pilot with a composite video image of the target on the cockpit display. IRMV is capable of being slaved to a target designated by the Radar/Dual Mode Tracker (DMT) or to the HUD with an INS designation. IRMV is a launch and leave missile; however, IR targets must be identified by the pilot and IRMV manually locked onto the target prior to launch.

IRMV employs a 300 pound blast-fragmentation warhead with a selectable delay fuze, and is designed primarily for use against hardened targets requiring delayed fuzing such as ships, bunkers, fortified structures, and armored vehicles. The missile may be employed against stationary and mobile land and sea targets, day and night, with sufficient standoff range to permit limited exposure to target area terminal defenses. Refer to NWP 3-22.5-AV8B, Vol. II, Chapter 2, for additional data on IRMV employment capabilities and limitations.

2.15.2.2 Aircraft Systems. AV-8B aircraft systems involved in IRMV system operation include:

1. Radar - as the primary target acquisition and designation sensor (Radar aircraft).

2. DMT - as the primary target acquisition and designation sensor (Night Attack aircraft).

3. INS - as the secondary target designation sensor and IRMV seeker slaving reference.

4. HUD - for displaying missile operation symbology.

5. MPCD - for missile selection and video display.

6. UFC - for quantity scratch pad entry.

7. ODU - for changing the weapon program (i.e., QTY, fuze).

8. MC - for primary calculating ranging information.

9. SMC - for signal management between the missile and aircraft.

10. HOTAS - to provide uncage, slaving, slewing and lock-on controls.

11. ACP - as a backup for selecting individual stations, and weapon program options.

2.15.2.3 Aircraft Checkout. Aircraft checkout procedures include release and control checks with the AN/AWM-92 test set, pre-taxi checkout and boresight operations (align mode and track mode).

2.15.2.3.1 AN/AWM-92 Test Set. The AN/AWM-92 test set is used to perform release and control checks of the AV-8B aircraft prior to missile/launcher loading. The AN/AWM-92 tests aircraft operating modes and functions of the IR Maverick missile system. Test procedures are contained in A1-AV8BB-LWS-210, dated 15 August 1994 or later.

2.15.2.3.2 Pre-taxi Checkout. Verify the following conditions exist before applying power to the aircraft or IRMV missile system:

1. Release and control checks (A1-AV8BB-LWS-210) - COMPLETED.

2. SAFE/ARM device (SAD) key - INSTALLED.

3. Weapon code: 55 Fuze code: 00

4. Launcher/missile physical integrity - WINGS, FINS, DOME, RAIL, etc.

5. Missile restraint device (MRD) - ENGAGED.

6. Launcher grounding pin - ENGAGED.

7. Electrical connections, launcher/missile connection - MATED.

8. Rocket motor ignitor connector - STOWED.

2.15.2.3.3 Align Mode Boresight (ABST). After initial missile select, all IRMV's can be align mode boresighted. Select the ABST pushbutton on the stores display; this is a 4 second operation that cannot begin until 3 minutes after missile select. This is denoted by RDY in the lower left hand corner of the MPCD, which will display STBY during the 3 minutes. Align mode boresight aligns the seeker with the missile, it does not boresight the missile to the aircraft. The boresight corrections are stored in the SMC and applied to the azimuth and elevation position data error received from the mission computer to eliminate previous track mode boresight error data that is present in all IRMV missiles. During the 3 minute period or the align mode boresight, any cage/uncage commands cancel the align mode boresight. After align mode boresight, the priority station is selected. An align mode boresight zeros any previous track mode boresight values, except for any track mode boresight performed during the current ESMS power up cycle.

2.15.2.3.4 Track Mode Boresight (TBST). The track mode boresight operation should be performed prior to tactical target engagement to harmonize the IRMV missile seeker with aircraft sensors and symbology; in other words, it aligns the missile with the aircraft. The track mode boresight operation should be performed in flight.

To align the IRMV HUD symbology with the IR Maverick seeker line-of-sight, an airborne track mode boresight must be performed individually for each IRMV loaded on the aircraft. This function updates the missile boresight memory with new boresight values and aligns the Maverick seeker to the aircraft sensors (RADAR/DMT/INS). In track mode and with master arm in the SAFE/OFF position, the TBST option appears on the MPCD. The track mode boresight procedure is performed by initially locating a target within the HUD FOV and locking onto the target in narrow FOV. For optimal accuracy, the boresight target should be a minimum of 6000 feet away and below the waterline of the aircraft. When target lock-on (track mode) is achieved, the TBST option appears on the MPCD. TBST is selected and the HUD IRMV box is slewed with the TDC to overlay the same target point as that being tracked within the IRMV crosshairs on the MPCD. TBST is deselected (unboxed) to conclude the track mode boresight operation and store the updated boresight values in IRMV memory. To verify that the track mode boresight procedure was successful, position the INS TD diamond over the boresight target and observe whether the target appears within the IRMV narrow FOV. If it does not, the track mode boresight procedure was unsuccessful and must be repeated.

NOTE

The amount of time spent with TBST selected (boxed) should be minimized to prevent IRMV seeker breaklock.

The best way to avoid seeker breaklock during the track mode boresight operation is to select an IR significant target to lock-on to. A target is considered IR significant when after lock-on, the crosshairs are stable and IRMV video pointing cross is *not* flashing (i.e.,″good-lock″). Boresight targets must be stationary and the probability of any object moving between the aircraft and the boresight target must be minimized. If breaklock appears imminent, press the undesignate switch to cancel the track mode boresight operation; otherwise the IRMV seeker could breaklock and run off on a new target.

If breaklock occurs while TBST is boxed, select FOV on the MPCD or press the undesignate switch to cancel the track mode boresight operation to cage the seeker. The system should return to slave mode, as indicated by the seeker returning to the target designation or the aircraft velocity vector if a target was not designated. If selecting FOV or pressing the undesignate switch does not return the seeker to slave mode and the seeker appears to wander away uncontrolled, deselect (unbox) TBST or deselect (unbox) IRMV, then start over.

To perform an airborne-initiated track mode boresight operation complete the following steps:

1. A/G master mode - SELECT

2. STRS - SELECT (verify one IRMV on wing planform).

3. IRMV - SELECT (RDY indication appears after 3 minutes)

4. Cage/uncage switch - PRESS/RELEASE (video displayed on MPCD)

5. Sensor select switch forward selects IRMV sensor mode. Subsequent sensor select switch forward toggles between INS and IRMV sensor modes. In Radar aircraft, each sensor select switch forward also schedules an AGR update.

6. FOV - SELECT NARROW FOV

7. Cage/uncage switch - PRESS/RELEASE (commands track, IRMV locks on boresight target)

8. TDC - SWEETEN IRMV SOLUTION (if necessary) AND RELEASE (command track, pointing cross does not flash)

9. TBST - SELECT

10. TDC - SLEW HUD IRMV BOX OVER BORESIGHT TARGET

11. TBST - UNBOX

12. FOV - PRESS/RELEASE (cages seeker)

NOTE

Verify boresight acceptance by depressing TDC and slewing the TD diamond to the boresight target. Then verify target is within IRMV video crosshairs.

13. Perform this procedure again for each IR Maverick missile loaded on the aircraft.

Although the preferred method of performing a track mode boresight is airborne, track mode boresight may also be performed on the ground. To perform track mode boresight on the ground, follow the procedure as outlined in A1-AV8BB-LWS-560 Conventional Weapons Checklist, AV-8B PASE (AGM-65 Maverick) dated 15 October 1994 or later.

2.15.2.4 MPCD Stores Display. The MPCD stores display shown in Figure 2-118 depicts an aircraft loaded with one AIM-9L on stations 1 and 7, one IRMV on stations 2 and 6, and 300 rounds of ammunition. The display shows the IRMV selected and launch priority assigned to station 2 as indicated by the inverted triangle.

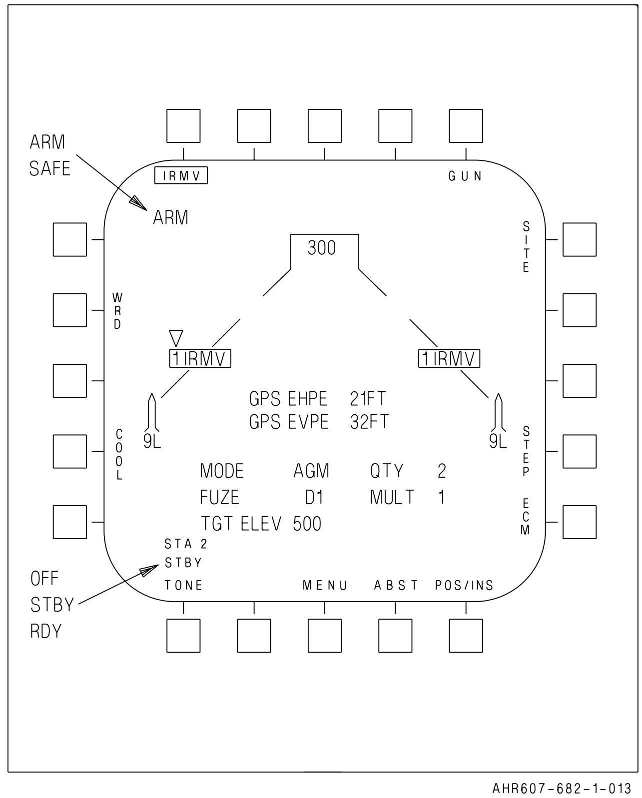


Figure 2-118. IRMV Selected, Wing Planform, and Weapon Program

The STBY legend on the bottom left of the display indicates the missile 3 minute cool down is in progress. OFF would be displayed if IRMV is selected with weight-on-wheels (armament bus power in not available) unless the armament bus override switch is placed in the OVERRIDE position.

The latest missile program is also provided as shown. If the missile was previously selected, the SMS displays that program; otherwise it defaults to QTY 1, MULT 1, FUZE D1. Mission planning system entries are not transferred via the DSU; IRMV QTY and FUZE must be programmed in the cockpit via the ODU or ACP.

2.15.2.5 IR Maverick Delivery Mode. IRMV delivery mode includes all actions required and indications necessary to successfully select, set up, and launch the IRMV missile. There are multiple so-called ″sub-modes″ of operation of the IRMV missile. These sub-modes may be transparent to the pilot, and often they are transient, changing automatically or as the pilot actuates various switches. Figure 2-119 summarizes these modes.

DISPLAY	MODE	CONDITION OR ACTION REQUIRED	INDICATION
Stores Page	Preparation mode	Armament bus power applied and IRMV boxed	STBY on MPCD
	Ready Mode	Missile cool down complete	RDY on MPCD
IRMV video (activate mode)	Slave mode	1st cage/uncage with or without target designated	IRMV seeker slaved to target designation or velocity vector
	Track mode	IRMV sensor mode followed by a slew command	Seeker locks onto IR significant target
	Slew mode	IRMV sensor mode Action or no-action slew with TDC (from track mode)	Seeker breaks lock and follows TDC commands. Track mode is automatically reentered when TDC is released
	Snowplow mode	IRMV sensor mode No sensor designation, not in track mode and no-action TDC commanded	Single circle velocity vector when selected from slaved to velocity vector. Action TDC command will enter track mode

Figure 2-119. IR Maverick Delivery Mode

2.15.2.5.1 IR Maverick Seeker Cool Down. Once airborne (weight-off-wheels) with IRMV selected (boxed) all IRMV missiles begin a 3 minute IR seeker cool down and gyro spin up. At the conclusion of the cool down and spin up, all IRMVs will be in the READY mode (RDY displayed).

CAUTION

To prevent IR Maverick missile seeker damage, adhere to the following missile operating time limits. The IR Maverick is operable in the ready mode (RDY displayed, video not present) for 1 hour maximum. In the active mode (video present), the missile is operable for 30 minutes maximum. After having been operated, the missile recovers at a rate of 1 minute of additional operating time available for every 2 minutes the missile is off.

2.15.2.5.2 Selection. IRMV is selected by pressing (boxing) the IRMV option on the MPCD stores display or by selecting the appropriate IRMV station via the ACP. After selecting IRMV via the MPCD or ACP, the IRMV option is boxed (Figure 2-118), the stores management computer (SMC) unlocks missile restraint devices (MRD) on all LAU-117 launchers and initiates missile seeker gyro spin up and detector cool down on all IRMV missiles regardless of master mode. STBY is presented in the lower left corner of the STRS page on the MPCD as an advisory that seeker detector cool down is taking place. After 3 minutes, STBY changes to RDY.

The IRMV weapon program is also presented in the STRS page and can be changed on the armament control panel (ACP) or by selecting WPN on the up front control (UFC), FUZE or QTY on the option display unit (ODU) and the desired fuzing and quantity options. Changeable weapon program settings include fuzing (SAFE, IN, D1, D2), and quantity (1 thru 4). Fuzing options IN, D1 and D2 correspond respectively to instantaneous, medium and long warhead detonation delay. The delay selected should correspond to the target hardness and depth of penetration desired. The default fuzing setting is D1, which is used for most tactical target engagements. The D1 option enables a delay of 14 msec between missile impact and warhead detonation. Selecting the D2 option enables a delay of 30 msec between missile impact and warhead detonation. IRMV weapons programs are NOT transfered from the mission planning system via the DSU; QTY and FUZE must be selected in the cockpit.

With a quantity greater than one selected, the second and subsequent IRMVs are automatically uncaged and slaved to the target designation, following launch of the first IRMV. Regardless of the quantity selected, only one IRMV can be launched at a time. Multiple IRMV launches are not supported by the avionics.

NOTE

A fuze setting of SAFE prohibits the A/G ready state and prevent launch of the IRMV missile.

a. STEP Option. If a different missile priority is desired, the pilot may change priority by pressing the STEP option until the desired missile is selected, or select the desired station on the ACP. When the STEP option is actuated, the SMS selects the next IRMV station (having the same weapon code) and the selected station number is indicated on the IRMV video display. Missile priority sequence is station 2, 6, 3, then 5. Stations with degraded weapons (i.e., HUNG) have the lowest priority and may be selected using the STEP option only after all the nonhung IRMVs are expended. The STEP option is removed with only one IRMV on board.

2.15.2.5.3 Uncage. In flight, IRMV can be uncaged before the RDY indication appears on the MPCD (3 minutes). After the 3 minute period expires, if IRMV is deselected and reselected, the 3 minute wait is also not required before uncage can be activated. However, IRMV video may appear fuzzy until the full 3 minute cool-down period is complete. Depending how long IRMV remained deselected, the IRMV seeker may need about 90 seconds before it can reactivate video.

When the RDY indication appears and uncage is commanded (1st cage/uncage command), IRMV video is displayed on the right MPCD in place of the STRS display. The seeker is in slave mode and moves to the target designation if one exists; otherwise the seeker is slaved to the velocity vector. The velocity vector becomes double circled when the IRMV becomes slaved to the velocity vector. At this point, the IRMV symbol is presented on the HUD, but remains unboxed. The boxed IRMV HUD symbol is presented only in slew, track, and snowplow modes. A "U" legend appears next to the IRMV symbol indicating that the IRMV is uncaged. The selected sensor (RADAR/DMT/INS) is used to control IRMV movement via the TDC until IRMV sensor mode is entered via Sensor Select switch forward. In IRMV sensor mode, the TDC is used to control the IRMV.

NOTE

IRMV video appears on the stores page or left MPCD with each initial uncage command only. If another display such as the EHSD is selected while IRMV video is displayed (i.e., via sensor select switch left HOTAS command), select MENU/STRS to return to IRMV video.

IRMV video remains displayed until a master mode change is made, a different missile is selected with the STEP option, IRMV is deselected (unboxed) or another A/G weapon is

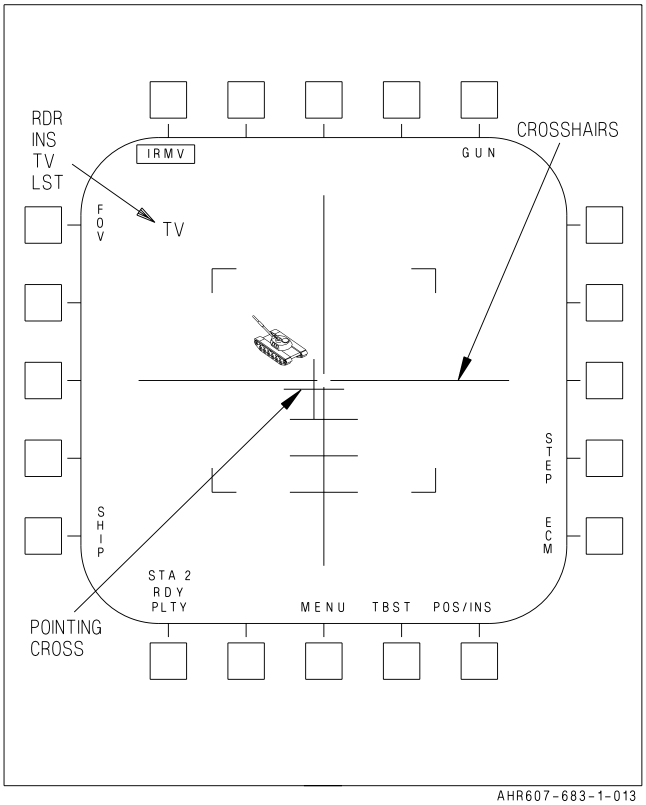


Figure 2-120. IRMV Uncaged, Video Symbology, Slave Mode

selected. Any of these four options removes the IRMV video and deselects the missile.

CAUTION

A HOTAS command (such as sensor select switch left to bring up the EHSD) replaces IRMV video with another display but does NOT deselect the IRMV missile; the missile remains in slave or track mode (capable of being fired), even though no IRMV video is displayed, until the missile is deselected via master mode change, STEP option, or unboxing IRMV, or selecting another A/G weapon.

2.15.2.5.4 Video Symbology. IRMV composite video provides an image of the target area within the field-of-view (FOV) of the seeker (Figure 2-120).Video symbology includes:

1. The target tracking gates (crosshairs)
2. The pointing cross representing the seeker line-of-sight
3. The 5°, 10°, and 15° depression marks
4. Narrow FOV brackets (if the seeker is in wide FOV)
5. Track polarity indication (white or black symbology)
6. Good-lock indication (target bounded by crosshairs and pointing cross NOT flashing)
7. Breaklock indication (crosshairs retracted and pointing cross flashing)
8. Ship/land track indications (crosshair opening size).

2.15.2.5.5 HOTAS Switch Functions. See Figure 2-121.

a. Cage/Uncage Button. The first actuation of the cage/uncage button displays video and uncages the seeker. The second actuation of the cage/uncage button commands align mode. Video is removed. IRMV no longer slaved.

b. Target Designator Control (TDC). After the first uncage (slave mode) and after Sensor Select switch forward (entering IRMV sensor mode), no-action movement (TDC not depressed) moves the seeker slowly. With no sensor designation and not in track mode, no-action TDC commands snowplow mode. Action movement (TDC depressed) moves the seeker at twice the rate as no-action movement. With action or no-action slewing after the first cage/uncage button actuation, the pilot is actually moving the selected sensor designation (RADAR/DMT/INS). The IRMV seeker is slaved to the designation and follows slewing commands. When the TDC is released, the sensor stops slewing. IRMV is slaved to the sensor. IRMV sensor mode must be entered (sensor select switch forward) and action slew or no action with a designation commands track.

No-action movement moves the seeker slowly. Action movement moves the seeker at twice the

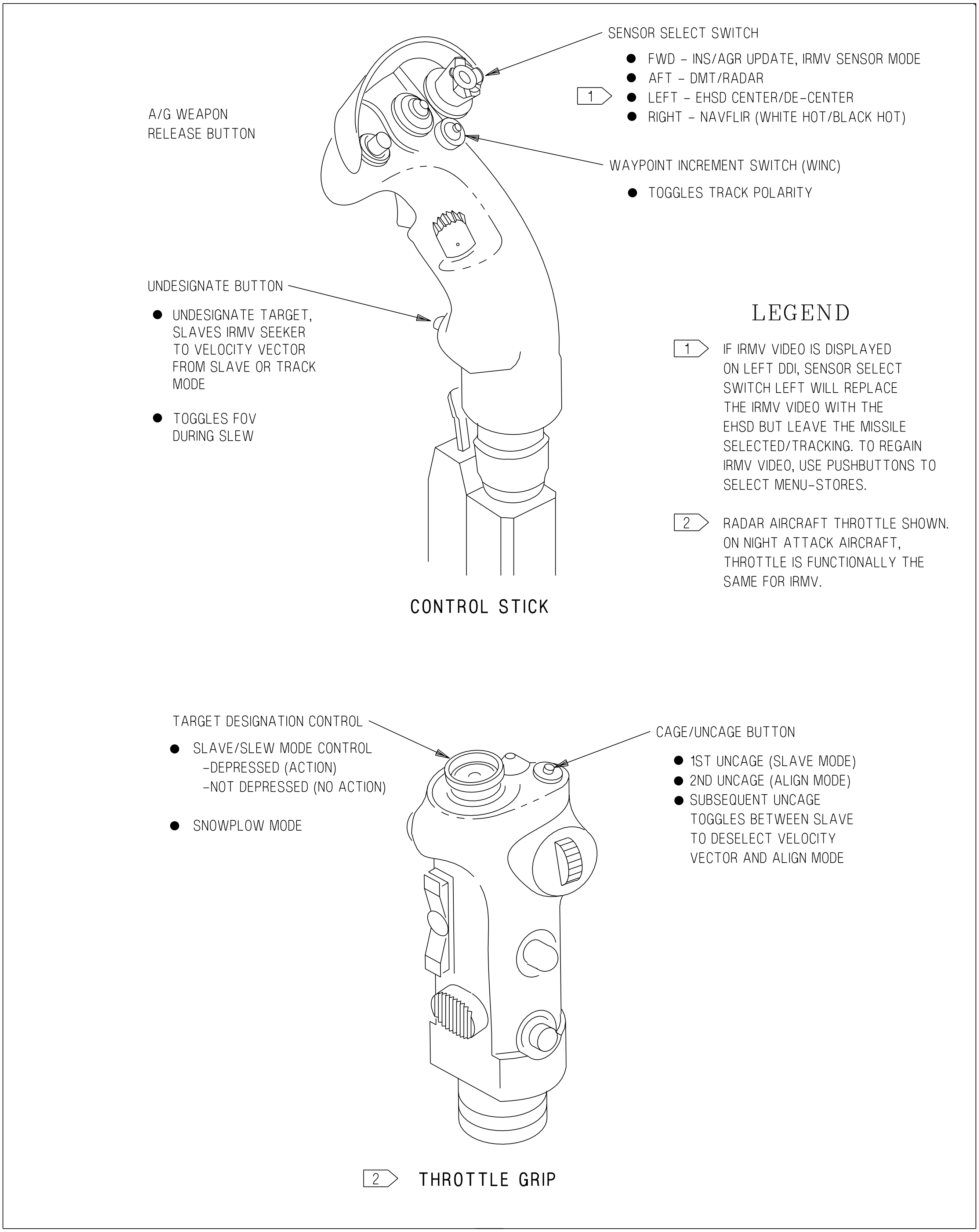


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Figure 2-121. HOTAS Switch Functions

rate as no-action movement. With action or no-action slewing, the pilot is moving the IRMV seeker in slew mode and the designating sensor follows slewing commands. Releasing the TDC after action or no-action slewing commands allows the IRMV seeker to lock-on and track the target located within the crosshairs.

c. Undesignate Button. If the IRMV is in Track mode, pressing the undesignate button sends an uncage command to the seeker head and causes it to slave to the velocity vector. If the IRMV is slaved to a target designation (IRMV video selected with an INS, DMT, or RADAR designation), pressing the undesignate button undesignates the target and slaves IRMV to the velocity vector. During slew mode or with IRMV slaved to the velocity vector the undesignate switch commands a field of view toggle.

d. Waypoint Increment (WINC) Switch. While in IRMV sensor mode this switch toggles between track polarities, hot track and cold track. This switch becomes unavailable upon entering track mode.

e. Sensor Select Switch. The first selection of the sensor select switch forward selects IRMV sensor mode; subsequent sensor select switch forward toggles between INS and IRMV sensor modes. In Radar aircraft, each sensor select switch forward also schedules an AGR update.

2.15.2.5.6 MPCD Option Functions. Options include STEP and TBST which have been previously discussed, Field-of-View (FOV, Track Polarity (PLTY), and Ship/Land Track Mode (SHIP).

a. Field-Of-View (FOV). When first uncaged, IRMV initiates in wide FOV, as indicated by narrow FOV brackets present on the IRMV video (Figure 2-120). In track mode narrow FOV becomes available upon selection of the FOV pushbutton or by use of the undesignate button while in slew mode. Selecting the narrow FOV option changes FOV to narrow mode and the magnification of the IR video changes to twice that of wide FOV. In narrow FOV, the brackets are not present in the video. Selecting FOV again changes back to wide FOV and the brackets return. Wide FOV is 8 power magnification and 3° wide. Narrow FOV is 16 power magnification and 1.5° wide. The FOV pushbutton is also used to cage IRMV and return the seeker to slave mode (Figure 2-120). While tracking a target, selecting FOV causes the seeker to break-lock and return to slave mode; the seeker is then slaved to an INS designation resulting from the IRMV track point.

Wide FOV provides coverage of a larger area, while narrow FOV provides increased launch range and a better presentation of target area thermal characteristics. A slightly blurred image may be present for up to 2 seconds after a FOV change. The missile may be launched in either wide or narrow FOV, but launch from narrow FOV is recommended to ensure that the best lock possible has been obtained.

b. Track Polarity (PLTY). The track polarity function sets the missile seeker to track hot targets on a cold background (hot track) or cold targets on a hot background (cold track). The appropriate track polarity selection must be made prior to commanding lock-on. When in hot track, the missile crosshairs are white, while in cold track the crosshairs are black. IRMV initializes in hot track. Selecting the PLTY option does not box the option but alternates between hot and cold track polarity with each selection as indicated by the change in color of the video display crosshairs. Selection of hot and cold polarity can also be toggled with the WINC switch; however the WINC switch becomes unavailable during track mode. The video crosshairs must match the intended target color in order for the seeker to track the target (i.e., white target/white crosshairs). If the pilot selects the incorrect polarity the missile may lock onto the targets shadow, or may not lock near the intended target at all.

The PLTY function on the MPCD changes polarity while the missile is in slave mode. If the missile is in track mode, selection of the PLTY option results in a "buffered" polarity change command; the polarity will does change until slew mode is entered. If the missile is in track mode and it is desired to change polarity to track a different target, push the PLTY pushbutton, then action or no-action slew mode is entered with TDC movement, and track gate can be slewed to the new target where it begins tracking as soon as the TDC is released.

c. Ship Track Mode (SHIP). The missile initializes optimized for land targets with the aimpoint at the center of the thermally defined target. Pressing the SHIP option (boxing SHIP) sends a ship tracking command to the missile which biases the missile tracking logic to ship targets, with an offset to impact the ship at the waterline. Pressing the SHIP option again reselects the land target option (unboxes SHIP). The opening in the center of the video crosshairs indicates which track mode (ship/land) is selected. Equal vertical and horizontal openings indicates land track mode, while a horizontal opening twice the size of the vertical opening indicates ship track mode.

The SHIP function on the MPCD changes aim points while the missile is in slave mode. If the missile is in track mode, selection of the SHIP option results in a ″buffered″ target change command; the aim point does not change until slew mode is entered. If the missile is in track mode and it is desired to change aimpoints push the SHIP pushbutton, then action or no-action slew mode is entered with TDC movement and the aimpoint change takes effect. Removal of the slew command recommands track.

2.15.2.5.7 Target Designation and Lock-on. Approaching the target area, IRMV should be selected, boresighted, and RDY. Designate the target area with the RADAR/DMT and uncage IRMV to slave to the target designation. The target can be designated by the Radar in FTT, GMTT, or MAP designation; it can be designated by the DMT in TV or in LST mode if a laser designator is available. Additionally, IRMV can be slaved to the HUD with an INS designation or slewed to targets-of-opportunity without any target designation.

IRMV initiates in wide FOV, land track mode and hot track polarity. The ship/land track option should be set to match the intended target type prior to beginning the target attack. A dashed wide FOV box over the designation indicates IRMV is slaved to the designation. IRMV sensor selct mode (sensor select switch forward) must be entered before the IRMV can be slewed. During slew mode the wide FOV box goes solid and the designation symbol is removed. Once in track mode and after locating the target area in the missile video, narrow FOV should be selected to magnify the target. Target track polarity is selected on the MPCD with the PLTY option so that the IRMV crosshair color (white for hot, black for cold) matches that of the target. Uncage is actuated a second time to command target lock-on. To sweeten the target track position, move the TDC to position the IRMV box over the desired target and release TDC to lock IRMV onto the new target position. If the lock is obtained from a radar designation, the radar will return to the previously selected scan pattern (MAP/GMT/FTT) once lock-on occurs.

NOTE

If IRMV reaches its gimbal limit while being slewed after being in track (slew mode), it slaves back to the velocity vector. If IRMV reaches its gimbal limit while in track mode (i.e., target overfly) the seeker remains at the gimbal limit (with the display ″bouncing along″ over the ground) until the undesignate button is pressed, the seeker is caged by pressing FOV, or it is slewed off the gimbal by the TDC.

a. Target Lock-on Verification. When IRMV is locked onto the target, the IRMV HUD symbol reduces and surrounds the target. *Lock-on must be visually verified on the MPCD IRMV display.* The target should be centered in the video and bounded on all sides by the crosshairs.

Missile seeker head position is indicated by the position of the small pointing cross relative to the larger crosshairs on the MPCD IRMV symbology. The small pointing cross represents seeker position, and the large crosshairs represent the center of the seeker head field of view. If

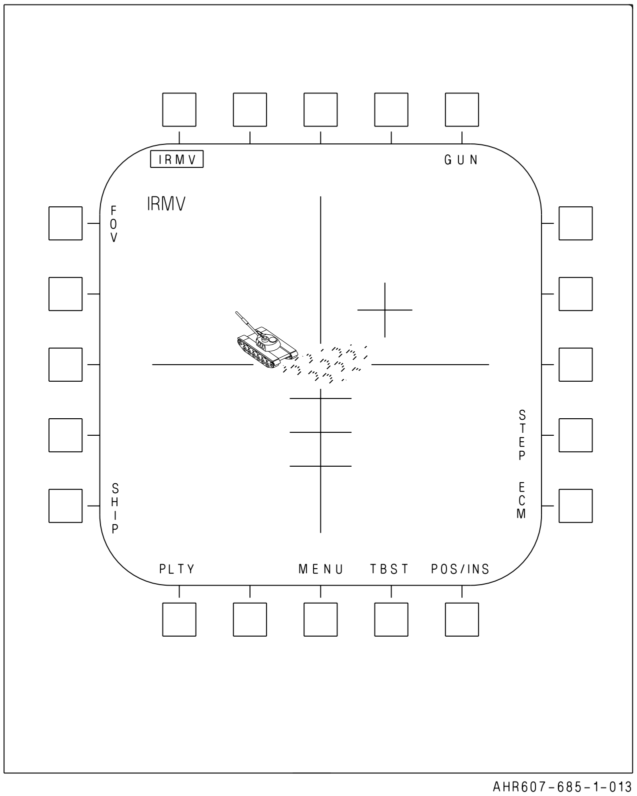


Figure 2-122. Bad Lock Indication - Crosshairs Expand on Dust

the pointing cross is 5° left and 10° below the center of the crosshairs, flying left and nose down would fly the center of the crosshairs to the pointing cross to align the seeker head with the missile; this technique is used to fly the seeker head into the launch keyhole prior to launch.

The three tick marks along the lower vertical crosshair are spaced 5° apart and provide a reference as to seeker head depression angle. When the missile is in track mode and launch criteria are not met the pointing cross flashes. This flashing pointing cross is a ″bad-lock″ indication (Figure 2-122). This bad-lock indication occurs when the launch criteria are not met because:

1. IR target signature is not sufficient for the seeker head to lock onto and tracking performance is poor (low or dispersed temperature gradients).

2. Missile seeker head is outside the launch keyhole. The launch constraint keyhole (Figure 2-123) is so named because of its shape.

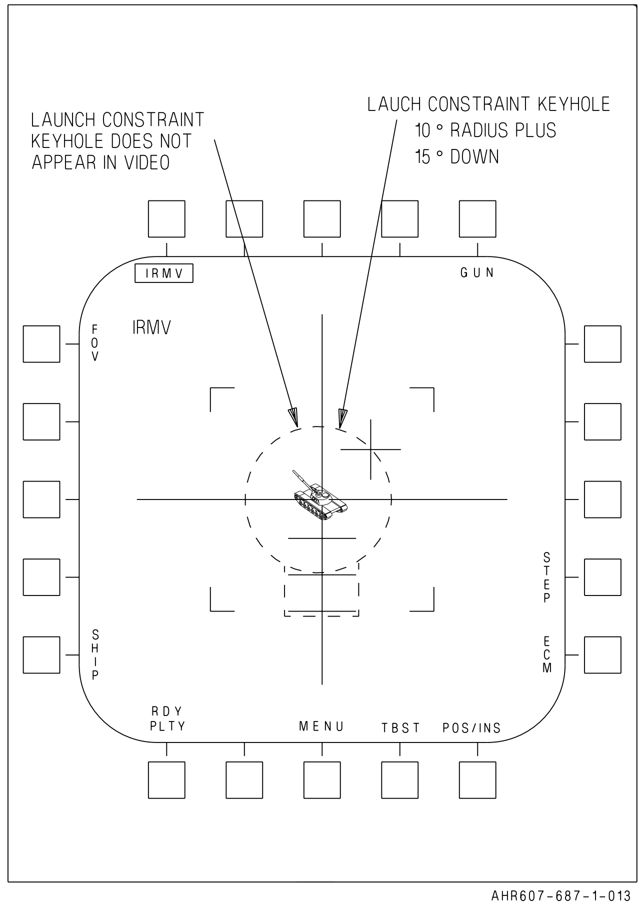


Figure 2-123. Launch Constraint Keyhole.

The keyhole is a 10° radius circle from boresight with a notch at 15° down. The launch constraint keyhole does NOT appear on the MPCD IRMV video.

A steady pointing cross indicates a good-lock (Figure 2-124). If the missile loses track (breaks lock) or fails to lock-on when commanded, a break-lock condition occurs. The missile then goes into correlation track (crosshairs retract to the edge of the MPCD IRMV display) and remain there until a TDC slew (action or no-action) is initiated to re-command track onto an IR significant target (cage/uncage returns to align mode).

In summary, after lock-on the pointing cross on the video display acts as a cue to indicate the type of lock achieved (i.e., good-lock or bad-lock). The flashing pointing cross indicates that launch criteria are not met and a bad-lock condition exist. Good-lock (pointing cross not flashing) indicates that launch criteria are met.

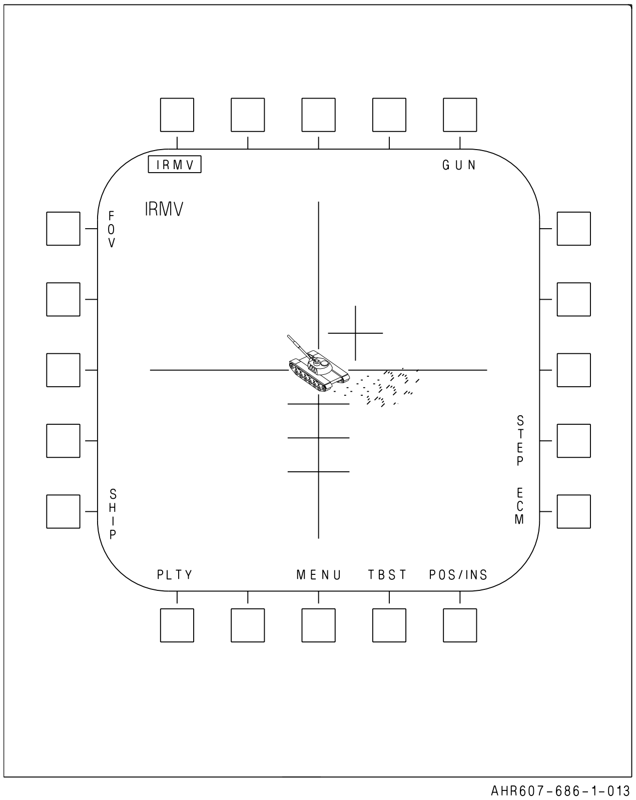


Figure 2-124. Good Lock Indication - Crosshairs Bound the Target

Launch criteria include: 1) IR target signature significance and 2) the launch constraint keyhole. The IR target signature is assessed for target shape and contrast within the crosshairs.

CAUTION

If IRMV is launched when the pointing cross is outside the launch constraint keyhole, IRMV may be unable to maneuver sufficiently to impact the target.

b. Vertical Reference Establishment. IRMV establishes its vertical reference at lock-on. *This is different than LMAV, which establishes its vertical reference when fired.* This vertical reference is used to establish the flight path of IRMV for the given launch parameters. The aircraft should be within 10° of wings level at lock-on to ensure the optimum flight profile of the missile to the target. Slew while in IRMV sensor select mode causes lock-on. The missile re-establishes the vertical reference each time it transitions from slew to track mode.

CAUTION

The g-bias algorithm in the IRMV seeker is responsible for determining the amount and *direction* of the loft maneuver. The g-bias algorithm assumes the *aircraft is wings level at lock-on* to determine the vertical reference of the missile. Any roll maneuver between lock-on and launch is memorized by the seeker autopilot. At launch, the missile rolls back to the attitude it was in when lock-on occured. If the seeker was commanded to lock-on with more than 30° roll, an incorrect vertical reference will be established and the missile's maximum range will be reduced.

2.15.2.5.8 HUD Displays. See Figures 2-125 and 2-126.

a. Missile Line-of-Sight (LOS) Symbol. The missile LOS symbol is a square box with an inside tick mark on each side and a 0.7 mil aiming dot in the center. The box is a 51 mil square in wide FOV (Figure 2-125) (even if Narrow FOV selected). The missile LOS symbol is caged to the missile boresight, roll stabilized, and limited to a 10.5° radius from the HUD center; the symbol becomes dashed when it reaches the limit. The symbol flashes if the LOS position exceeds the missile launch constraints (pointing cross outside the keyhole).

b. Missile Lock-on Symbol. The lock-on symbol is a 17 mil square with an inside tick mark on each side and NO aiming dot in the center (Figure 2-126). This symbol indicates the missile is in track mode; the lock must be verified for ″good-lock″ indications on the MPCD prior to launch.

c. Availability Cue. The number of IRMV missiles available for employment is indicated next to the IRMV legend (i.e., 2 IRMV).

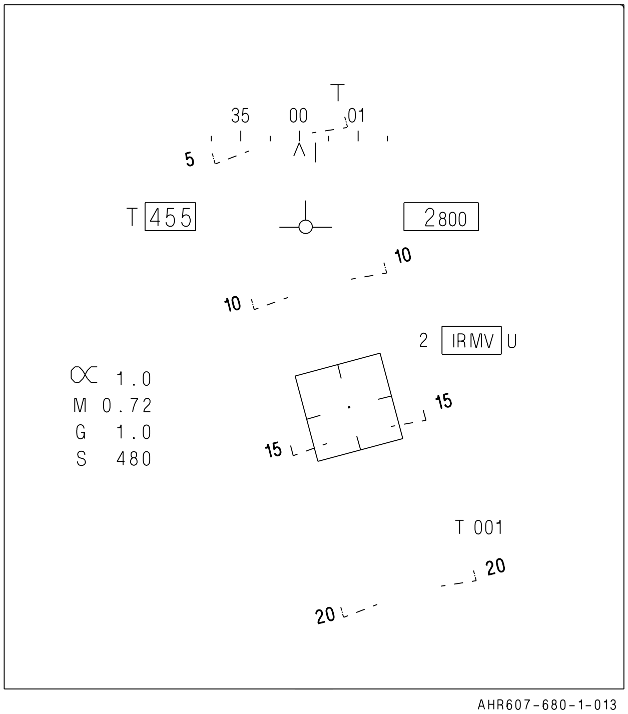


Figure 2-125. HUD Symbology - Wide FOV (Slew Mode)

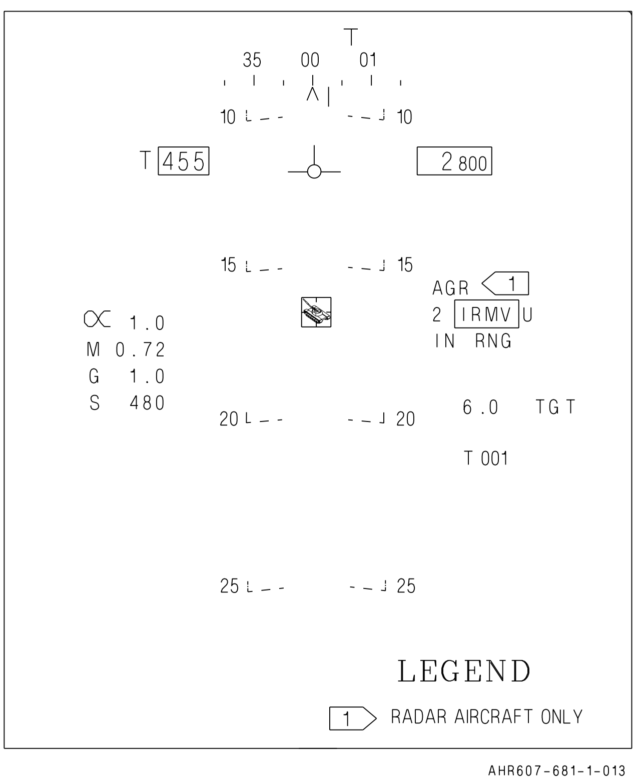


Figure 2-126. HUD Symbology - Track Mode and Ranging Information

d. In Range Cue. Ranging information is presented on the HUD when a target is designated and a launch solution exists. Ranging information includes the IN RNG indication above the TGT indication and distance to target (slant range) in nautical miles (Figure 2-126). Ranging information is based on IRMV gimbal angles and best available aircraft altitude when in IRMV track mode. The IN RNG cue indicates that the mission computer has determined that the target being tracked is within the missile launch envelope (it assumes vertical reference is correct). A target must be in the forward hemisphere before an IN RNG cue can be obtained. See section 5.9 for additional information on range cueing.

2.15.2.5.9 Target Ranging Information. IRMV ranging HUD symbology includes the following:

1. IRMV legend - appears when IRMV is selected. The number of IRMVs loaded is also given (i.e., 2 IRMV).

   (a) Cage/Uncage status "U" next to IRMV indicates uncage status. Nothing indicates cage status.

   (b) A boxed IRMV indicates IRMV sensor mode.

2. AGR legend - in Radar aircraft, appears above the 2 IRMV legend. AGR is displayed when valid AGR exists.

3. IN RNG legend appears below IRMV legend and indicates the aircraft position is inside the IRMV aerodynamic launch envelope (Figure 2-126).

4. TGT legend and distance - appears below IN RNG legend and provides distance to target in nautical miles (Figure 2-126).

a. The DMT or INS is used for providing bearing and distance to the target. Baro corrected altitude is used to determine the altitude of the aircraft. With a DMT target designation, angle rates from the DMT and baro corrected aircraft altitude provide ranging information to the target track point. With an INS designation, ranging information is based on the HUD placement of the target designation (TD) diamond and baro corrected aircraft altitude; this requires that waypoint elevation be correctly entered by the pilot in order for ranging information to be accurate. Alternate sources for altitude data include global positioning system (GPS) and radar altimeter (RALT). For GPS or RALT to provide ranging information, an INS designation must exist and all parameters regarding GPS or RALT operation and validity must be met.

b. Radar Aircraft. The APG-65 can be used to locate the target and to slave the IRMV seeker to the target. After IRMV is locked onto the target, the APG-65 resumes scanning in the previously selected scan pattern (MAP / GMTT/ FTT). To get ranging information to the IRMV track point, schedule an INS/AGR update by actuating sensor select switch forward. When AGR becomes valid, it is automatically applied to the IRMV track point. Valid AGR is indicated by:

1. The AGR legend appearing in the HUD.

2. The wing planform (stores page) initializing on the right MPCD with AGR information displayed in the lower right corner.

With an INS designation, ranging information is provided based on the HUD placement of the TD diamond and baro corrected aircraft altitude; this requires that waypoint elevation be correctly entered by the pilot in order for ranging information to be accurate. Alternate sources for altitude data include global positioning system (GPS) and radar altimeter (RALT). For GPS or RALT to provide ranging information, an INS designation must exist and all parameters regarding GPS or RALT operation and validity must be met.

c. Target Ranging Summary. When IRMV is locked onto a target, the ranging information is based on IRMV gimbal angles and best available aircraft altitude.

2.15.2.6 IRMV Performance Charts. Charts on IRMV warhead penetration capability, range reduction due to bank angle, aerodynamic launch range, loft profiles, and splash patterns are found in NWP 3-22.5-AV8B, Vol. II, Chapter 2.

a. Missile Aerodynamic Range. IRMV aerodynamic range is a function of aircraft altitude, velocity, and target altitude. The HUD IN RNG legend indicates that the aircraft-to-target range is within the aerodynamic launch envelope of the missile. The aerodynamic launch envelopes of the IRMV missile are based on target lock-on within 10° of wings level for airspeed from Mach 0.3 to 0.9. The IRMV performance charts assume target elevation is 0 feet MSL altitude and target bearing is 0° (on the nose).

b. Missile Post-Launch Maneuver. IRMV preforms a lofting maneuver after launch to maximize the aerodynamic range of the missile. The amount of loft above the launch altitude is highest at low altitude and long range. The amount of loft above the launch point decreases as launch altitude increases and launch range decreases. Refer to the IRMV performance charts in NWP 3-22.5-AV8B, Vol. II, Chapter 2, to determine minimum clearance below overcast skies during mission planning. As an example (Missile Loft Profile - Mach 0.5) with a launch altitude of 1000 feet AGL and launch distance at 30,000 feet, the missile would loft to 1800 feet AGL in order to reach the target at 0 feet AGL.

2.15.2.7 IRMV Missile Launch. The following conditions are required for missile launch:

1. A/G mode - SELECTED

2. IRMV and priority station selected.

3. Fuzing option other than SAFE selected.

4. Master arm - ARM

5. The HOTAS missile uncage command not present after having been present (IRMV must be in track mode).

With the above conditions met, pressing the A/G weapon release (pickle) button launches the selected priority missile. At launch, the SMS steps to the next IRMV station in priority. The next IRMV is now ready to be uncaged. With a quantity greater than one selected, the second and subsequent IRMVs are automatically uncaged and slaved to the target designation following launch of the first IRMV. Launch tone is inoperable with IRMV; no launch tone is transmitted even if TONE is boxed.

If the missile commanded to launch is HUNG, the SMS steps to the next IRMV station in priority. HUNG weapon stations cannot be selected again until all other Maverick missile stations of the same type have been selected and launch attempted.

2.15.2.7.1 IRMV Missile Launch Constraints. The following launch limitations apply to the IRMV missile (refer to NWP 3-22.5-AV8B, Vol. II, Chapter 5):

1. Launch load factor: +0.5 to +3.0g

2. Roll rate: ±30° per second

3. Maximum dive angle: 60°

4. Maximum launch bank angle: 30°

5. Altitude:

   (a) Station 2 and 6. Minimum firing speed is 200 KCAS, sea level to 33,000 feet MSL. Launch is not authorized above 33,000 feet.

   (b) Station 3 and 5. Minimum firing speed is 400 KCAS, sea level to 10,000 feet MSL; 450 KCAS 10,000 to 15,000 feet MSL. Launch is not authorized above 15,000 feet MSL.

2.15.2.7.2 IRMV Weapon Release Data (WRD). WRD is not available on the MPCD or on the DSU for Maverick missile launches.

2.15.2.7.3 IRMV Backup Mode Operation. Primary operation consists of designation of the target with an aircraft sensor (RADAR/DMT/INS). If the radar, DMT or INS are inoperable or not used for tactical reasons (i.e., quick-reaction launch), IRMV can be used autonomously. The pilot can slew the IRMV symbol over possible targets as they appear in the IRMV video.

If the avionics mux bus is lost (mission computer failure), the SMS reverts to a backup release mode. In this mode, with IRMV selected (via ACP), point the aircraft at the target using the hot gun cross as an aiming reference. Press the cage/uncage button once to uncage the missile and a second time to command missile track (lock-on) on the target beneath the hot gun cross. Press the A/G weapon release (pickle) button to launch the missile. The field-of-view, polarity, ship track, and track mode boresight options are not available in the backup mode; the options selected at the time of the failure are used. The TDC is not available, and IRMV video is available when it was already being displayed or can be brought up using the weapon video (WPNV) pushbutton via the DC back-up mode.

If the armament bus fails the weapon system becomes inoperable and launch is not possible.

2.15.2.7.4 Hangfire Procedures. If a missile rocket motor fails to ignite upon a missile firing attempt, a hangfire has occurred. Deselect the IRMV missile. The mission may be continued with other missiles on board the aircraft. The missile may be safed after landing, but 1 hour should elapse between the firing attempt and missile downloading to allow the missile thermal battery to cool down.

2.15.2.8 Mixed Loads. If an LMAV and an IRMV are loaded on the aircraft, only one at a time may be selected.

If another store is being carried on the same mission with IRMV, selecting that store (bomb, CBU, etc.) deselects the IRMV. Once IRMV is reselected (boxed), video may be fuzzy for 3 minutes.

2.15.2.9 Captive IRMV Training Missile (CATM-65F). The CATM-65F is available for training with the IRMV missile. This missile consists of a standard IRMV missile with an inert rocket motor and a video tape recorder (VTR) added to the aft end of the missile. The

CATM-65F functions like the AGM-65F with the following exceptions:

1. External markings - the CATM-65F has blue bands painted on the missile body, compared to brown bands for the live AGM-65F.

2. The addition of the VTR to the CATM-65F often results in IRMV video "flicker" on the MPCD display; the picture blinks periodically, and sometimes disappears altogether for several seconds. This is caused by a timing imbalance induced by the VTR line loss, and should not occur with live AGM-65F missiles.

3. TRAINING MODE is not available with IRMV. CATM-65F uses the same stores code (55) as AGM-65F. If launch conditions are met and the pilot attempts to fire the CATM-65F (depresses pickle button), the SMS attempts to fire the missile and indicate HUNG for that store. The missile is then hung and cannot be reselected if there is a non-hung missile available. To use the hung CATM-65F missile again, attempt to fire the other non-hung CATM-65F to cause it to go hung; the other missile should then be selectable.

See NWP 3-22.5-AV8B, Vol. II, Chapter 2 for additional details on CATM-65F.

2.15.2.10 Operational Delivery Profiles

2.15.2.10.1 Night Attack Aircraft. For the Night Attack aircraft there are four operational delivery profiles, one for each aircraft sensor (DMT-TV, DMT-LST, and INS) and a fourth for IRMV autonomous operation (aircraft sensor not in use). Each operational delivery profile consists of a list of steps and indications for delivery of IRMV with either DMT-TV (paragraph 2.15.2.10.4), DMT-LST (paragraph 2.15.2.10.5), INS (paragraph 2.15.2.10.6), or IRMV autonomous operation (paragraph 2.15.2.10.7). All procedures assume the desired weapon program selections were made (i.e., fuzing and quantity) and a valid track mode boresight has been performed for all IRMV missiles loaded on the aircraft.

2.15.2.10.2 Radar Aircraft. For the Radar aircraft there are three operational delivery profiles, one for each aircraft sensor (radar and INS) and a third for IRMV autonomous operation (aircraft sensor not in use). Each operational delivery profile consists of a list of steps and indications for delivery of IRMV with a radar designation (paragraph 2.15.2.10.3), or an INS designation (paragraph 2.15.2.10.6) and autonomously (paragraph 2.15.2.10.7). All procedures assume the desired weapon program selections were made (i.e., fuzing and quantity) and a valid track mode boresight has been performed for all IRMV missiles loaded on the aircraft.

2.15.2.10.3 IRMV/APG-65 Radar Operation. The procedure for utilizing IRMV aided by the APG-65 radar is as follows:

1. APG-65 scanning (MAP designation/ GMTT/FTT)

2. A/G master mode - SELECT

3. IRMV - SELECT (RDY appears after 3 minutes)

4. Cage/Uncage button - PRESS AND RELEASE (IRMV video present, IRMV slaved to radar scan center)

5. Sensor select switch forward - Selects IRMV sensor mode

6. GMTT, FTT or RDR designation established - IRMV SLAVED TO RADAR TRACK POINT

7. SHIP - AS REQUIRED

8. PLTY - AS REQUIRED

9. MPCD - CONFIRM TARGET PROXIMITY TO CROSSHAIRS

10. FOV - SELECT NARROW FOV (no brackets in video)

11. Wings level, TDC - PRESS (commands track, IRMV locks on or near target, radar resumes scan)

12. Wings level, TDC - SWEETEN IRMV SOLUTION AND RELEASE (commands track, IRMV locks on target)

13. Sensor select switch - FORWARD (within 10 nm of target) - AGR UPDATED

VERIFY:

HUD-IRMV box not flashing
HUD-IN RNG appears
MPCD-pointing cross not flashing

14. MASTER ARM - ARM

15. A/G weapon release (pickle) button - PRESS AND RELEASE

If run is aborted -

16. MASTER ARM - SAFE

17. FOV or undesignate button - PRESS AND RELEASE (wide FOV, brackets in video, IRMV returns to radar scan center)

2.15.2.10.4 IRMV/DMT-TV Operation. The procedure for utilizing IRMV with a DMT-TV target designation is as follows:

1. Sensor select switch - AFT (TV video appears)

2. A/G master mode - SELECT

3. IRMV - SELECT (RDY appears after 3 minutes)

4. TDC - SLEW DMT/TV TO TARGET AND RELEASE

5. Cage/Uncage button - PRESS AND RELEASE (IRMV video, IRMV slaved to DMT track point)

6. Sensor select switch forward - Selects IRMV sensor mode

7. SHIP - AS REQUIRED

8. PLTY - AS REQUIRED

9. FOV - SELECT NARROW FOV (no brackets in video)

10. Wings level, TDC - PRESS (commands track, IRMV locks on or near target)

11. Wings level, TDC - SWEETEN IRMV SOLUTION AND RELEASE (commands track, IRMV locks on target)

VERIFY:

HUD-IRMV box not flashing
HUD-IN RNG appears
MPCD-pointing cross not flashing

12. MASTER ARM - ARM (weapon inhibit removed from HUD)

13. A/G weapon release (pickle) button - PRESS

If run is aborted -

14. MASTER ARM - SAFE

15. FOV or undesignate switch - PRESS (wide FOV, brackets in video, IRMV slaved to velocity vector)

2.15.2.10.5 IRMV/DMT-LST Operation. The procedure for utilizing IRMV with a DMT-LST target designation is as follows:

1. Laser code - ENTERED

2. Sensor select switch - AFT twice - LST mode selected

3. A/G master mode - SELECT

4. IRMV - SELECT (RDY appears after 3 minutes)

5. TDC - PRESS, SLAVE TD DIAMOND OVER TARGET (LST scans in NAR mode through TD diamond)

6. Cage/uncage button - PRESS AND RELEASE (IRMV video, IRMV slaved to DMT scan center)

7. Sensor select switch forward - Selects IRMV sensor mode

8. Verify LST lock - LST appears in IRMV video

9. SHIP - AS REQUIRED

10. PLTY - AS REQUIRED

11. FOV - SELECT NARROW FOV (no brackets in video)

12. Wings level, TDC - PRESS (commands track, IRMV locks on or near target)

13. Wings level, TDC - SWEETEN IRMV SOLUTION AND RELEASE (commands track, IRMV locks on target)

VERIFY:

HUD-IRMV box not flashing
HUD-IN RNG appears
MPCD pointing cross not flashing

14. Call - "LASER OFF"

15. MASTER ARM - ARM (weapon inhibit removed from HUD)

16. A/G weapon release (pickle) button - PRESS

If run is aborted -

17. MASTER ARM - SAFE

18. FOV or undesignate switch - PRESS (wide FOV, brackets in video, IRMV slaved to velocity vector)

2.15.2.10.6 IRMV/INS Designation Operation. The procedure for utilizing IRMV with an INS designation is as follows:

1. A/G master mode - SELECT

2. IRMV - SELECT (RDY appears after 3 minutes)

3. TDC - PRESS, SLAVE TD DIAMOND OVER TARGET (IF REQUIRED) AND RELEASE

4. Cage/uncage button - PRESS AND RELEASE (IRMV video, IRMV slaved to TD diamond position)

5. Sensor select switch forward - Selects IRMV sensor mode

6. SHIP - AS REQUIRED

7. PLTY - AS REQUIRED

8. MPCD - CONFIRM TARGET PROXIMITY TO CROSSHAIRS

9. FOV - SELECT NARROW FOV (no brackets in video)

10. Wings level, TDC - PRESS (commands track, IRMVlocks on or near target)

11. Wings level, TDC - SWEETEN IRMV SOLUTION AND RELEASE (commands track, IRMV locks on target)

VERIFY:

HUD-IRMV box not flashing
HUD-IN RNG appears
MPCD pointing cross not flashing

12. MASTER ARM - ARM (weapon inhibit removed from HUD)

13. A/G weapon release (pickle) button - PRESS

If run is aborted -

14. MASTER ARM - SAFE

15. FOV or undesignate switch - PRESS (wide FOV, brackets in video, IRMV slaved to velocity vector)

2.15.2.10.7 IRMV Autonomous Operation. The procedure for utilizing IRMV without the aide of aircraft sensors is as follows:

1. A/G master mode - SELECT

2. IRMV - SELECT (RDY appears after 3 minutes)

3. Cage/uncage switch - PRESS AND RELEASE (IRMV video, IRMV slaved to velocity vector)

4. Sensor select switch forward - Selects IRMV sensor mode

5. SHIP - AS REQUIRED

6. PLTY - AS REQUIRED

7. FOV - AS REQUIRED

8. Velocity vector - AT OR NEAR TGT

9. Wings level, TDC - PRESS (commands track, IRMV locks on or near target)

10. Wings level, TDC - SWEETEN IRMV SOLUTION AND RELEASE (commands track, IRMV locks on target)

VERIFY:

HUD-IRMV box not flashing
MPCD-pointing cross not flashing

11. MASTER ARM - ARM (weapon inhibit removed from HUD)

12. A/G weapon release (pickle) button - PRESS AND RELEASE

If run is aborted -

13. MASTER ARM - SAFE

14. FOV or undesignate switch - PRESS AND RELEASE (wide FOV, brackets in video, IRMV slaved to velocity vector)

PART II

AIR-TO-AIR WARFARE

CHAPTER 3

Air-To-Air Weapon Delivery Theory and Employment

3.1 INTRODUCTION

The A/A weapon system consists of the AIM-9L/M Sidewinder missile, the fuselage mounted gun, and associated controls and indicators (Figure 3-1). The A/A master mode is entered by selecting an air-to-air weapon with the weapon select switch on the control stick.

3.2 AVIONICS DESCRIPTION

Refer to chapter 1 for a complete description of the avionics subsystems.

3.3 A/A CONTROLS AND INDICATORS

3.3.1 Station Select Buttons. When in A/A master mode, the station select buttons on the ACP can be used as a backup method to select any Sidewinder station. This method is a manual station selection and ignores the normal priority sequencing. Selection of Sidewinder by this method also commands the boresight mode and SEAM cannot be selected.

3.3.2 IR Coolant Switch. The IR coolant switch is a two position switch with positions of OFF and IR COOL. The switch enables the pilot to manually apply IR (infrared) detector cooling to the Sidewinder seekers. Sidewinder seekers must be cooled for proper operation. Placing the IR coolant switch to IR COOL applies cooling to all Sidewinder stations. Placing the switch to OFF deselects IR cooling. For additional information refer to chapter 1, paragraph 1.14.5.4.8.

Sidewinder seeker cooling is automatically initiated by the SMC when a Sidewinder is selected and the master arm switch is placed to ARM.

3.3.3 Sidewinder Tone Volume Control. The auxiliary (AUX) control knob on the amplifier-control ACNIP controls the volume of the Sidewinder audio tone. Rotating the control clockwise increases the tone volume.

3.3.4 Master Arm Switch. The master arm switch controls armament power for A/A weapon launch/firing. The switch has positions of OFF and ARM. The OFF selection inhibits launch/firing of A/A weapons. Placing the master arm switch to ARM enables launch/firing.

3.3.5 HUD Symbology. Figure 3-2 depicts the relative size and location of symbols that may be displayed on the HUD in the A/A weapon mode.

Refer to chapter 23 in the NATOPS Flight Manual, A1-AV8BB-NFM-000, for description of the basic aircraft flight data symbology displayed on the HUD. These items include heading scale, velocity vector, flightpath ladder, altitude, G, angle of attack, calibrated airspeed, and Mach number.

3.3.5.1 Sidewinder Circle. The Sidewinder circle appears on the HUD when the Sidewinder is selected on the A/A weapon select switch. The circle is 28 mils in diameter and represents the Sidewinder seeker line-of-sight. It also indicates whether the Sidewinder is in an acquisition mode or locked on a target. When in acquisition mode the circle is dashed (broken); after seeker lock on the circles becomes solid. Two acquisition modes are selectable on the A/A weapon select switch, SW (boresight) and SEAM/Slaved to Radar LOS.

With SW selected the dashed Sidewinder circle is stationary and represents approximate Sidewinder seeker field of view. Targets must be placed within the circle to obtain target detection and seeker lock on.

With SEAM selected the dashed Sidewinder circle rotates to cover an area 64 mils in diameter to represent the expanded seeker field of view

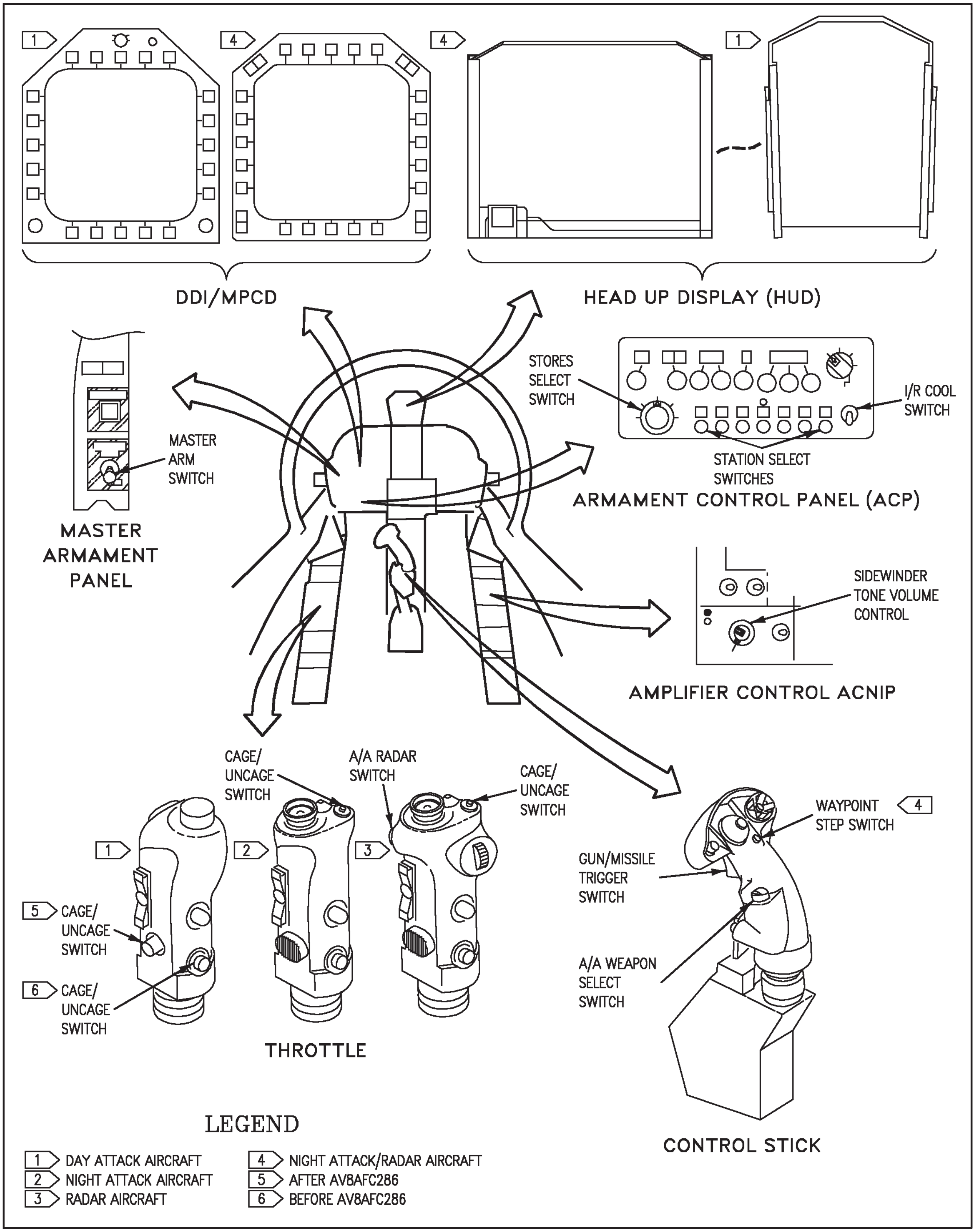


Figure 3-1. A/A Weapon Controls and Indicators

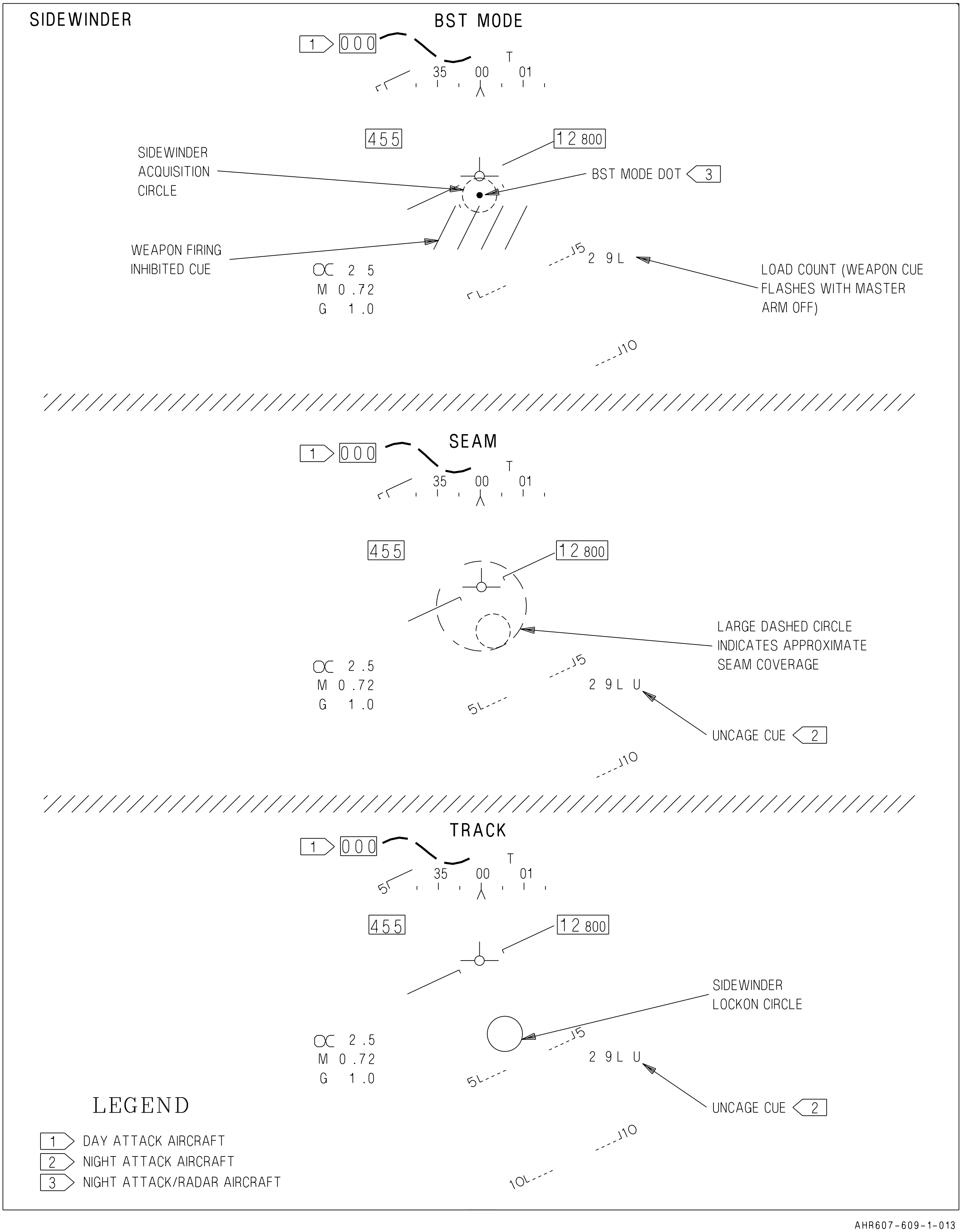


Figure 3-2. HUD Symbology (Sheet 1 of 2)

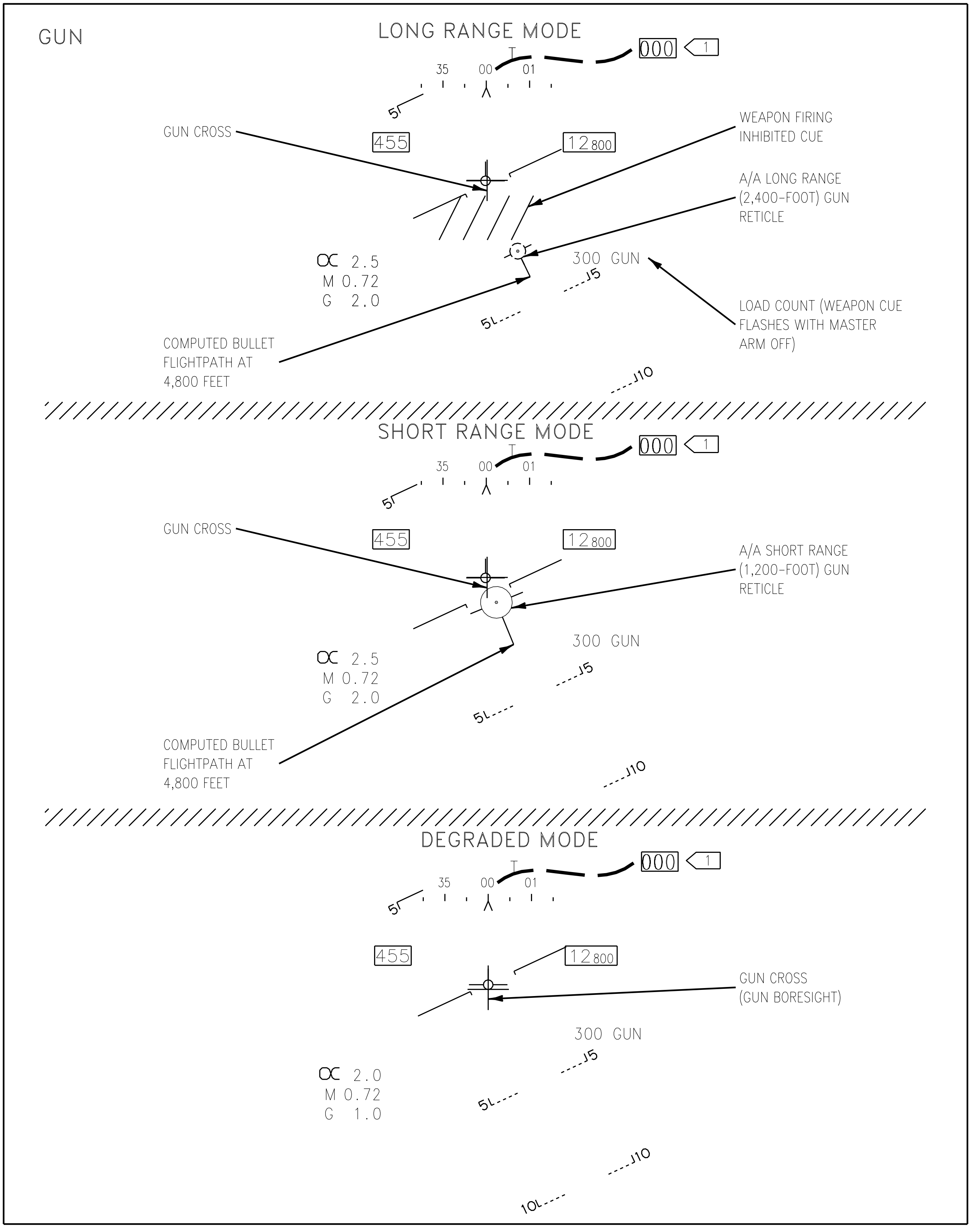


Figure 3-2. HUD Symbology (Sheet 2 of 2)

while it is in the circular scan mode. Targets must be placed within the circular scan area to obtain target detection and seeker lock on.

The dashed Sidewinder circle (either stationary or nutating) is replaced by a solid circle when Sidewinder seeker is commanded. The solid circle follows the tracking Sidewinder seeker head to denote LOS to the target.

In REJECT levels 1 or 2 the velocity vector is occluded when it touches the Sidewinder circle.

3.3.5.2 SEAM Circle. Upon selection of SEAM with the A/A weapon select switch, a SEAM circle (large dashed circles) appears on the HUD in which the Sidewinder acquisition circle nutates. The SEAM circle is 64 mils in diameter and represents the total SEAM FOV. At missile lock on the SEAM circle is removed and the (dashed) Sidewinder acquisition circle is replaced with a solid circle..

3.3.5.3 Gun Reticle. A long range reticle and a short range reticle are provided for gun employment. Either reticle may be selected by the pilot with the cage/uncage button on the throttle.

When A/A gun is initially selected, the long range reticle appears as a winged dashed circle with a straight line protruding beneath it. The dashed circle is 12.5 mils in diameter with an aiming dot in the center and is optimized for a range of 2,400 feet. The wings extending from the reticle are designed to provide a roll reference to the pilot and are 5.5 mils in length. The line extending from beneath the long range reticle constantly changes length and direction as the aircraft maneuvers to point to where the computed bullet flightpath is at 4,800 feet.

The short range reticle is larger than the long range reticle and appears as a winged continuous circle with a straight line beneath it. The continuous circle is 25.5 mils in diameter with an aiming dot in the center and is optimized for a range of 1,200 feet. The wings extending from the reticle are designed to provide a roll reference to the pilot and are 10 mils in length. The line extending from beneath the short range reticle is identical to the one beneath the long range reticle. The line constantly changes length and direction as the aircraft maneuvers and points to where the computed bullet flightpath is at 4,800 feet.

In the computed firing mode (steady state condition), the center of the long range and short range reticles represent the computed bullet flightpath at the appropriate firing range.

Gun reticle deflection is limited to 6.7° from the optical center of the HUD. The reticle flashes at a 2 Hz rate when limited.

3.3.5.4 Gun Cross. The gun cross appears on the HUD in the A/A gunnery mode. The cross is displayed at gun boresight position which is 2° below the waterline.

3.3.5.5 Firing Inhibit Cue. The firing inhibit cue (barber pole) appears on the HUD if weapon firing launch is inhibited for reasons, such as weapon count of zero or SMS BIT failures detected. The position of the master arm switch is not included in the release ready logic; that is, a firing ready indication can be obtained with the master arm switch in OFF or ARM. However, the gun legend will flash when the master arm switch is OFF.

3.3.5.6 Load Count. Load count is displayed on the HUD for either gun or Sidewinder. With gun selected, the load count indicates rounds remaining, and in Sidewinder mode, the number of Sidewinders loaded is displayed.

3.3.6 DDI Displays. Figure 3-3 depicts the A/A displays that can be selected on the DDI.

3.3.6.1 Stores Display. The stores display is obtained by selecting the stores (STRS) option from the menu legends on the DDI. The A/A load (Sidewinder stations and gun rounds) is inserted on the weapon loadout panel by maintenance personnel (see chapter 1). These store codes appear on the stores displays wing form as alphanumeric legends. Figure 3-3 shows Sidewinder missiles loaded on outboard and intermediate wing pylons and 300 rounds of ammunition in the fuselage gun. With Sidewinder selected, the inverted triangle symbol adjacent to the 9L legend indicates the

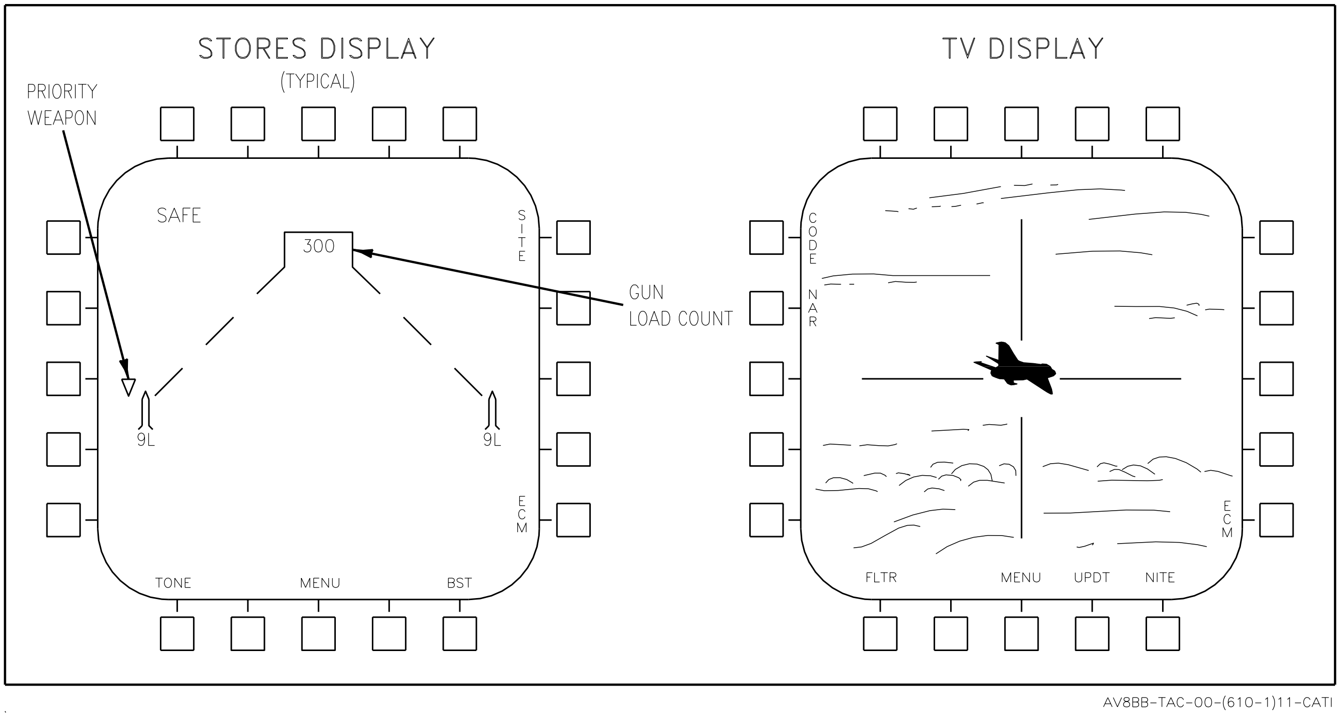


Figure 3-3. DDI Displays

priority station; i.e., the station from which the first Sidewinder will be launched.

The rounds remaining indication will decrement as the fuselage gun is fired to always indicate the number of rounds available.

3.3.6.2 Sidewinder Boresight Option. The BST (boresight) option appears on the DDI stores display (Figure 3-3) when Sidewinder is selected and the master arm switch is OFF (SAFE displayed on DDI). The boresight option enables the pilot to align the HUD symbology (Sidewinder circles) with the Sidewinder seeker head position.

Actuate IR coolant switch to IR COOL. Point Sidewinder missile at an IR target and compare sharp tone position relative to the Sidewinder circle on the HUD. If the target is outside the Sidewinder circle when the sharp tone is heard, lock on to the target. Select BST option on DDI and slew the Sidewinder circle over the target using the TDC. This function also provides alignment for the DMT TV display. This procedure must be repeated for each Sidewinder on board. Step to the next Sidewinder station using the weapon select switch. To exit this mode deselect the BST option.

If the alignment does not seem to be correct after boresight procedure, the alignment slewing can be cancelled by actuating the cage/uncage button in the BST (alignment) mode. The boresight procedures can then be repeated.

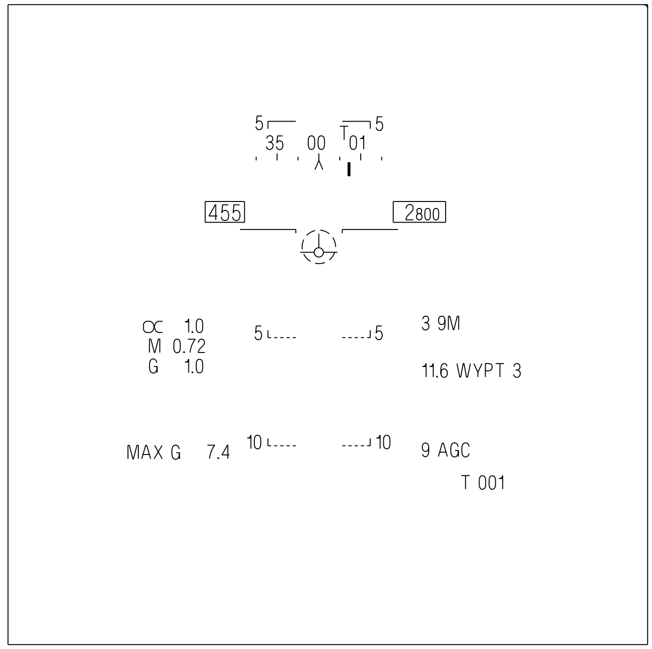
3.3.6.3 DMT TV Display. On Day and Night Attack aircraft, the DMT TV display can be utilized in the A/A mode. When the DMT is ON and a Sidewinder is locked on a target, the TV sensor is automatically slaved to the Sidewinder seeker LOS and provides a 6:1 magnification of the target if the DMT display on the sensor switch is selected.

3.4 AIR-TO-AIR RADAR MODES AND OPERATION

3.4.1 Sidewinder Operation. Boresight and Slaved to Radar LOS Sidewinder modes are available for selection. Once selected, subsequent selection of the respective AIM-9 weapon select switch steps Sidewinder stations the same as the current AV-8B mechanization. On the Radar aircraft, selecting Sidewinder also automatically initializes the radar to the appropriate radar mode depending on tracking status or AIR option selection in NAV, VSTOL, or A/G. Whenever a new Sidewinder mode (Boresight or Slaved to Radar LOS) is selected while in A/A master mode or while in NAV, VSTOL, or A/G master mode with the radar operating in a surface radar mode, the radar is commanded to RWS using the “SET” search parameters. If the aircraft master mode was NAV, VSTOL, or A/G and the radar was operating in an Air radar mode prior to the pilot selecting Sidewinder, then the existing radar mode and search parameters are maintained rather than going to RWS with the “SET” values. If while in the A/A master mode with Sidewinder selected, the pilot reselects Sidewinder Boresight or Slaved to Radar LOS, then a Sidewinder station step occurs and the radar mode and search parameters remain the same. The following default “SET” parameters are used:

Sidewinder
140° Azimuth
4 Bar Elevation
INTL PRF
8 second Aging
40 nm Range Scale

As in the Day and Night Attack aircraft, the station selected and missile status is available on the STRS format on the MPCD. The formats presented on the HUD and MPCD depend on whether the radar is operating and its tracking status.



AHR607-591-1-013

Figure 3-4. HUD With No Sidewinder or Radar Track Options

3.4.1.1 Radar Not Operating. Sidewinder mechanization with the radar off is Boresight mode only. A 1.5° dashed circle representing the AIM-9 seeker line-of-sight is displayed boresighted 2° below aircraft waterline when the Sidewinder is not tracking. See Figure 3-4.

As in the Day and Night Attack aircraft, the pilot can maneuver the aircraft to position the target within the missile acquisition circle and, when audio tone is present, press the cage/uncage switch on the throttle to command Sidewinder lock on. When lock on is achieved, the dashed circle is replaced by a solid circle and tracks across the HUD. Also, a chirping audio tone from the AIM-9L or a lock on tone from the AIM-9M is provided. With the Sidewinder tracking, actuating the cage/uncage switch breaks track and returns the Sidewinder to the boresighted position. This is indicated by the reposition of the Sidewinder circle to the boresight position and its changing from a solid (tracking) to a dashed (acquisition) circle.

3.4.1.1.1 Radar Operating But Not Tracking. If the radar is operating but not tracking, selecting the Sidewinder mode initializes the radar to

RWS and the stored search initialization parameters (SET) are selected unless the AIR option is selected (NAV, VSTOL, or A/G master modes). As previously described, with AIR selected, the current radar mode and operating parameters are retained.

The AIM-9 initialization parameters (either default or pilot modified through the SET option) appropriate to Boresight or Slaved to Radar LOS operation are enabled. Once in Sidewinder mode, the pilot can change radar search parameters as desired. These parameter values are retained when changing the selected AIM-9 station but not retained as initialization parameters. When not tracking, the selected missile seeker is caged at boresight and the AIM-9 seeker circle is displayed on the HUD. The HUD display appears the same as without the radar operating.

The pilot can change search and acquisition modes as desired after Sidewinder initialization. All ACM modes (except GACQ), all search modes, and AACQ are available with Sidewinder selected.

3.4.1.2 Radar Tracking. If the radar is in STT or in TWS with a Launch & Steer (L&S) target, the missile seeker is automatically slaved to the radar LOS represented by the TD box if Slaved to Radar LOS is selected. Whenever the radar and the Sidewinder are tracking the same target, steering and launch acceptability cues are provided both head-up and head-down (covered below). The only exception to this is when angle-of-coincidence (i.e., close together) fails and the missile is tracking from the boresight position. In this situation, steering commands are not displayed since boresight lock on was most probably commanded by an overt pilot action and does not represent the radar track. See Figure 3-5.

To command Sidewinder lock on, the pilot depresses the cage/uncage switch. If a track is achieved, the chirping or lock on tone is heard in the pilot's headset. If a lock on is not achieved within 1 second, the results depend on the missile mode that was selected (Boresight or Slaved to Radar LOS) Once Sidewinder track is achieved, the dashed circle is replaced by a solid circle. When the TD box and Sidewinder seeker circle exceed the HUD FOV limits, the sidewinder seeker circle flashes to indicate the target being tracked by the radar is outside the HUD FOV. If radar gimbal limits are exceeded, radar lock is broken and the Sidewinder is caged at boresight.

3.4.1.3 Boresight Mode. The Sidewinder Boresight mechanization remains basically unchanged from the Day and Night Attack aircraft. When Sidewinder Boresight is selected or station step is commanded while in Boresight mode, the missile is always caged at missile boresight regardless of whether or not the radar has a valid angle track. Once the cage/uncage switch is depressed, the missile is commanded to track the target. If the missile fails to achieve lock within 1 second or the pilot selects cage/uncage, the missile is re-caged at the boresight position. If the missile achieves lock and then subsequently loses its lock or if the pilot selects cage/uncage, the missile is re-caged at boresight.

3.4.1.4 Slaved to Radar LOS (RDR) Mode. When RDR is selected or station step is commanded while in RDR mode, the missile is slaved to the Radar LOS. Angle of Coincidence (AOC) is the primary requirement for the AIM-9 to lockon in this mode and allows the missile to self track without a valid tone. AOC is defined as the angle between the Radar LOS and the missile seeker LOS. When the AOC is 1.5° or less the missile attempts to self track without a valid tone. When a valid tone is present, the missile self tracks as long as the AOC is 5° or less. If the cage/uncage switch is pressed and held the AOC check is eliminated and the missile attempts to self track until the switch is released.

Any time the missile is in self track, quickly pressing and releasing the cage/uncage switch reslaves the missile to the Radar LOS.

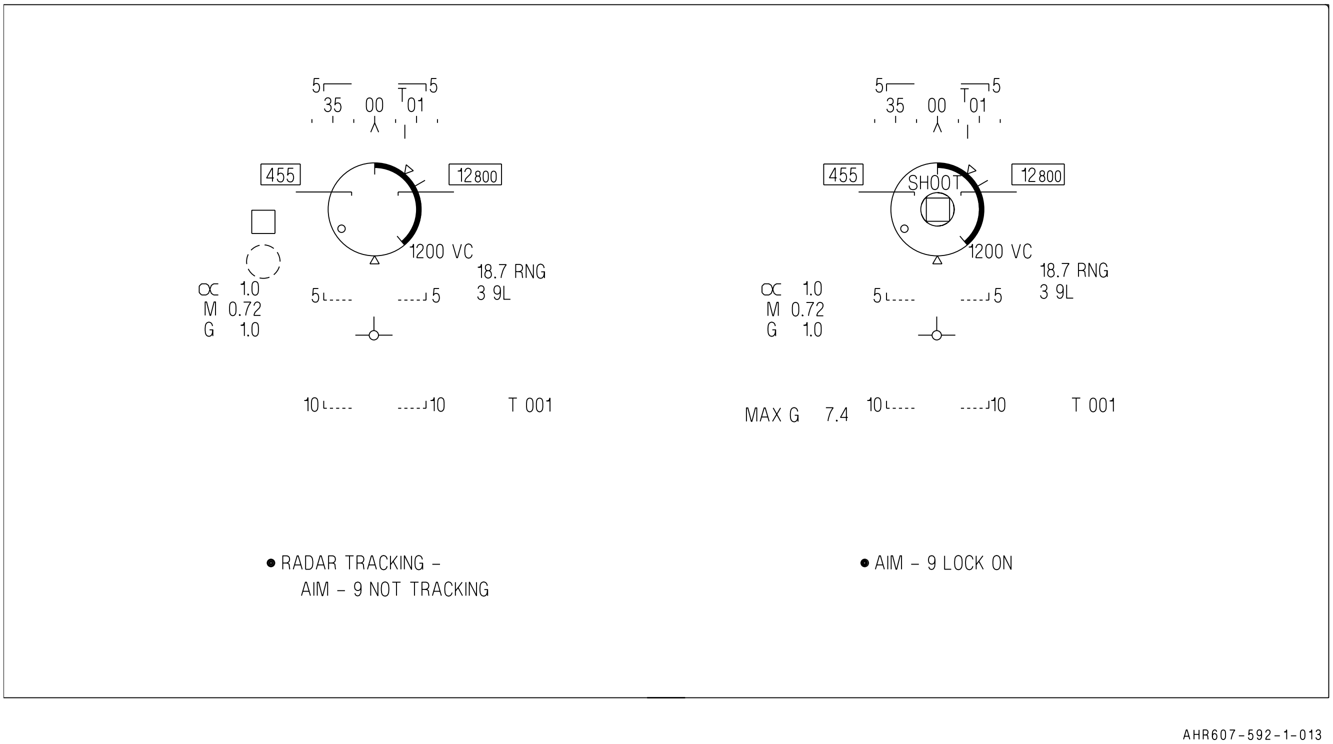


Figure 3-5. Radar Sidewinder Display

3.4.1.5 Sidewinder Symbology with Radar Tracking. As noted, both the HUD and head-down radar display provide steering information via a steering dot and allowable steering error (ASE) circle, missile in-range information via R_{min} and R_{max} indicators, and missile firing command via a SHOOT legend.

3.4.1.6 Allowable Steering Error (ASE)/Steering Dot. The allowable steering error is represented on the HUD via the Normalized In-Range Display (NIRD). The NIRD/ Steering Dot are used to provide the pilot with steering information which he used in conjunction with the launch acceptability region data to determine when the Sidewinder missile is within desirable launch conditions. See Figure 3-6.

The pilot flies the aircraft so that the steering dot is inside the NIRD circle. When the steering dot is inside the NIRD circle, the aircraft is within the allowable steering error for the Sidewinder missile. The ideal launch condition would be when the steering dot is positioned in the center of the NIRD circle. The NIRD/ Steering Dot are displayed when the Sidewinder missile is selected, the radar has a complete STT or TWS track file and the missile is slaved to the radar or tracking the same target as the radar. The angle-of-coincidence check performed within the MC determines whether or not the Sidewinder and the radar are tracking the same target.

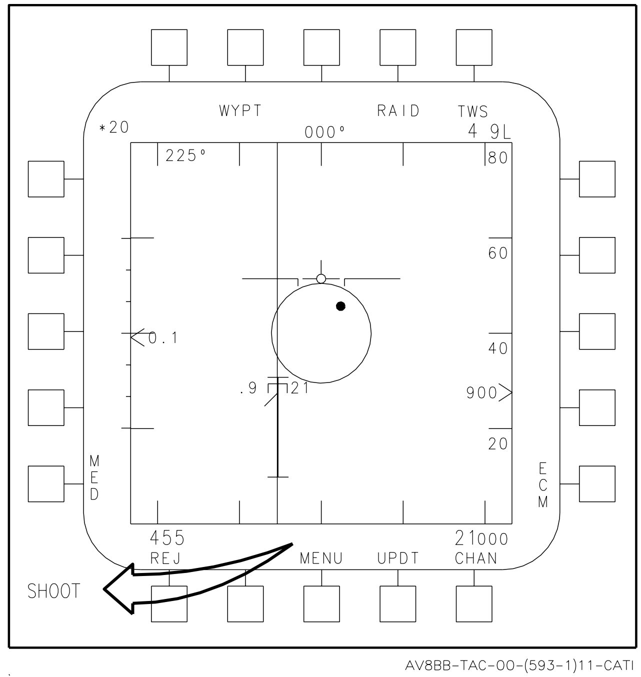


Figure 3-6. Sidewinder STT Radar Display Options

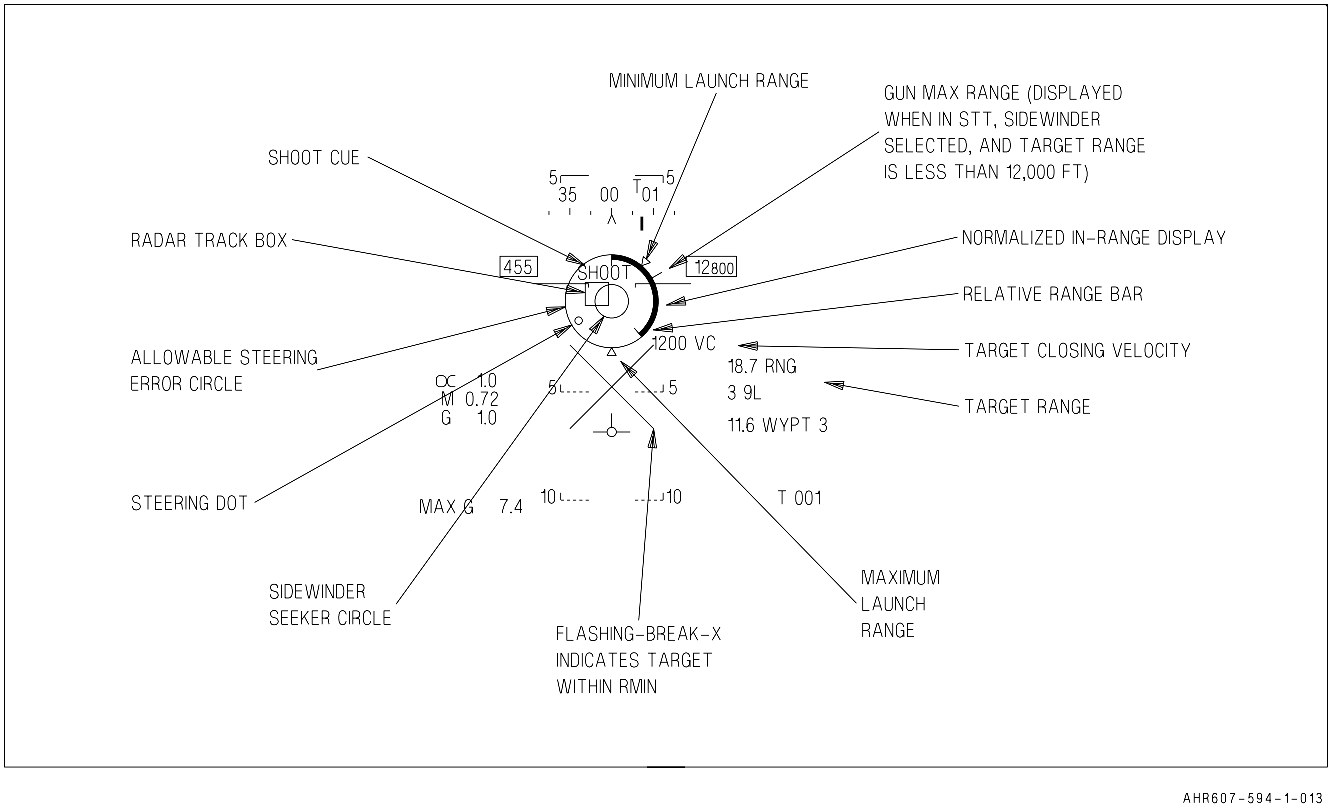
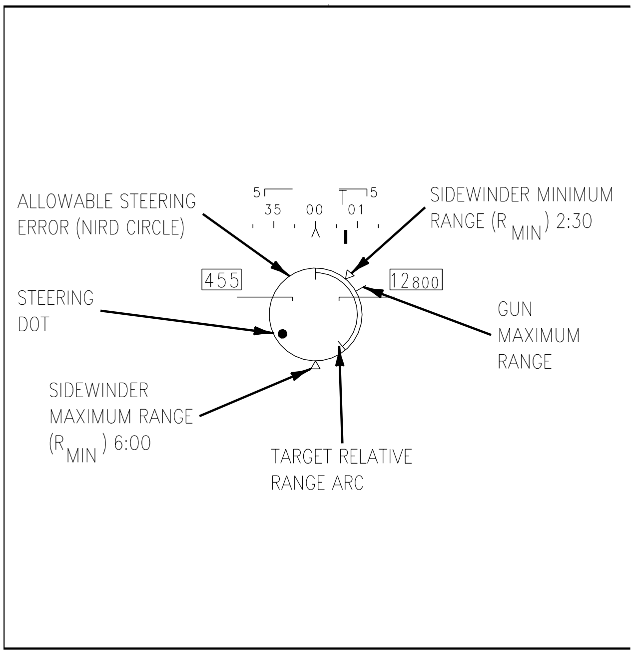


Figure 3-7. HUD Sidewinder Symbology With Radar Tracking

3.4.1.7 Launch Acceptability Region (R_{min}, R_{max}) for Sidewinder. The Launch Acceptability Region is displayed to indicate to the pilot when the target is within the minimum and maximum launch ranges for the Sidewinder missile. The minimum and maximum launch ranges are computed and displayed on the HUD and radar displays.

The launch zone information is displayed when the Sidewinder is selected, the radar has a full track in TWS or STT, the Sidewinder is slaved to the radar or the Sidewinder and the radar are tracking the same target, and a “no zone” condition does not exist. The “no zone” condition is defined as when R_{min} exceeds R_{max} for the computed intercept.

HUD Sidewinder symbology with the radar tracking is shown in Figure 3-7.



AV8BB-TAC-00-(595-1)11-CATI

Figure 3-8. Normalized In-Range Display Options

3.4.1.8 Normalized In-Range Display (NIRD). Consists of a 6° diameter circle centered on the aircraft waterline, a relative range bar displayed inside and tangential to the circle and weapon launch envelope marks on the outside of the circle. The relative range bar emanates from the 12:00 position and rotates clockwise as range increases. The NIRD circle flashes at 2.5 times per second when the radar tracked target is within 15° in azimuth and 5° in elevation of the radar gimbal limits. If a radar lock on is provided but the Sidewinder achieves lock on from boresight, the NIRD circle is not provided unless angle-of-coincidence is valid. See Figure 3-8.

Target Range - Indicates range to the target in tenths of a nautical mile.

Target Closing Velocity - Indicates target range rate in knots to the nearest 10 knots. Closing velocities are displayed as positive numbers and opening velocities are displayed as negative numbers.

Maximum Launch Range - Indicates computed maximum launch range. Displayed at 6:00 on the NIRD circle when target range is available from the radar.

Minimum Launch Range - Indicates computed minimum launch range. Displayed at 2:30 position on NIRD circle when target range is available from the radar.

Relative Range Bar - Indicates target range relative R_{max} and R_{min}. Displayed inside the NIRD circle whenever the radar set is tracking a target and is removed in the case of a “no zone” condition.

Gun Maximum Range - Indicates maximum effective gun firing range. Displayed on outside of NIRD circle only in STT and range less than 12,000 feet.

SHOOT Legend - Appears flashing on the HUD display when the following conditions are met: Master Arm is selected, the radar and Sidewinder are tracking the same target, the Sidewinder tone is valid, target range is between R_{max} and R_{min}, and the steering dot is within ASE circle. Displayed directly above the TD box.

Target Designation Box - The TD box is a 25 mil square which indicates the radar LOS to the target. It is positionable over the total HUD FOV and flashes at 2.5 times per second when the radar is in MEM.

Steering Dot - In conjunction with the NIRD circle, a steering dot indicates pure pursuit steering. It, along with the NIRD circle, flashes at 2.5 times per second to indicate the target is within 15° of radar azimuth gimbal limits or within 5° of the elevation gimbal limit.

Breakaway X - Indicates the range to target is less than R_{min} and the pilot must alter his position to achieve a weapon solution. Displayed at the HUD optical center and flashes at 2.5 times per second.

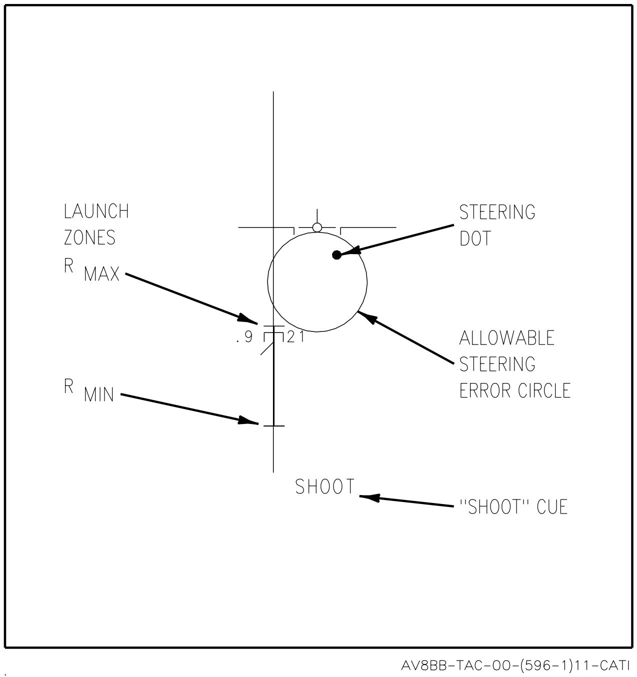


Figure 3-9. Head Down Sidewinder Launch and Steering Information Options

NOTE

It is important to remember that the Break X has two separate functions; one for the A/G master mode (ground avoidance "Altitude Alert Cue") and one for the A/A master mode) target range less then R_{min}).

3.4.1.9 Head-Down Sidewinder Display. The Sidewinder can also be delivered head-down using the information provided on the radar display. This information includes a launch acceptability reticle and steering information as shown in Figure 3-9. This information is not presented unless radar lock on is achieved.

Similar to HUD information, launch range information and a SHOOT cue are provided on the MPCD. However, the launch range presentation has not been "normalized" for combined presentation with the allowable steering error circle (ASE). Instead, it is presented as R_{max} and R_{min} tick marks along a half-intensity azimuth line bracketing the L&S or STT target and indicates absolute rather than relative range. Unlike the HUD, neither the seeker pointing circle or the TD track box is presented on the display. Therefore, whether the Sidewinder and radar are tracking the same target cannot be determined from the radar display until all launch conditions are met and the SHOOT legend is flashed indicating satisfactory angle of coincidence. Tracking information is available head-up or head-down with the HUD displayed on the other MPCD.

Like the HUD, the steering information presented indicates the allowable steering error. When the radar set is tracking a target, the weapon system computes a pursuit steering solution without lead to position the steering dot with respect to the allowable steering error circle. As on the HUD format, with missile lock on, it is the pilot's task to fly the steering dot into the circle which remains fixed at the center of the display. The ASE circle and steering dot are flashed if the target LOS is within 15° of radar gimbal limits.

3.4.1.10 Launch Sequence. Like the Day and Night Attack aircraft, the Sidewinder missile can be launched anytime the master arm logic is in the ARM state (i.e., no inhibits such as weight-on-wheels), an AIM-9 is selected, and the trigger is depressed. Missile lock on is not a prerequisite for launch and the missile can be launched with lock on achieved during flight. However, radar slaving greatly increases chances for Sidewinder lock on at the earliest possible time in the launch sequence, and launch and steering symbology make it easier for the pilot to determine launch requirements. In addition to auditory cueing, acceptable launch conditions are visually indicated by the launch and steering symbology and directly through the addition of the SHOOT legend. A flashing SHOOT cue is displayed when the following conditions are met:

1. Sidewinder onboard/selected
2. Radar/Sidewinder tracking same target
3. Sidewinder tone valid
4. Master arm switch - ARM
5. Target range between R_{max} and R_{min}

6. Steering dot is within ASE circle

The display cueing mechanization along with HOTAS operations ensures a straight forward launch sequence as described in Figure 3-10. The sequence described assumes Sidewinder was selected from NAV, VSTOL, or A/G master mode without the AIR option enabled.

Pilot Action	System Response
1. Select Sidewinder or SEAM using A/A weapon select switch on flight control stick.	1. SMS automatically selects missile station. RWS radar mode initiated. 2. Sidewinder seeker circle display on HUD. 3. RWS format displayed on right MPCD.
2. Command radar acquisition either manually using radar display or one of the auto acquisition modes.	1. Radar display changes to acquisition display. 2. Selected acquisition mode legend displayed on HUD. 3. TD box appears with radar lock on. 4. NIRD circle displayed on HUD. 5. Radar display acquisition format changes to STT format.
3. Command Sidewinder track by depressing cage/uncage switch.	Track indicated by dashed circle changing to solid.
4. Verify Sidewinder/radar coincident track. Check tone.	Solid circle located in immediate vicinity of TD box.
5. Fly aircraft to place steering dot in ASE circle.	HUD and radar display indicate relative position and flight solution.
6. Monitor launch solution and depress trigger to launch missile.	Steering and range indications met. SHOOT cue provided.

Figure 3-10. Sidewinder Launch Sequence With Radar Tracking

3.5 AIR-TO-AIR BACKUP WEAPONS DELIVERY

The aircraft has limited backup weapons delivery capability in the air-to-air master mode.

The weapons delivery avionics interface with each other and the air-to-air weapons retains Sidewinder launch and/or gun firing capability after sustaining an avionics failure. Figure 3-11 represents the basic relationship between weapon delivery avionics and the air-to-air weapons. Figure 3-12 summarizes lost capabilities, backup displays, and alternate selections for specific avionics failures that affect air-to-air weapons employment.

3.5.1 HUD Failure. If the HUD fails, the Sidewinder and fuselage gun selection are unimpaired. On Day Attack aircraft, select the standby reticle on the HUD. Set the depression angle to 40 mils to approximate the centroid/center of the Sidewinder FOV in SEAM/SW and to approximate the position of the fuselage gun boresight. The actual centroid/center of the Sidewinder FOV in SEAM/SW is located 35 mils below the waterline. Targets must be placed within 32 mils of the centroid of the FOV in SEAM or within 14 mils of the center of the FOV in SW to obtain target detection and seeker lock on.

If the fuselage gun is selected, the depression angle for the standby reticle can be set to approximate the position of the gun boresight (actually 35 mils below the waterline) or adjusted to indicate the elevation lead angle required for a desired firing range. The pilot must estimate the elevation and azimuth lead angles for gun employment when the standby reticle is used. HUD symbology can be displayed for reference on the DDI by selecting MENU, then the HUD option.

3.5.2 INS Attitude Failure. Several different types of INS failures can occur which will affect fuselage gun employment. In general, INS failures result in loss of the computed gun reticles if INS derived body rates are not valid. Sidewinder employment is not affected.

If INS attitude fails, the pilot loses HUD attitude, INS position keeping, and true heading. The pilot is alerted to INS failure by illumination of the MASTER CAUTION light, CIP/AUT light, and the INS light. The velocity vector is replaced by the waterline symbol when HUD attitude is lost. Use the standby attitude indicator.

If the fuselage gun is selected, INS attitude failure causes the backup gun mode to be automatically selected. The computed gun reticle is removed and the pilot must use the fixed gun cross. The pilot must estimate the elevation and azimuth lead angles for gun employment when the fixed gun cross is used.

3.5.3 ADC Failure. If the ADC fails, the pilot loses airspeed, barometric altitude, AOA, and vertical velocity (FPM) on the HUD. The pilot is alerted to ADC failure when the MASTER CAUTION and CIP/AUT lights illuminate, ADC derived information is removed from the HUD and DDI, and the waterline symbol is displayed in place of the velocity vector. Sidewinder employment is unaffected. If the fuselage gun is selected, the gun reticles will be displayed; however, ADC derived information used in the computer calculations for the display will be replaced with fixed values. For the purpose of the calculations, AOA is fixed at 3°, true airspeed is calculated by subtracting pilot entered winds from INS velocities, and aircraft altitude is assumed to be 5,000 feet. Use the standby instruments for airspeed, altitude, AOA, and vertical velocity.

3.5.4 MC Failure. If the MC fails, the system automatically reverts to a backup mode operation. This is indicated by the presences of the HUD symbology on both the HUD and DDI, and the illumination of the MASTER CAUTION and CIP/AUT lights.

In backup mode, the display computer provides limited communications with other avionics systems on the mux bus in order to provide the HUD VSTOL and HUD NAV display. This occurs automatically if the MC switch on the

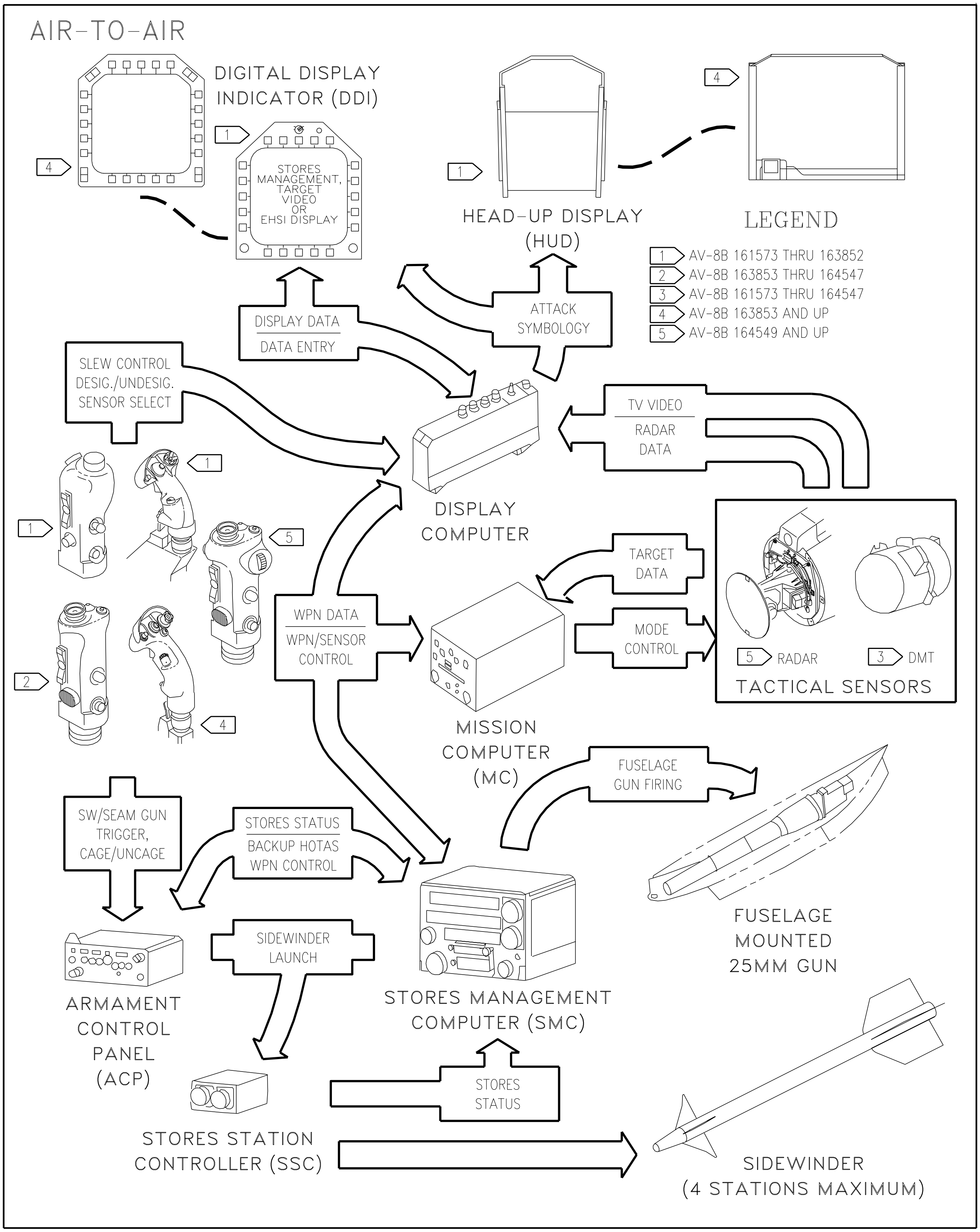


Figure 3-11. A/A Weapon Management Interface

miscellaneous switch panel is set to AUTO (normal flight position) or OFF. In the OVRD position, STANDBY will be displayed on the DDI and HUD because the automatic backup mode function is overridden and no communications is taking place on the mux bus.

In the backup mode, all master modes are selectable; however, only the HUD NAV or HUD VSTOL displays are available. In the A/A master mode, the HUD NAV display will appear. True heading, true airspeed, aircraft G, and DDI pushbutton options are not displayed. The SEAM capability is lost. If SEAM selection is attempted, SW will be selected.

The Sidewinder and gun reticles are not available after MC failure. Select the standby reticle on the HUD. Set the depression angle to 40 mils to approximate the center of the Sidewinder FOV or fuselage gun boresight (actually 35 mils below the waterline).

If Sidewinder is selected, the capability to slave the DMT to an AIM-9 seeker as well as previously discussed Sidewinder indications are lost. Targets must be placed within 14 mils of the center of the Sidewinder FOV to obtain target detection and lock on.

3.5.5 SMC Failure. The pilot is alerted to the SMC failure when the MASTER CAUTION and CIP/AUT lights illuminate. In this situation the DDI stores display is blank and the HUD reverts to a backup NAV display with the gun cross. There are no computed aiming reticles for either SW or gun although the standby reticle may be used to approximate the location of the Sidewinder FOV by setting a 40 mil depression angle (actual SW depression is 35 mils). Sidewinder capability is further reduced due to the loss of SEAM, cage/uncage, automatic IR cooling, and SW load count on the HUD. HOTAS is still functional for SW and gun selection; however, the SEAM position of the A/A weapon select switch is inoperative. The ACP may also be used for SW selection by depressing the desired station select button. There are no cues for either gun rounds remaining or gun not clear.

3.5.6 SMC and ACP Processor Failure. The pilot is alerted to this failure mode by illumination of the MASTER CAUTION and CIP/AUT lights. In addition, ACP processor failure is indicated by all the windows displaying dash (-) or zero (0) and no response when any control switch or station select button is actuated (MAN switch is NORM). In this situation the DDI stores display is blank and the HUD reverts to a backup NAV display with the gun cross.

There are no computed aiming reticles for either SW or gun although the standby reticle may be used to approximate the location of the Sidewinder FOV by setting a 40 mil depression angle (actual SW depression is 35 mils). The gun cross is available for the fuselage gun. Sidewinder capability is further reduced due to the loss of SEAM, cage/uncage, automatic IR cooling, SW load count, tone and HOTAS selection. HOTAS selection for the gun is still operable (SW and SEAM positions are inoperative). The ACP must be used for Sidewinder selection/display/step by rotating the MAN knob out of the NORM position and selecting the desired station select button. Sidewinder launch in this failure mode is accomplished by ensuring that the A/G master mode light is on and pressing the bomb pickle button instead of using the trigger.

WARNING

A potential for inadvertent stores release exists since a release pulse will be sent to all selected stations.

There are no cues for either gun rounds remaining or not clear.

If the fuselage gun is selected, the depression angle for the standby reticle can be set to approximate the position of the actual gun boresight or can be adjusted to indicate the elevation lead angle required for a desired firing range. The pilot must estimate the elevation and azimuth lead angles for gun employment when the standby reticle is used. No rounds remaining indication is available.

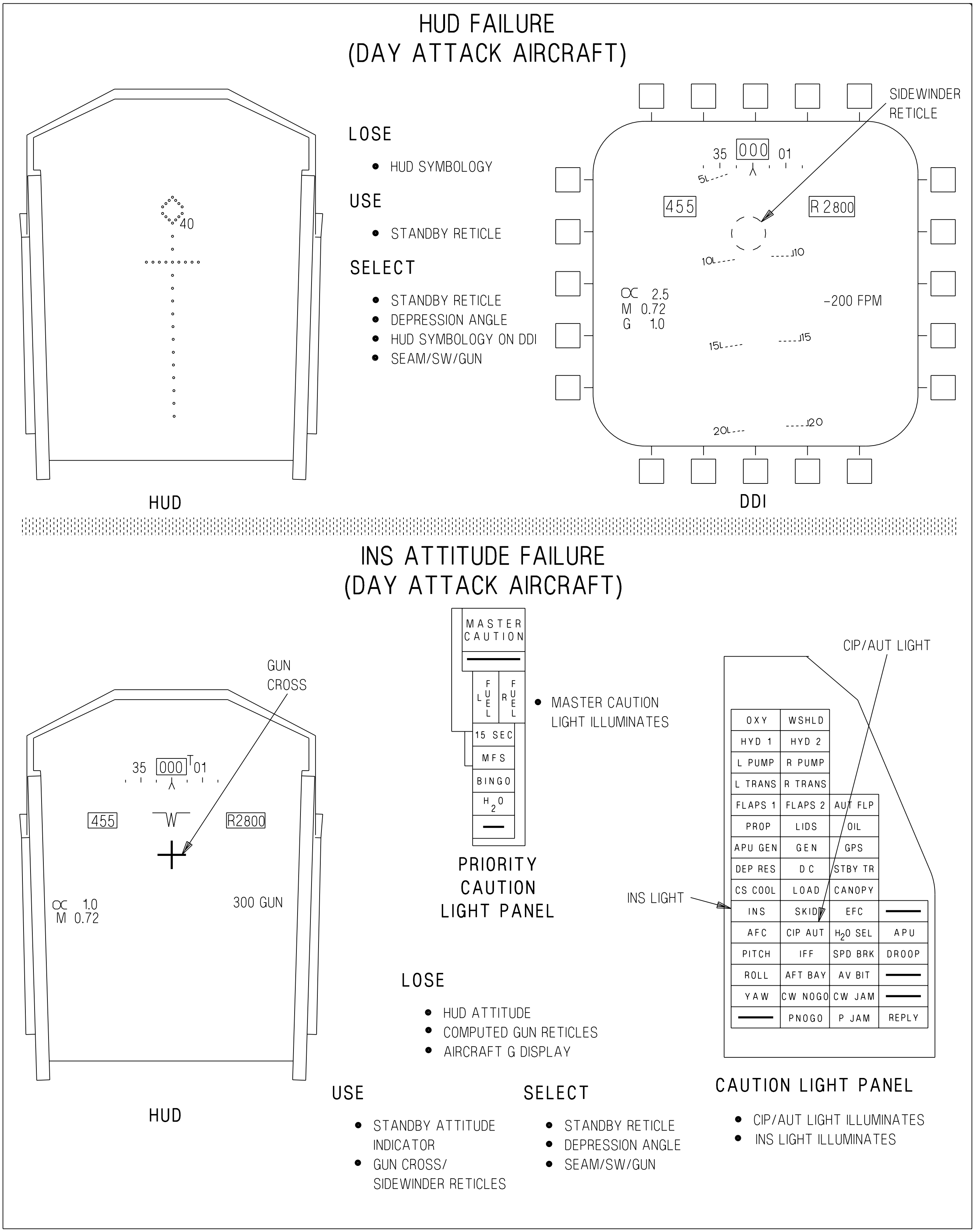


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Figure 3-12. A/A Weapon Backup Weapons Delivery (Sheet 1 of 8)

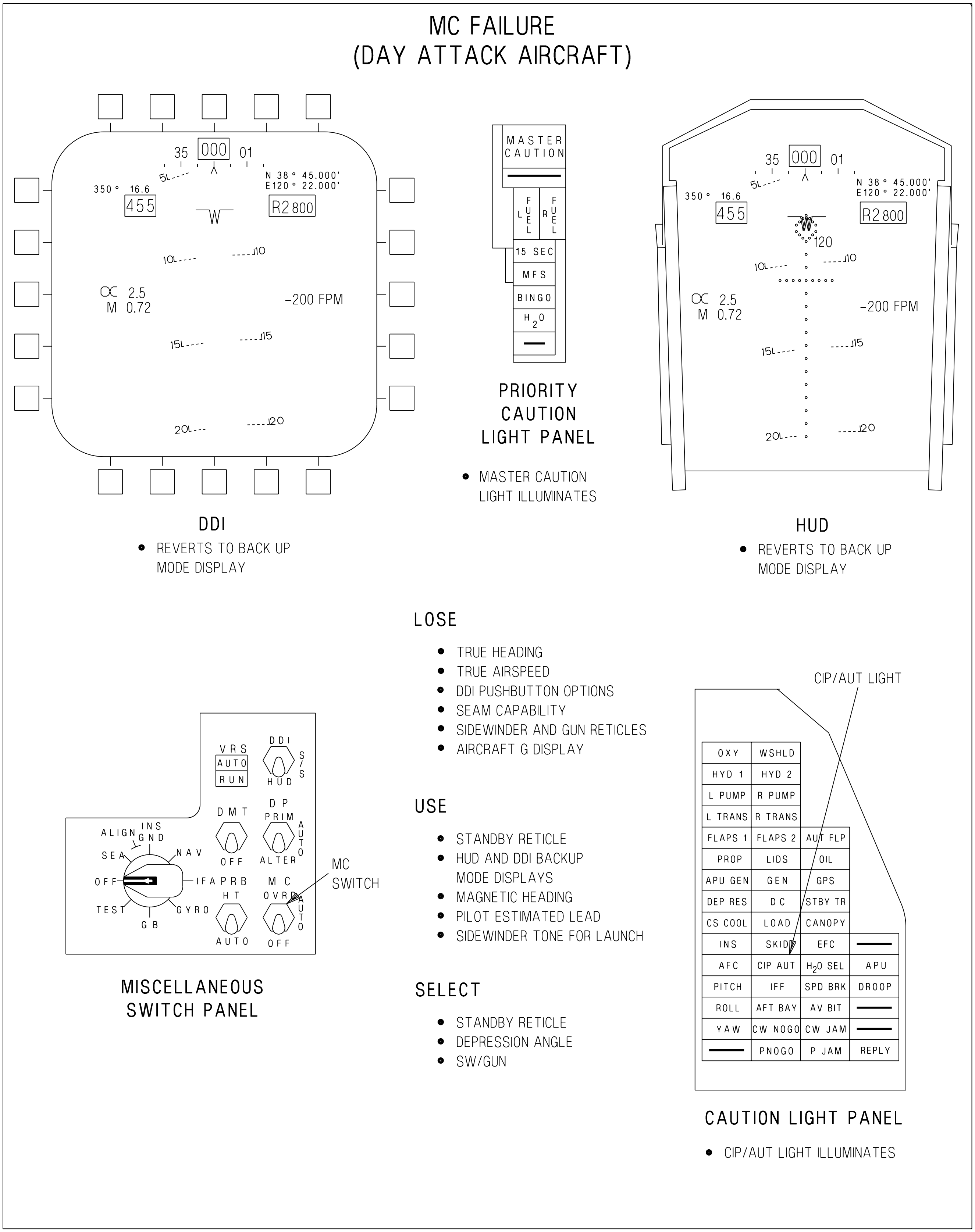

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Figure 3-12. A/A Weapon Backup Weapons Delivery (Sheet 2 of 8)

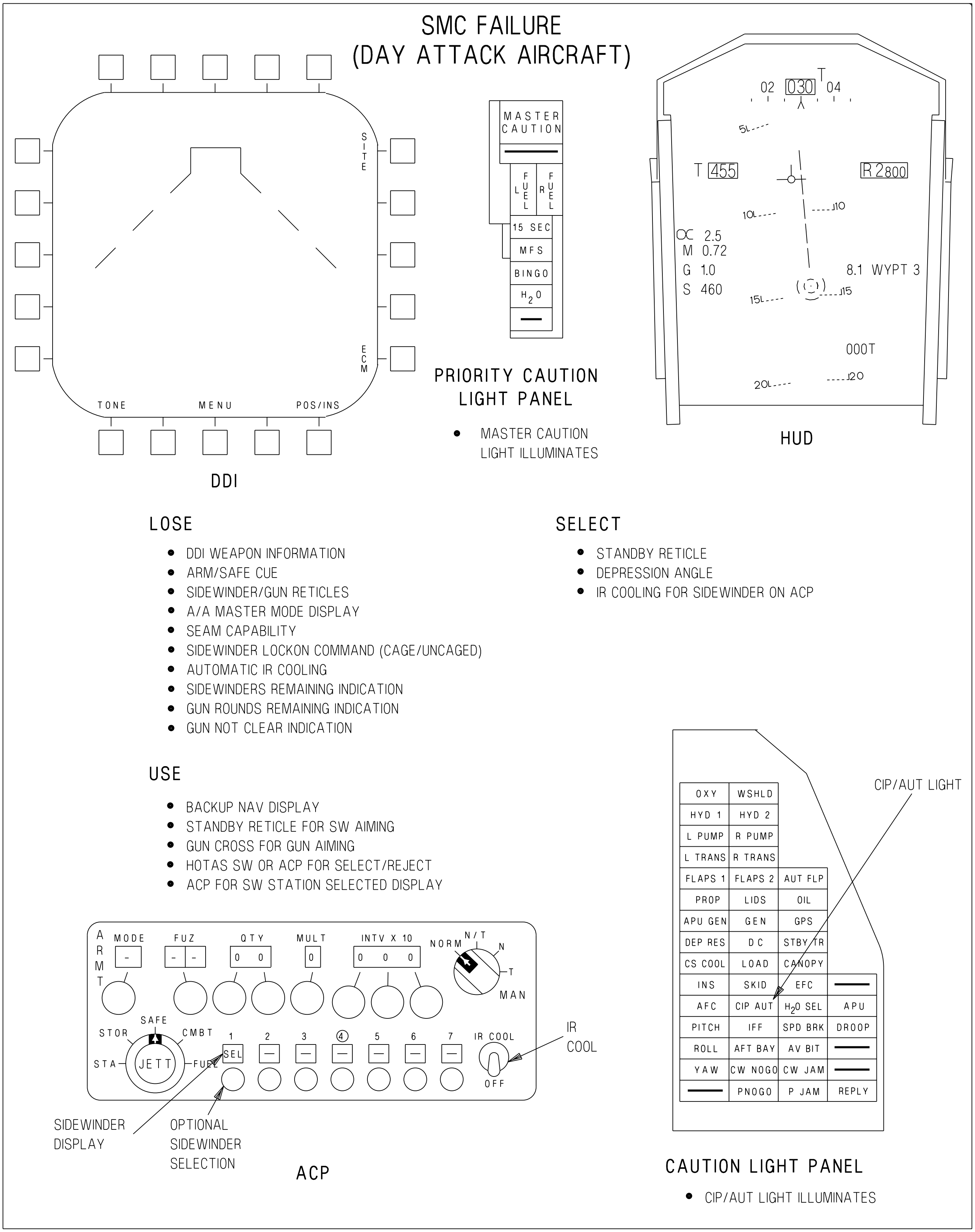

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Figure 3-12. A/A Weapon Backup Weapons Delivery (Sheet 3 of 8)

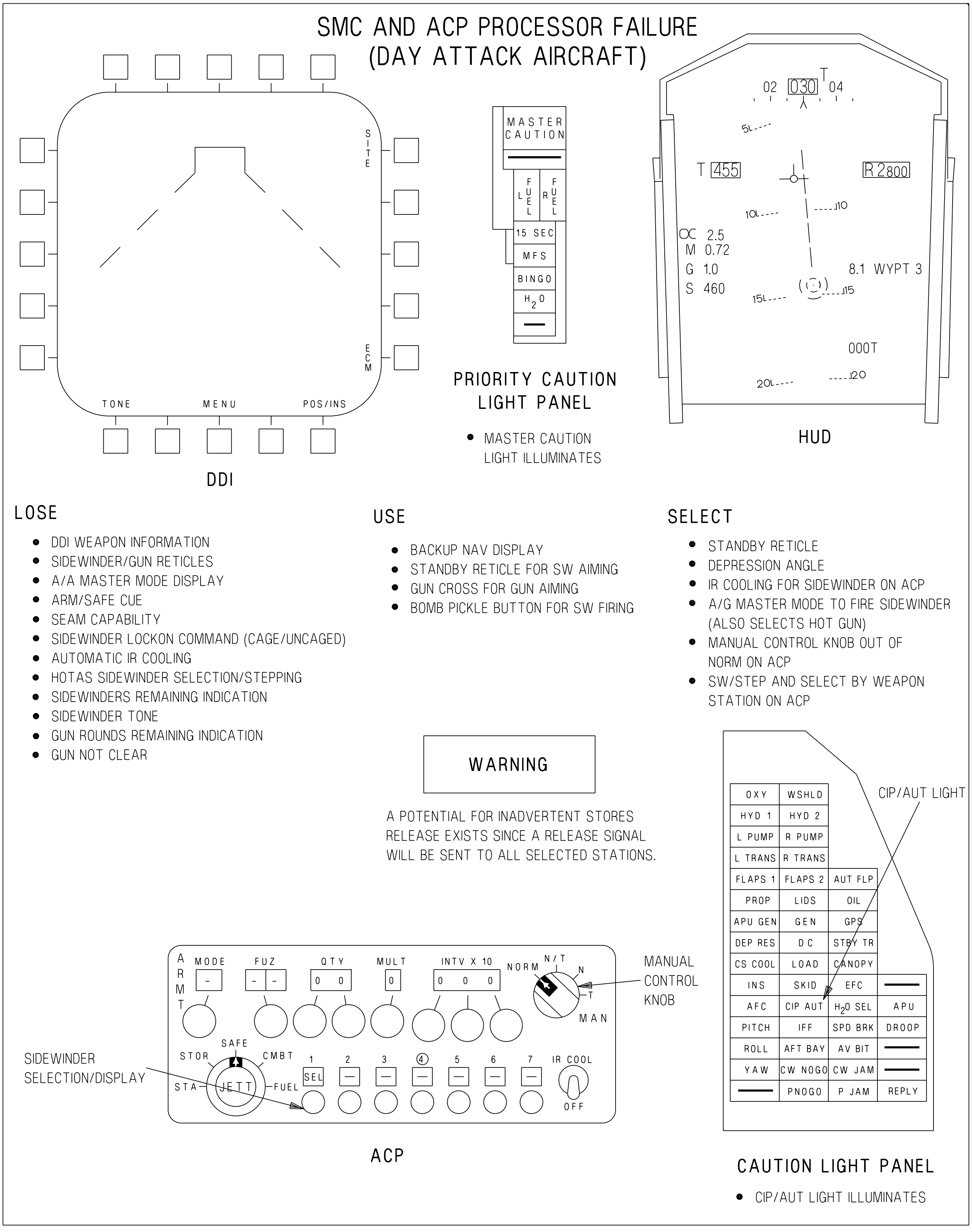

Figure 3-12. A/A Weapon Backup Weapons Delivery (Sheet 4 of 8)

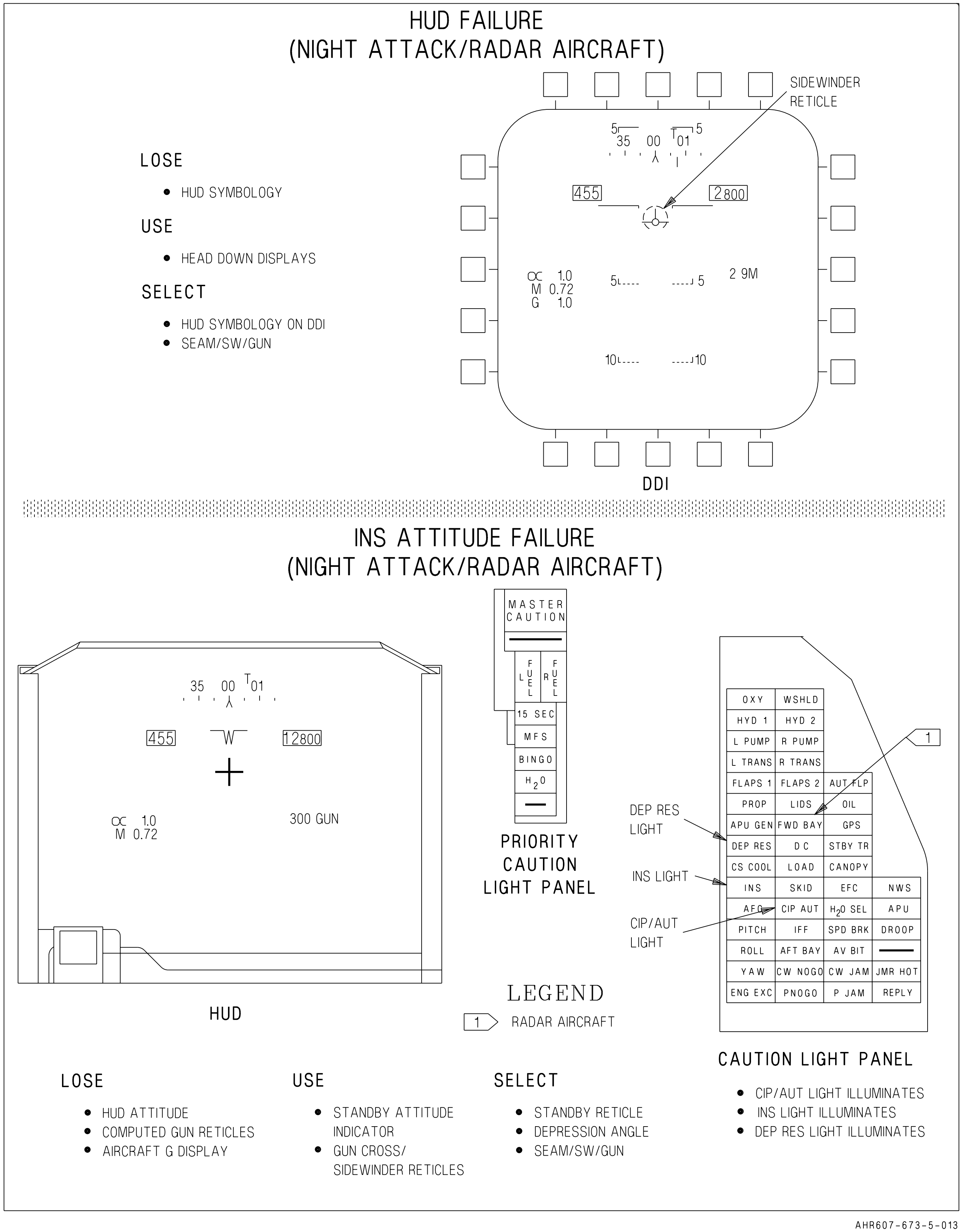

Figure 3-12. A/A Weapon Backup Weapons Delivery (Sheet 5 of 8)

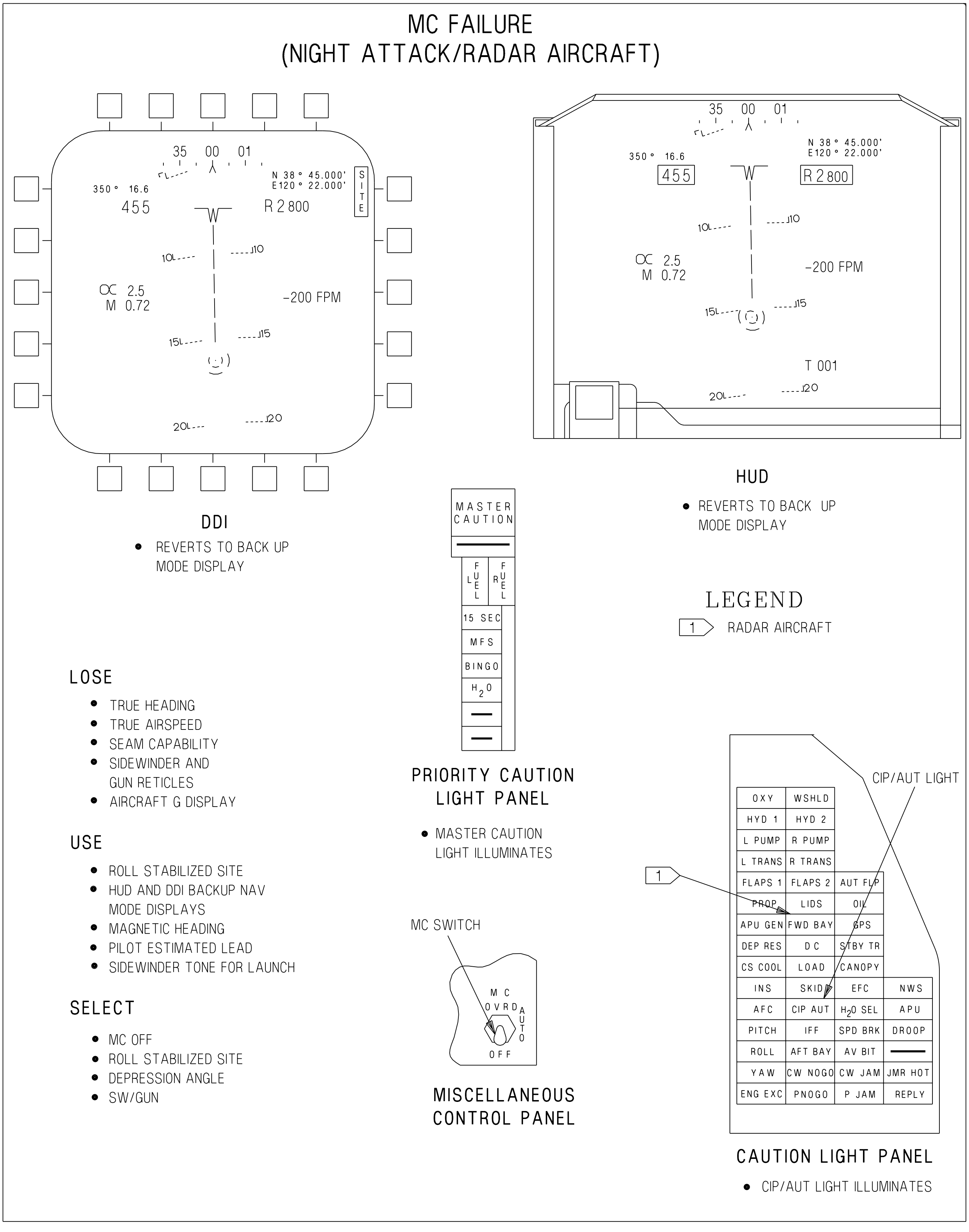

Figure 3-12. A/A Weapon Backup Weapons Delivery (Sheet 6 of 8)

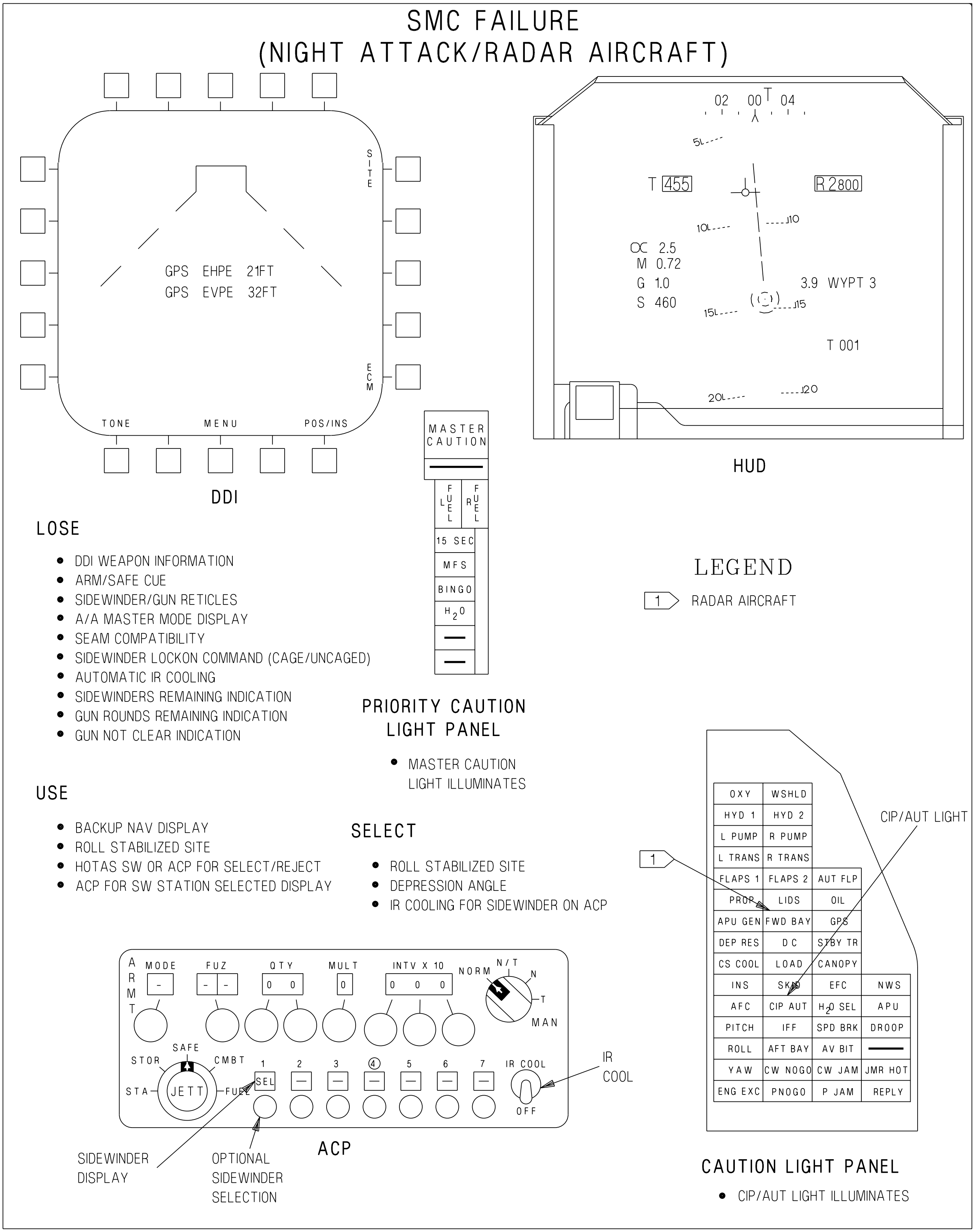

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Figure 3-12. A/A Weapon Backup Weapons Delivery (Sheet 7 of 8)

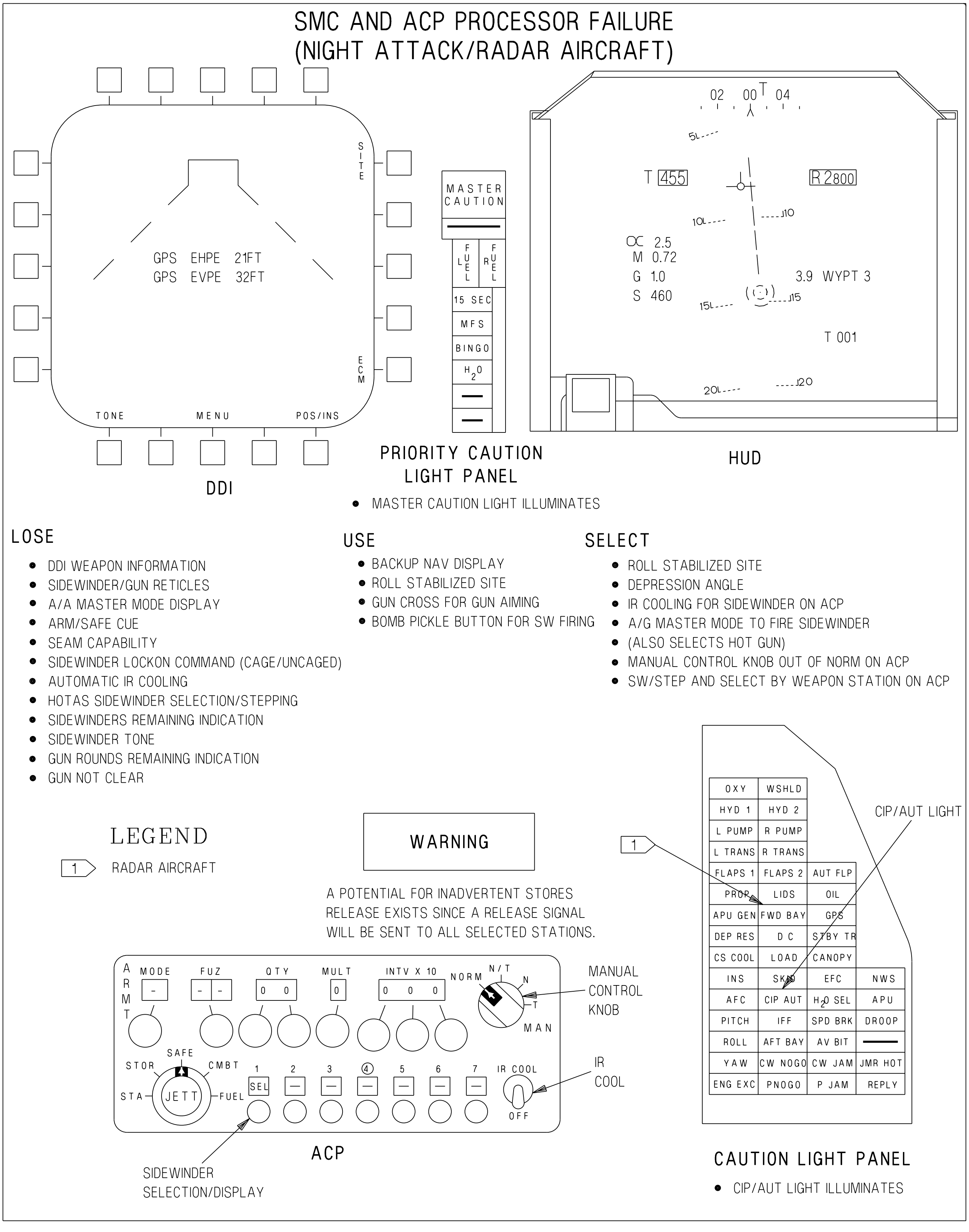

Figure 3-12. A/A Weapon Backup Weapons Delivery (Sheet 8 of 8)

3.6 A/A GUNNERY

3.6.1 Introduction. The continuing proliferation of Category IV aircraft throughout the world, and their associated Category III IR all aspect missile systems have virtually eliminated the AV-8 pilot's option to extend away from a fight in search of weapons separation for fear of being engaged by a similar system. The violent, tight turning, energy bleeding fights that result will likely make the gun the fighter's primary, and possibly only weapon available in this engaged maneuvering arena. These gunnery opportunities will likely be further limited to high angle attacks.

A through understanding of basic air-to-air circular gunnery pattern and the forward quarter gunnery pattern , as applied to the AV-8B aircraft, will be an absolute necessity in order to effect full utilization of the aircraft total weapons system and capability.

3.6.2 A/A Circular Gunnery Pattern. The topics of air-to-air circular gunnery pattern are:

Gun Preflight

The Banner

The Pattern

Errors and Corrections

Safety

Perch Rendezvous

Emergencies

3.6.2.1 Gun Preflight. Note the quantity and color of target practice (TP) rounds loaded. The quantity of rounds is entered into the SMC by maintenance personnel, and may be checked on the DDI/MPCD after engine start.

3.6.2.2 The Banner. The banner is a woven material that has radar reflective qualities. But more important from a safety standpoint is the bar that the banner is attached to. An eight foot by three inch thick steel bar is inserted in a sleeve in the forward edge of the banner and this is attached to four nylon straps which in turn are held by a turnbuckle to the tow cable itself. This is the main danger in shooting off the banner.

The banner comes in two sizes, 40 feet long by 8 feet high, or 30 foot long by 6 feet high. It is attached to a cable 1,500 to 1,800 feet long.

3.6.2.3 The Pattern. Refer to Figure 3-13 and Figure 3-14.

3.6.2.3.1 Spacer

1. Tractor. The tractor will maneuver as necessary to a clear area. The tractor will normally tow at 8,000 feet MSL, 200 KCAS in a 45° bank turn.

2. Lead.

   (a) The flight leader should decide which direction of pass to use and position the flight in loose echelon (about 100 feet) on the appropriate side. Roll in will be from approximately 1 to 1 1/2 mile at 12,000 feet MSL, 250 KCAS emphasizing that the first pass is a spacer pass only and used to set up a correct departure.

   (b) The air-to-air tacan, set between the tractor and the shooters, will help determine range to the tractor. Make sure the TACAN is boxed.

   (c) The lead will make sure everyone in the flight has the tractor in sight prior to rolling in.

3. Wingman.

   (a) Wingman will roll in using an 8 second interval and full power. Call "______'s In, Spacer."

   (b) If the tractor or banner is not in sight, follow approximately 1 nm in lag on interval until banner is visible.

   (c) Initially place the velocity vector above and behind the tractor until 1.3 nm DME. Then, smoothly move the velocity

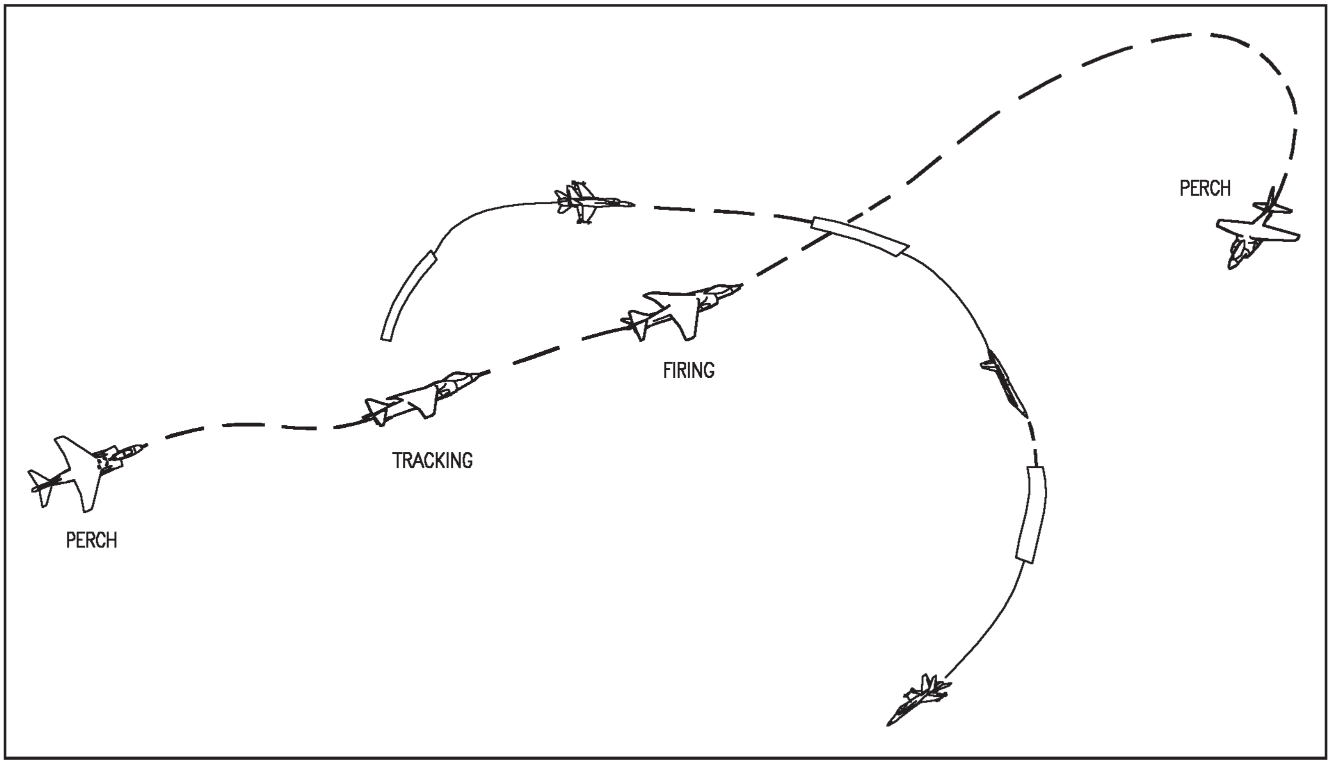

Figure 3-13. Circular Pattern

vector to above and in front of the banner until 0.6 to 0.8 nm DME.

(d) Do not attempt to track on the spacer pass, set the departure at 2,000 to 1,000 feet slant range.

3.6.2.3.2 Departure

1. To set the departure, simply maintain g and roll to approximately 15 to 20° angle of bank away from the banner. This allows the shooter to pass above and behind the banner. Call "______'s Off."

2. Never depart before reaching 2,000 to 1,000 feet range or the pattern will be disrupted.

3. Departure Angle

(a) Allow the tractor to drift back to a position along the leading edge of the shooter's wing and then reverse to the perch. This will set an approximate 45° angle of departure.

(b) Once the angle of departure is set, roll wings level, set power at 80 to 85 % rpm, and establish a 20° nose up attitude. Delay a couple of seconds until reaching 10,500 feet check point and start a 2 to 3 g reversal turn to the perch, flying out in front of your interval.

4. Pattern flying should now be referenced to the tractor rather than the banner.

3.6.2.3.3 Perch

1. The perch is the starting point for each run. It is a transitory point at 12,000 feet MSL and 250 to 300 KCAS. It occurs when the aircraft's nose is on the tractor at his dead six o'clock at 1.8 to 2.0 nm.

(a) A consistent perch yields a consistent pattern. For example, a 3 mile perch will produce a high g, high aspect pass, while a 1 1/2 mile perch will produce a low g, low aspect pass.

(b) Keep in mind, if the proper departure

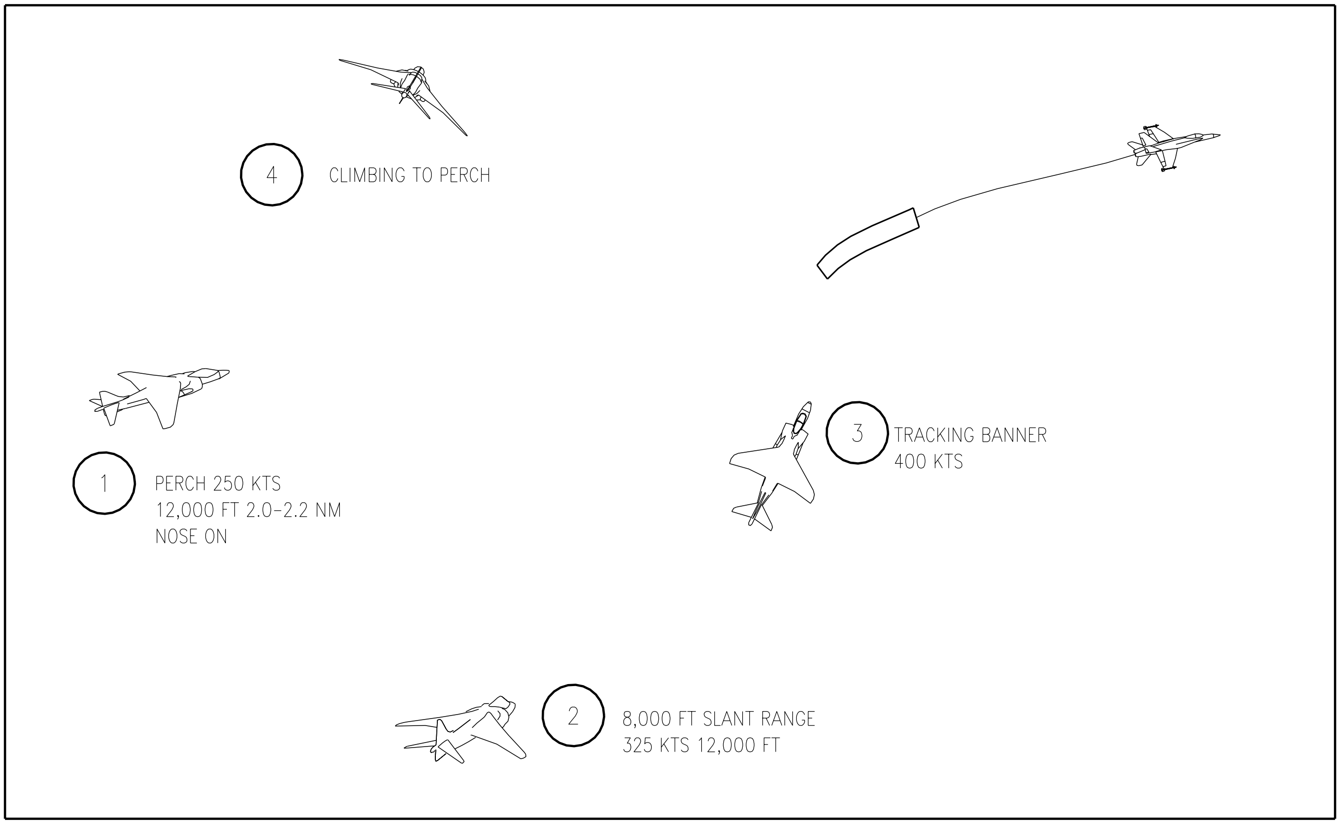

Figure 3-14. Seeing The Pattern

angle is not set, arrival at a proper perch can't be achieved.

2. Seeing the Pattern.

(a) Roll in from the perch with interval in sight. Your interval should be low at 2 to 3 o'clock and accelerating ahead. Call "______'s In." For a right hand pattern.

(b) The aircraft in front of your interval should be in or just finishing his firing run.

(c) The aircraft following you, should be starting his perch reversal turn and going belly-up in front of you.

3.6.2.3.4 Sight Handling

1. After rolling in, position the velocity vector above and forward of the banner to ensure a look down firing pass. Hold the velocity vector in this position and the circular tow pattern will build aspect, allowing for the correct path across the circle.

2. Check Point. At 10,000 feet and 325 knots, the shooter should be 10 to 15° angle off the banner with 8,000 feet slant range (1.3 nm DME). The banner should now be in the HUD field of view.

3. With the VV still above and forward of the banner, select short range AA gun. If the range is hot, place the MASTER ARM on.

3.6.2.3.5 Tracking

1. At 5,000 feet (0.8 nm DME) begin to fly the pipper to bull - 38 mR/2° lead. Fly the pipper smoothly so that at 2,500 feet the pipper is on the aimpoint and plane of motion is solved.

2. To hold the pipper steady will require constantly increasing g and bank angle. Smooth use of rudder is condoned.

3. Don't bring the pipper to bull any earlier than 5,000 feet as this will induce a look-up firing pass.

3.6.2.3.6 Firing. Plane of motion and range are the critical aspects to solve to ensure hits on the target.

1. 2,000 to 1,000 feet, 15 to 30° angle off with the banner below the horizon (the closer to 30° angle off, the better).

2. 380 to 400 knots.

3. 3.5 to 4g's.

4. Steady pipper on the banner.

5. Sight picture is the vertical dimension of the banner filling 25% of the short range reticle.

6. Fire a 1 second burst, (minimum).

(a) 1,000 feet range (don't press it).

(b) 15° angle off (square banner).

(c) No look-up (banner below the horizon).

(d) Watch the g.

7. If the pipper is not on the banner, the bullets are not going to hit the banner. So don't pull the trigger.

3.6.2.3.7 Breakaway

1. Maintain g (rolling pull) and roll 15 to 20° away from the banner.

2. Set 80 to 85% rpm, departure angle of 45° and 20° nose up.

3. Call "_____'s Off." Select Master Arm OFF and deselect gun by selecting Sidewinder boresight.

4. Delay a couple of seconds and start a 2 to 3 g reversal turn to the perch; flying out in front of your interval.

3.6.2.4 Errors and Corrections

3.6.2.4.1 General. Try to be consistent. If you are not consistent, then it is difficult to adjust and correct errors without knowing the cause.

3.6.2.4.2 Perch Roll In. The most common pattern error is roll in from a perch position of 7 o'clock in a right hand pattern, or 5 o'clock in a left hand pattern. This usually is caused by not setting the proper departure angle following a low angle run.

3.6.2.4.3 Drop Back

1. If the perch position is correct (12,000 feet, 250 knots, 2 nm at tractors's 6 o'clock), but consistently too close to your interval in the pattern, you need to drop back.

2. This is done by adjusting the departure angle and nose up attitude. Just maintain less departure angle (30° to 35°) for a longer time by positioning the tractor forward of the wing line and don't pitch as high (15° nose up), and using less g to pull to the tractor when returning to the perch.

3.6.2.4.4 Catch Up

1. Conversely, to catch up, you need to arrive at the correct perch position earlier.

2. To do this, turn to a greater departure angle (50° to 55°) for a shorter time by positioning the tractor aft of the wing line and pitch a little higher (22°), and using more g to pull to the tractor when returning to the perch.

3.6.2.4.5 Minor Adjustments

1. Minor corrections can be made to aspect by either leading or lagging the tractor or banner with the velocity vector.

2. Strive for a consistent 10 to 15° angle off at 8,000 feet (1.3 nm DME).

3. If continually firing looking up, the problem is with sight handling. Positioning the VV above and behind the tractor initially and

then ensuring that the VV is above and forward of the banner until 5,000 feet (0.8 nm DME) slant range will help alleviate this problem.

3.6.2.5 Safety

3.6.2.5.1 Lost Sight. The turn to the perch is a continuous turn. If lost sight occurs, the worst thing to do is to level your wings and delay on the perch.

1. Continue your turn and if you can't find the tractor, find your interval and follow in lag.

2. If still no tally with anyone, Call "_____'s, Lost Sight " and climb 1,000 feet above the pattern. Lead will call you back in. Rejoin by way of the spacer pass.

3.6.2.5.2 Simultaneous Run

1. Simo runs can occur if too far back on the perch. For example, if a shooter establishes a 3 nm perch and the aircraft behind flys to the correct perch, the shooter will have a high aspect, high g pass and the aircraft behind will be too close to the shooter for a successful firing pass.

2. Courtesy. The danger associated with simo runs can be avoided by ensuring your interval is in sight when on the perch. Never delay on the perch, proceed normally with the courtesy call "3's In, 2 In Sight."

3. Danger.

(a) With only 3 or 4 aircraft in the pattern, if the call "Simo Run" is called by someone else, you must be involved.

(b) If this is the case, and no tally call is made, immediately find the other aircraft.

(1) If in a right hand pattern and the last aircraft to call in, then the other aircraft involved in the simo run is probably off your low right side.

(2) If the aircraft following just called in, then he's probably above and off your left side.

3.6.2.5.3 Bad Run. If a particular run is so bad it cannot be salvaged by minor correction inside the circle, a spacer pass is required.

1. This spacer pass may be initiated on your own judgement, "2's Thru Spacer," or the lead/tractor, may tell you to "2, Take It Thru Spacer."

2. Your action is to get 400 knots and simply fly to the banner to set up the correct departure.

3. Don't depart early.

4. Appropriate corrections to drop back or catch up can be made from the departure.

3.6.2.5.4 Arm/Safe

1. The Master Arm should be armed only when:

(a) Interval has broken away from the banner.

(b) Interval has cleared your HUD field of view.

(c) Shooter begins to track the banner.

2. The Master Arm will be safed once the shooter has safely broken away from the banner.

3.6.2.6 Perch Rendezvous

3.6.2.6.1 Initial Call. Lead will call "Lead/1's In, Last Run" either due to bingo fuel within the flight or range time has elapsed.

3.6.2.6.2 Procedures. The run is normal up to the point of departure.

1. Once safely clear of the banner, instead of setting a normal departure (45°), SB ±15° angle of departure with full power to the

original pattern direction and look for the lead or interval.

2. Keep the noses pointed ahead of the lead aircraft (lead pursuit). Do not reduce power until closure is observed to avoid getting sucked. Lead will be maintaining 10,000 feet, 350 knots and 0.8 to 1.0 nm abeam the tractor.

3. This does not look like a normal rendezvous.

4. Example: In a right hand pattern, lead will be at the tractor's 9:30 to 10:00 o'clock within 1 nm, and 2,000 feet high, at 350 knots.

3.6.2.6.3 Join Up

1. Call: The join up call is "_____'s Off, Switches Safe, Lead In Sight." Make sure that the gun is deselected and Master Arm is SAFE.

2. Escort.

(a) After the flight rendezvous, lead will designate the high fuel state wingman as escort. When cleared by lead, the escort will detach from the flight and join the tractor.

(b) Be careful, the escort has 150 knots and 2,000 feet altitude advantage on the tractor.

3.6.2.7 Emergencies

3.6.2.7.1 Gun

1. Treat all gun malfunctions (not clear, misfiring and limited) the same by safing the Master Arm and deselecting the gun.

2. Runaway Gun.

(a) The position in the pattern where a runaway gun will most likely occur will be approaching the banner after firing, so make sure that you break away safely from the banner.

(b) Turn the Master Arm off and point the nose toward a safe area.

(c) With a gun firing rate of 3800 rpm and a 300 round limit, this condition will only exist for a maximum of 5 seconds.

3.6.3 Forward Quarter Gunnery. When engaged with Category IV adversary, the AV-8 pilot's best option is an aggressive pressure gameplan that trades energy for nose position, with little regard for airspeed, and where given the choice, one circle flow would be preferred. Marine fighter pilots are taught to pull inside the turning circle of their opponent, aggressively maneuver to remain there, and anticipate fleeting gun shots at each subsequent pass. In this situation, the AV-8 pilot may be limited to a dynamic forward quarter gun opportunity as his *only* shot.

The AV-8 pilot's training should be to maneuver to position himself for forward quarter gunnery attempts. Presently, the only prescribed forward quarter training is conducted in a guns weave exercise, where both the shooter and the target fly to a forward quarter gunnery solution in a cooperative fashion. In this drill, the AV-8 VTR tape and its post mission evaluation are our only methods of shot validation. Avoiding a lengthy aerial gunsight discussion, suffice it to say that the AV-8 gunsight, in the disturbed LCOS mode, is of extremely limited value in both real time and post mission debrief shot validation. The AV-8 director mode is somewhat better, though not without its own inherent limitations. Obviously, short of flaming bandits, holes in a target banner are the only real way to measure success. The AV-8 pilot needs a means by which to conduct live aerial gunnery training in the forward quarter.

Presently, this chapter describes in detail several techniques for conducting live fire aerial gunnery training in the rear hemisphere. In addition to this, the Training and Readiness manual includes one sortie for aerial gunnery. The Training and Readiness manual specifies the particulars of how the gun should be employed. Certainly, rear aspect, director mode gunnery must be practiced, though such opportunities rarely present themselves to the AV-8 pilot engaged with well flown Category IV adversaries. The pattern that is discussed will allow AV-8 pilots to definitively train to and evaluate the shot opportunities which are experienced in nearly all BFM and DACT sorties. This pattern observes the strictest of safety regulations, the standing training rules that limit forward quarter gunnery attempts, and is extremely easy to execute from both the shooter and banner tow positions. The basic pattern diagram is shown in Figure 3-15.

The banner tow will fly a straight line track at 10,000 feet AGL and 200 KCAS. The shooter(s) will commence the pattern from a perch position approximately 1.5 nm abeam and slightly above the banner. The first shooter begins by accelerating and climbing in front of the tractor and banner, flying to a position approximately 1.5 nm offset abeam and 3.0 nm ahead of the tractor's extended wingline, arriving there at an altitude of 11,500 AGL and an airspeed of 400 KCAS. Each shooter must parallel the tractor/banner flight path to arrive at this position. The tractor should communicate the base heading when he establishes the pattern and any time he changes his heading. A visual reference point for the shooter to commence his turn back toward the banner will be the sight picture of the banner drifting to the far aft edge of the shooter's LAU-7 launcher rail. Air to air tacan ranging will be the primary shooter to tractor ranging method.

At the "turning in" point, the shooter must padlock the tractor/banner in order to prevent losing sight. If a shooter does lose sight, an immediate "blind" call should be transmitted with the shooter continuing his turn in ensuring positive altitude deconfliction, selecting GUN-ACQ to acquire either the tractor or the banner, and then shifting lock as required for final banner track. The tractor can certainly assist the shooter in regaining sight by calling his eyes on, dispensing a flare, or momentarily dumping fuel. An easy (2 to 3g) level turn toward the extended flight path of the tractor/banner is initiated crossing above and directly in front of the tractor at a range of approximately 2.5 to 3.0 nm. Once the shooter crosses the tractor's extended 12 o'clock, he must increase the g to expeditiously come nose on. The turn is continued, by increasing the pull to 4 to 5g and slicing slightly to come nose on to the banner at a range of approximately 1.3 to 1.5 nm. Power is modulated to maintain 350 to 400 KCAS through the slice turn and descent. Using boresight mode, the banner is locked at approximately 1.2 nm, with gun symbology now flown towards the banner.

The shooter will attack the banner in a moderate g, 15° to 20° nose low attitude. The shooter closes to approximately 3000 to 5000 feet, and is positively "cleared hot" by the tractor as the angles off the nose of the banner increase from approximately 20° on initial lock to approximately 50° as the banner proceeds downrange. *Selecting master arm to ARM and firing is commenced only after receiving a "cleared hot"* with slant ranges varying from 4000 feet down to 1000 feet. When the firing pass is complete, or a minimum range of 1000 feet is reached the shooter pulls up, never to fly below or in front of the banner, and initiates a high (5 to 6g) climbing turn to cross the tractors flight path to parallel the tractor's overground track. At this point, the required lateral separation of approximately 1.5 nm is established and the pattern is repeated.

The pattern, like the rear quarter circular pattern currently used, has the capability to easily handle up to four shooters. Ideally, with four shooters in the pattern, one aircraft will be "off" , the second aircraft will be "abeam", the third will be "turning in ", and the fourth will be "in" the firing run. Like any other circular weapons firing pattern, comm calls for position keeping and deconfliction will be standardized as, "perch", "turning in", "in cold", and "off", with "approaching" used to further describe any of these calls. Spacing between the shooters will be initiated from the perch start with approximately 20 seconds delay between each shooter climbing away from the perch. Spacing corrections once the pattern is established will be made on the turn in at 2.5 to 3.0 nm, using lead or lag to catch up or fall back respectively. In some cases, airspeed adjustment alone may be enough to reestablish pattern spacing. Once the tractor and banner approach the end of the gunnery track, the tractor must call "last run" and call for a "perch rejoin" on the side away from which he desires to turn to reverse the track. With the turn complete, and the base heading established, the pattern can be recommenced.

Control of the pattern is both the responsibility of the shooter flight lead and the tractor. Only the tractor will be allowed to clear each shooter hot in each run. Only after being cleared hot will the shooter be armed up. The relatively short range at which the tractor will be able to call "cleared hot" will require that each shooter have his hand on the master arm switch, ready to arm up immediately on the tractor's call. When the firing run is completed, the master arm will first be safed, and the shooter will call "off safe".

From the tractor's perspective, the pattern will be above and in front of his flight path making visibility much easier than that of the rear quarter pattern. Even at the maximum pattern separation of 3.0 nm, the tractor should have little trouble observing the shooter's planform turn across his extended flight path to come nose on. The shooters will appear to transit from one canopy hand rail to the other, transiting through the top of the HUD in the process. Most shooters will pass precisely through both the airspeed and altitude boxes in the HUD. As the angles increase and the tractor is comfortable with the shooter's nose position, he positively calls "cleared hot". The tractor pilot will develop a "feel" for each shooter's nose position, and will be able to detect the increased line of sight rate and the resultant nose off attitude as he passes the 10 or 2 o'clock position of the tractor. The tractor pilot will certainly require several dry runs to develop this sight picture. After that, the "cleared hot" calls will be easily distinguished.

3.6.3.1 Emergencies

3.6.3.1.1 Gun

1. Treat all gun malfunctions (not clear, misfiring and limited) the same by safing the Master Arm and deselecting the gun.

2. Runaway Gun.

   (a) The position in the pattern where a runaway gun will most likely occur will be approaching the banner after firing, so make sure that you break away safely from the banner.

   (b) Turn the Master Arm off and point the nose toward a safe area.

   (c) With a gun firing rate of 3600 rpm and a 300 round limit, this condition will only exist for a maximum of 5 seconds.

The forward quarter gunnery pattern we have developed and evaluated is easy to execute, easy to control and meets the strictest of safety requirements. This pattern will allow Marine AV-8 pilots to employ the gun in training much like we anticipate its potential employment in combat. Dynamic forward quarter gunnery skills take time and training to master, but will be invaluable to the Harrier pilot, who someday finds himself engaged with an aggressively flown FULCRUM, FLANKER, or MIRAGE 2000. We must continue to train like we'll fight, and for aerial gunnery, this is a start.

On your squadron's next gun shoot, fly the normal circular, rear quarter gun pattern until everyone is comfortable and proficient. Then try the forward quarter pattern. This may be a great evolution for the squadron to participate in as a competitive shoot.

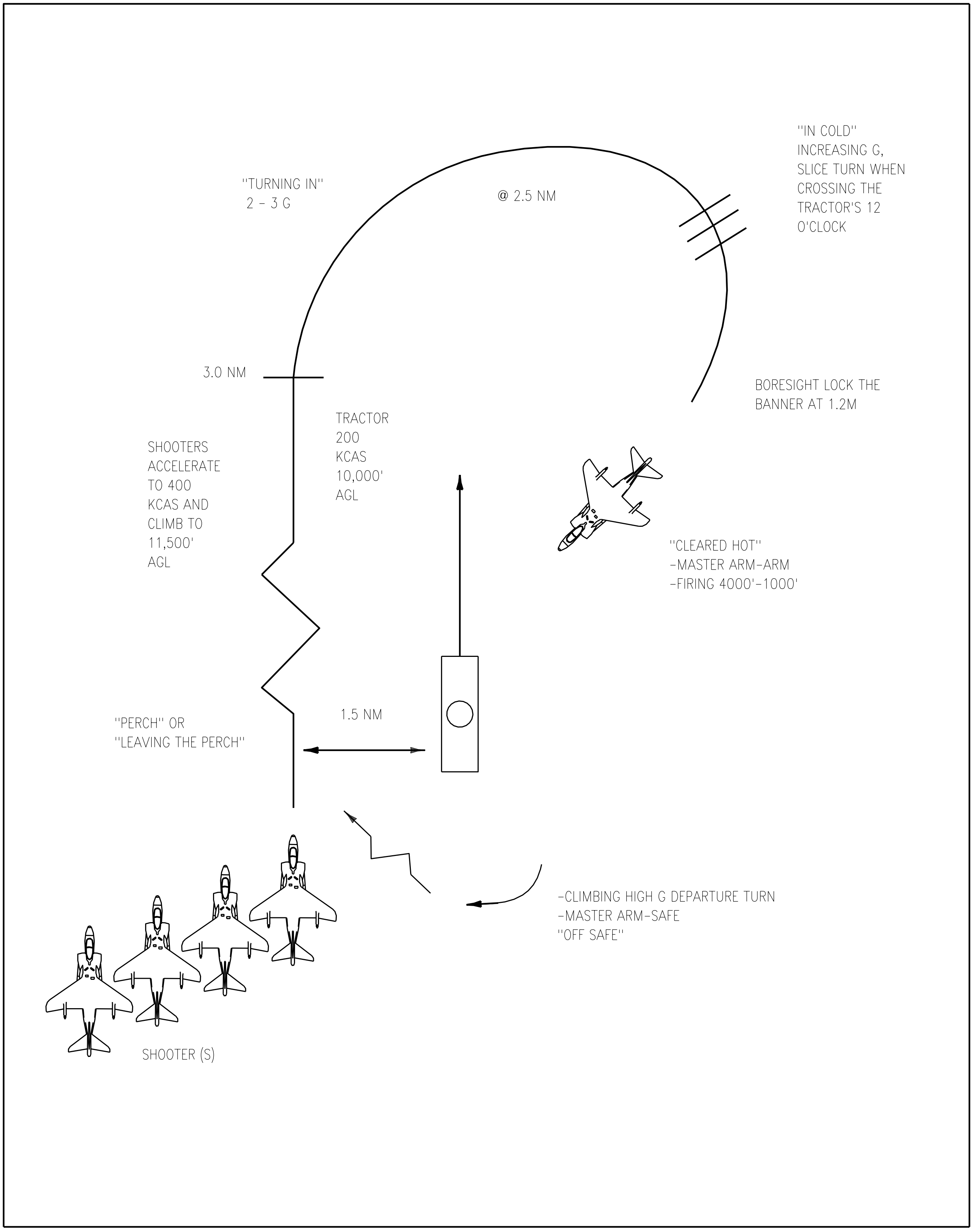

Figure 3-15. Forward Quarter Gunnery Pattern

PART III

NUCLEAR WARFARE

(Not Applicable)

PART IV

AIRCRAFT LIMITATIONS

(Refer to Volume II)

PART V

SPECIAL PURPOSE EQUIPMENT

(Not Applicable)

PART VI

AIRCRAFT PERFORMANCE

CHAPTER 4

Aircraft Performance

4.1 AIRCRAFT PERFORMANCE DATA.

4.1.1 Introduction. Aircraft maneuverability can be defined as the ability to change direction and/or magnitude of the aircraft velocity vector. While this definition describes maneuverability accurately, it provides little feel for the pilot on how to acquire best (optimum) maneuverability. From experience, the best way to maneuver for positional advantage, or to deny this same advantage to an opponent, depends on the type of ordnance used and the performance of the aircraft. Delivery conditions can be depicted by launch or firing envelopes. Once the initial delivery conditions are known, the problem becomes one of maneuvering into the effective launch envelope. Such maneuverability is dependent upon the ability of the pilot to control turn, altitude, airspeed and acceleration (operational maneuverability). The following discussion will show how energy maneuverability is related to operational maneuverability and how this relationship may be exploited by the AV-8 pilot in developing valid maneuvering and/or weapons employment tactics.

4.1.2 Operational Maneuverability. Operational maneuverability can be considered as the capability to perform changes in altitude, airspeed, and direction. The theory of energy maneuverability was developed in an attempt to describe this capability in a quantitative form for graphical comparisons. The following are the factors considered in establishing these performance diagrams.

4.1.2.1 Load Factor (g). The ratio of total lift to aircraft weight is the load factor, (represented by g in the cockpit). For turns or directional changes at a constant altitude, total lift must exceed aircraft weight; thus, g-loads greater than one are required.

Total g (cockpit) is composed of the total forces generated by the aircraft divided by the weight of the aircraft. The aircraft stalls as a function of the g.

Radial g is composed of all the forces acting on the aircraft turning plane of motion, divided by the weight of the aircraft. The aircraft turns as a function of this g.

The egg flightpath produced by an aircraft performing a loop is a good example of the relationships between total and radial g's. As can be seen, total (cockpit g) is held constant at 6g while the effect of gravity added to total g produces radial g, which determines flightpath. See Figure 4-1.

4.1.2.2 Turn Radius and Turn Rate. Turn radius and turn rate are each dependent on two items, airspeed and normal load factor.

$$\text{Turn radius (R)} = \frac{V^2}{g\,(n_z{}^2-1)^{1/2}}$$

$$\text{Turn rate (TR)} = \frac{57.295g\,(n_z{}^2-1)^{1/2}}{V}$$

where
V is velocity
n_z is normal load factor
g is gravity

The relationship of velocity with respect to rate/radius is important in that changes in the velocity will have a greater effect on radius than rate.

When comparing turn radius and turn rate of two aircraft, it is apparent that at a given true airspeed the aircraft that can sustain the most g will have the smallest turn radius and greatest turn rate. See Figure 4-2.

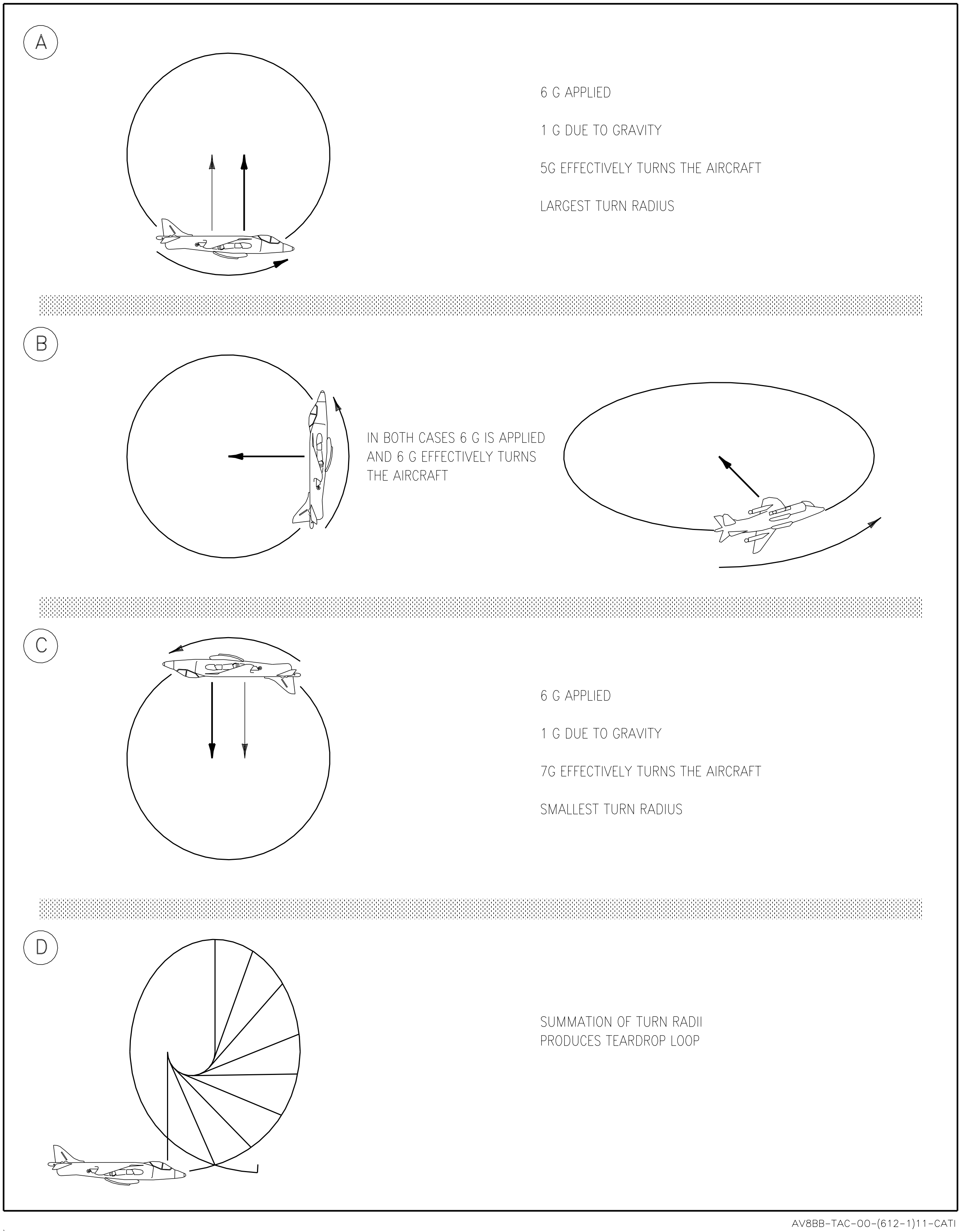

Figure 4-1. The Tactical Egg

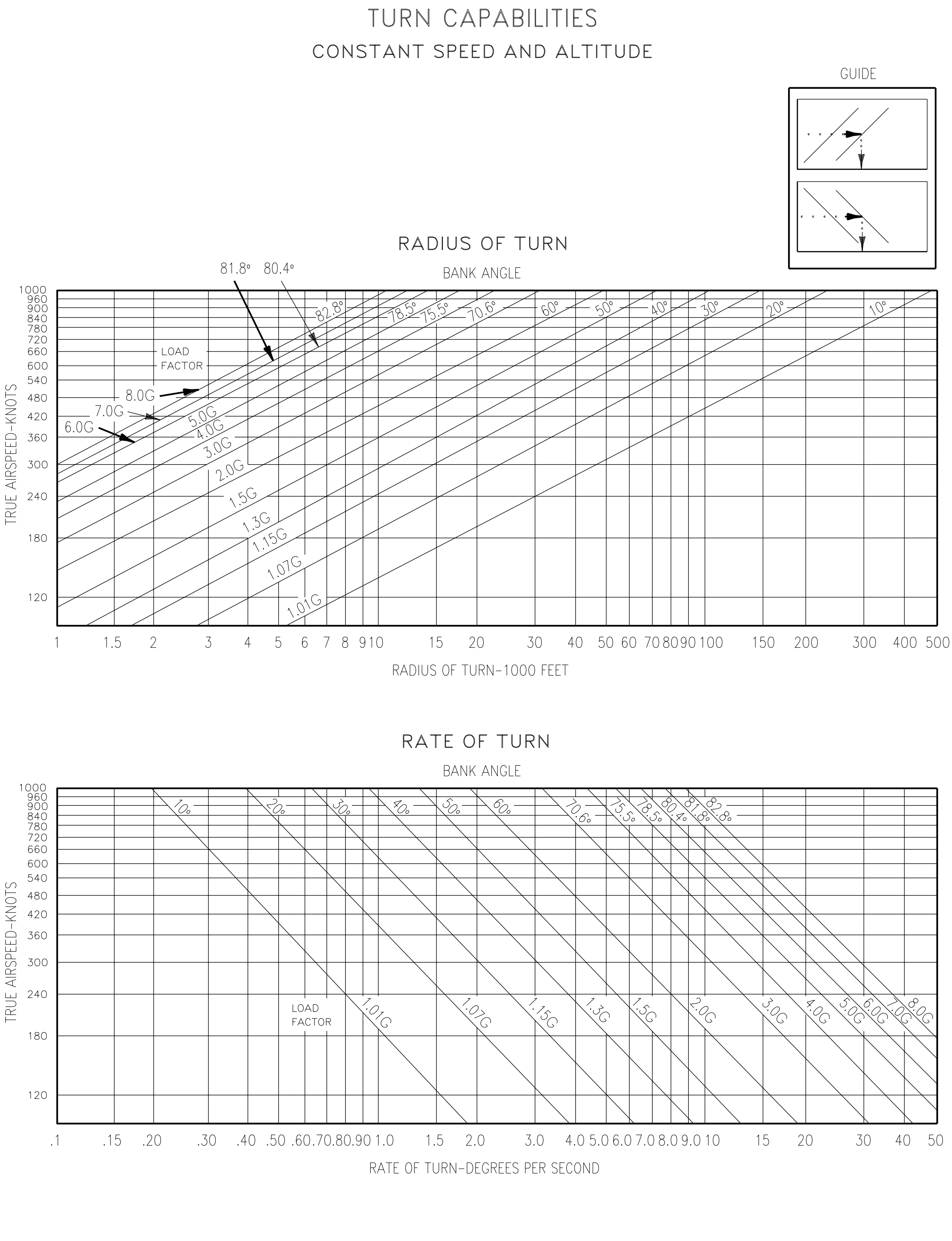

Figure 4-2. Turn Capabilities

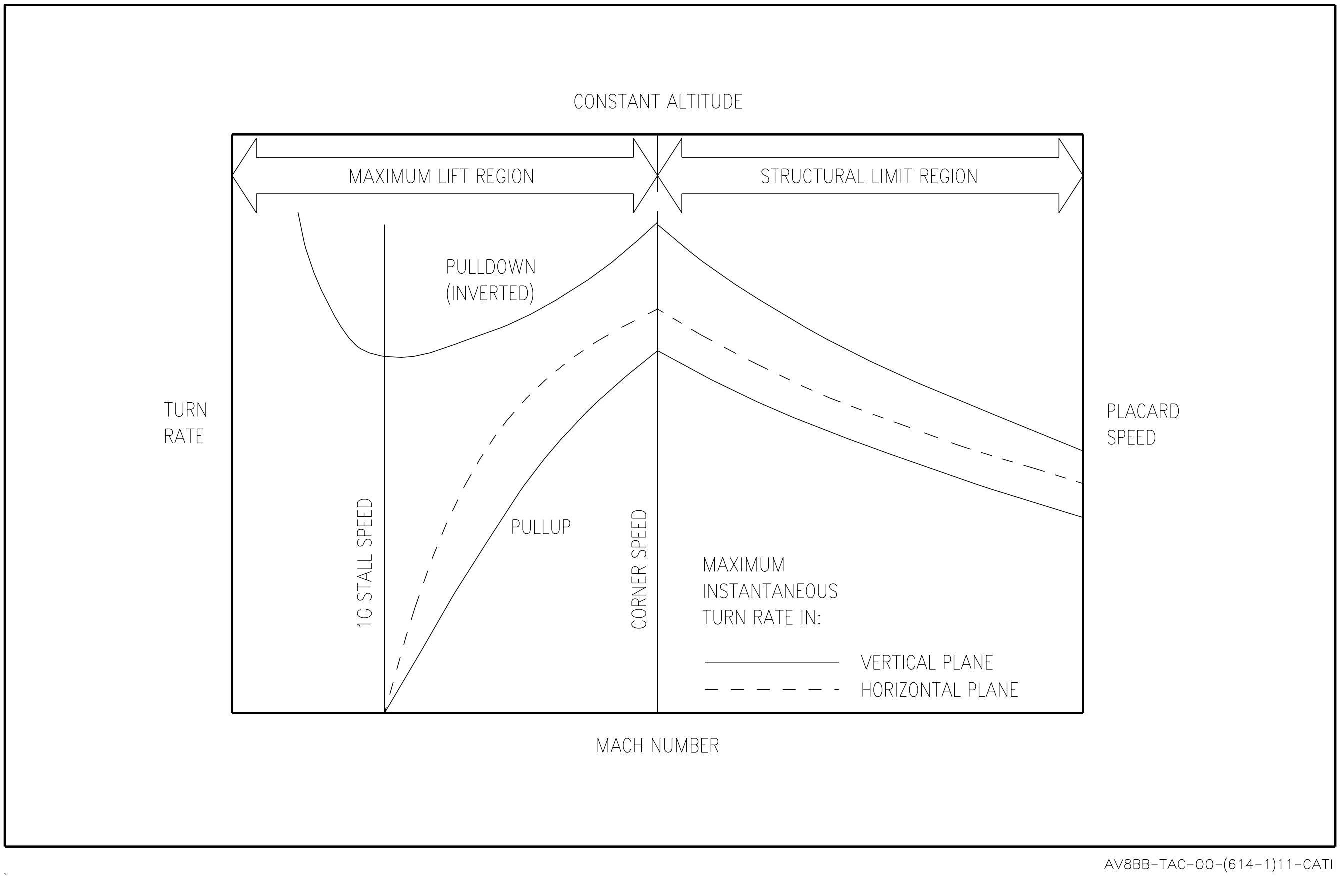

Figure 4-3. Three Dimensional Turn Spectrum

4.1.2.2.1 Three- Dimensional Turn Spectrum. The air battle is by no means confined to the horizontal plane and the three-dimensional aspects of turning are also very important to understand. Figure 4-3 shows the three-dimensional turn spectrum in terms of maximum instantaneous turn rates at constant altitude. Both the minimum and maximum turn rate are achievable in the vertical plane. A vertical pullup (bank angle of zero) has the lowest turn rate because it is in direct opposition to the effect of gravity and an inverted pulldown (bank angle of 180°) has the highest rate because gravity is aiding the turn. Horizontal maximum instantaneous turns are closer to the pullup turns in the maximum lift region and midway between the pullup and pulldown turns in the structural limit region. Turn factors for turns in the vertical plane are shown in Figure 4-4. These factors can be used to determine the vertical-plane turn rate that is equivalent to the horizontal-plane turn rate at the same load factor.

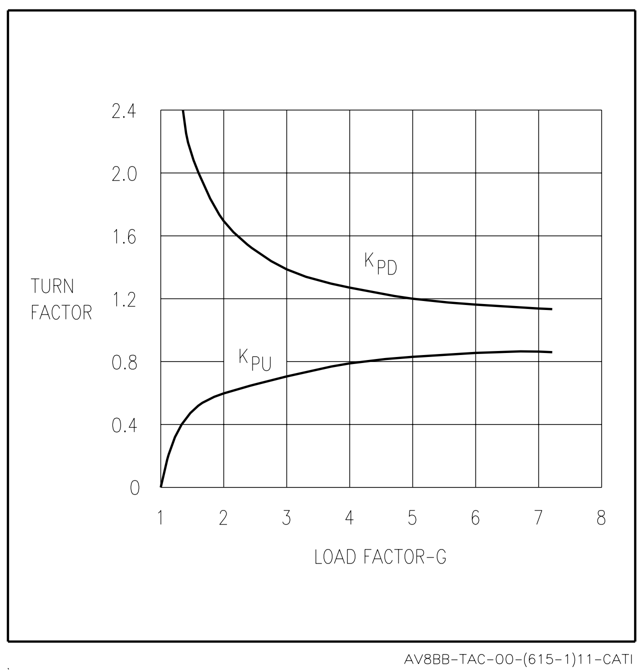

Figure 4-4. Vertical Plane Turn Factors

For example, if you are at a flight condition where your level turn rate is 16° per second at 6 g, your equivalent vertical-plane instantaneous turn rates at that load factor would be:

$$\text{Pullup turn TR} = K_{pu} \times \text{Level TR} = 0.84 \times 16 = 13.4^\circ \text{ per sec}$$

$$\text{Pulldown turn TR} = K_{pd} \times \text{Level TR} = 1.18 \times 16 = 18.9^\circ \text{ per sec}$$

Note that a pulldown turn at 2g would be 74 percent greater (K_{pd} = 1.74) than a horizontal turn at the same load factor; hence, a horizontal turn at 2g would be 74 percent greater than a pullup turn at the same load factor.

Referring again to Figure 4-3, the region below 1g stall speed is where the highest vertical-plane turn rates can be achieved, because the turn rate continually increases with decreasing speed.

4.1.2.2.2 Effect of Gravity. If an aircraft's turn radii for various attitudes at the same true airspeed and indicated g were compared, the following phenomenon could be seen:

1. An aircraft in a straight and level attitude pulling into the vertical achieves an effective turn of 1g less than indicated g (Figure 4-1, part A).

2. An aircraft 90° nose up, or in a 90° angle of bank, does not lose any turn performance due to gravity (Figure 4-1, part B).

3. An aircraft wings level and inverted has the smallest turn radius of all, since it is aided by the effect of gravity (Figure 4-1, part C).

When these phenomenon are combined into a plot of the path of an aircraft doing a loop while maintaining constant true airspeed and indicated g, it will be obvious that the turn radius is longest at the bottom of the loop, and that it decreases to its shortest length at the top of the loop. The result is a teardrop loop (Figure 4-1, part D).

Of course, the AV-8B does not maintain a constant true airspeed in a loop. If the loop is started at a low enough altitude and high enough airspeed so that constant indicated g can be maintained, the effect is more pronounced and the flightpath will be an even more graphic teardrop.

The highest possible instantaneous turn rate is generated at corner airspeed, inverted, with maximum g. A thorough comprehension of the effect of gravity on turn performance and flightpath displacement is essential to understanding the maneuvering performance of the AV-8B.

4.1.2.3 Wing Loading. Wing loading is defined as the aircraft weight divided by the wing area. Combat wing loading is obtained by dividing a defined combat weight by the wing area. Combat weight equals empty weight plus armament, useful load, and a percentage of internal fuel, and is used for tactical comparison of aircraft.

Generally:

Navy is 50 percent internal fuel.

Air Force is 75 percent internal fuel.

4.1.2.4 Thrust-to-Weight. Aircraft thrust to weight ratio equals a defined aircraft thrust divided by the combat weight. Thrust can be based on static, dynamic, installed or uninstalled thrust. Make sure when comparing aircraft that the means of deriving thrust is the same.

Thrust varies with altitude and airspeed.

4.1.2.5 Maneuverability. Maneuverability may be divided into instantaneous and sustained maneuverability. Instantaneous g is the aircraft load factor, limited by aerodynamics or structural considerations, which can be generated at a given airspeed. Sustained g is the load factor the aircraft can generate, limited by aerodynamic performance, at a given power setting, constant airspeed and altitude and still maintain level flight. Sustained g is a function of engine thrust, overall aircraft drag, and the L/D characteristics of the wing.

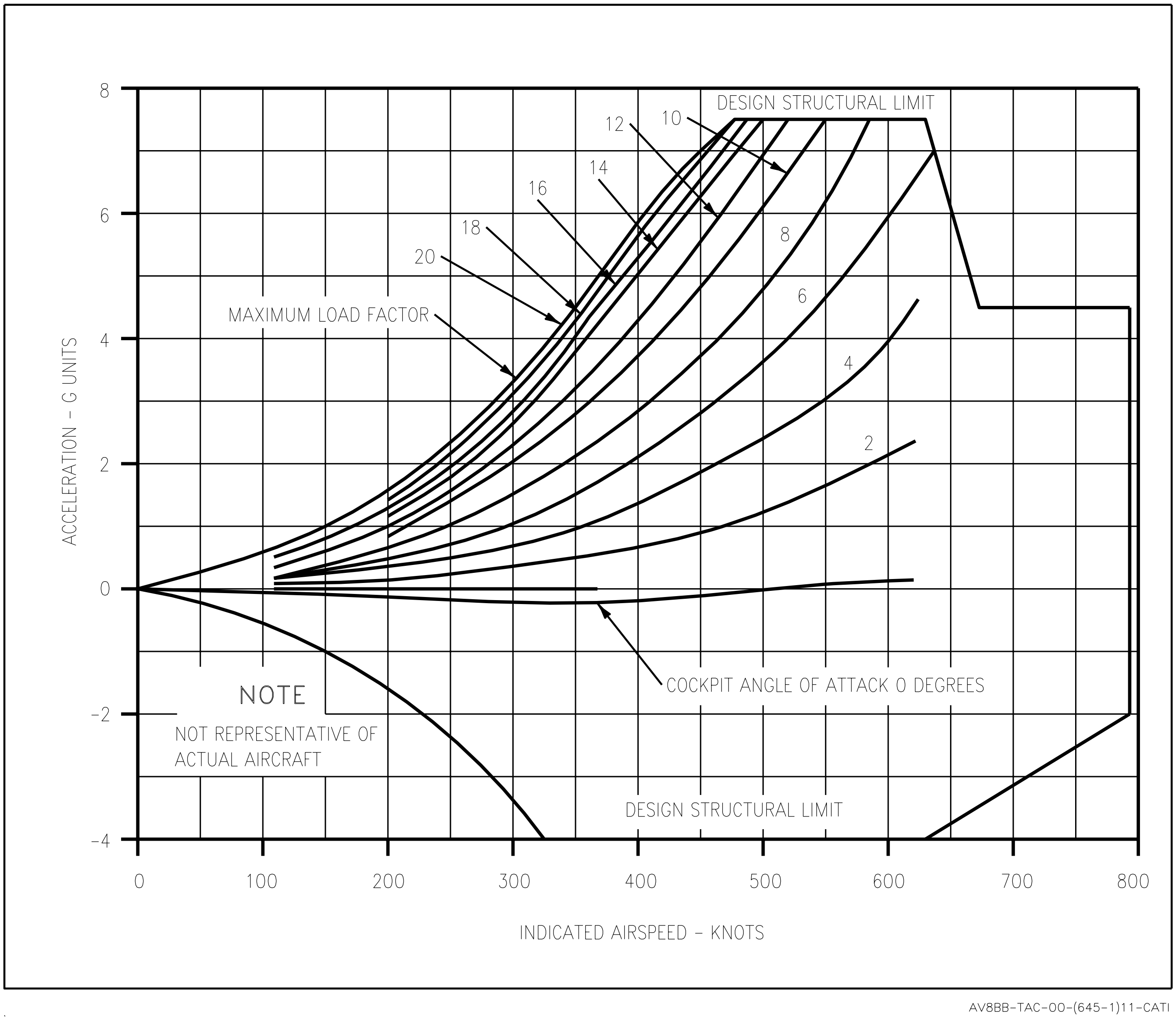

Figure 4-5. Velocity Load Factor Diagram

4.1.2.6 Operating Load Factor Limitations. The operating load factor limitations of a particular aircraft are graphically displayed on a velocity load factor (V_n) diagram, Figure 4-5. From the upper and lower boundaries of the V_n diagram one can determine the structural limits of the airframe. From this diagram one can also determine the maximum g which can be instantaneously pulled at any given airspeed. It should be noted that the instantaneous g discussions on the V_n diagram makes no statement of ability to sustain altitude or airspeed. As a result, no measure of sustained maneuvering can be acquired from a study of this diagram.

Data from a V_n diagram:

1. Structural limits for positive and negative g.

2. Structural speed limits.

3. Aerodynamics limits or stall boundary maximum load factor.

4. Lowest maneuvering airspeed.

4.1.3 Energy Maneuverability

4.1.3.1 Total Energy. The Total Energy (TE) possessed by an aircraft is a combination of its altitude Potential Energy (PE) and its airspeed Kinetic Energy (KE) and is called Mechanical energy (ME).

ME = PE + KE

Where:

PE = Potential Energy (Altitude) = Weight (W) × Height (H)

KE = Kinetic Energy (airspeed) = 1/2 Mass (M) × Velocity^2 (V^2)

Then:

$$ME = W\ H + 1/2\ M\ V^2$$

By substituting weight (W) and acceleration of gravity (g) for mass (mass = W/g) in the ME equation and symbolizing energy by E, then total energy is expressed as:

$$E = WH + \frac{W\ (V^2)}{2g}$$

$$E = W(H + \frac{V^2}{2g})$$

Then:

E = Energy in foot-pounds

Foot-pounds are unusable in the cockpit and tend to portray an energy advantage to the larger, heavier aircraft. Energy per pound of gross weight (specific energy E_s), provides a means for true comparative analysis. Specific Energy is derived by dividing E by W:

$$\frac{E}{W} = H + \frac{V^2}{2g} \quad \text{or} \quad E_s = H + \frac{V^2}{2g}$$

A diagram may therefore be plotted equating E_s in feet to velocity in Mach number by using an altitude (H) versus Velocity/Mach (V or M) diagram. These charts are referred to as Height-Mach charts. See Figure 4-6.

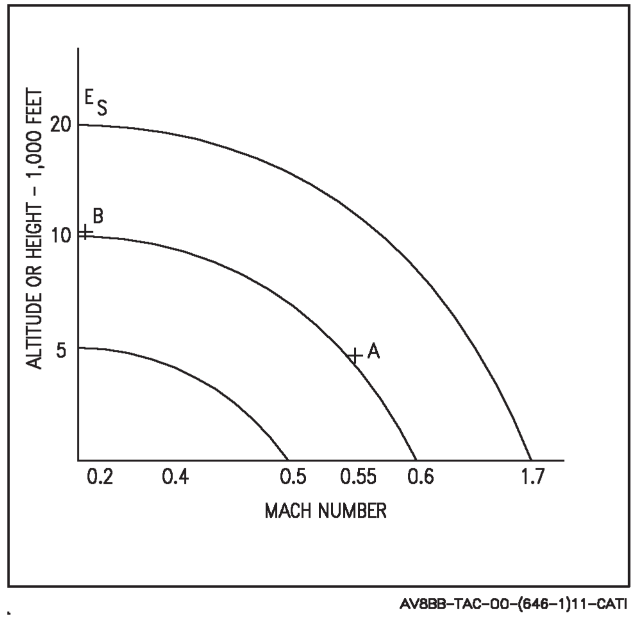

Figure 4-6. Energy Maneuverability

E_s plots in Figure 4-6, referred to as specific energy contours, demonstrate the value of E_s as the same at any point along a given contour or energy level, i.e. E_s = PE + KE. For example, choose two points along the same E_s contour on Figure 4-6.

Point A equals: 5,000/0.55 Mach

Point B equals: 10,000/0 Mach

Example:

E_s at 5,000 and 0.55 Mach (Point A)

Equals

E_s at 10,000 and 0 Mach (Point B)

Where:

$$E_s = H + \frac{V^2}{2g}$$

Then:

$$E_s = 5{,}000 + \frac{(335\ \text{KTAS})^2}{64.4\ \text{feet per second}}$$

or

$$5{,}000 + \frac{(566 \text{ feet per second})^2}{64.4 \text{ feet per second}^2}$$

E_s= 5,000 feet + 5,000 feet (4,977)

Therefore:

E_s = 10,000 feet = point A = point B

In an air-to-air battle, a certain advantage belongs to the aircraft with a higher energy level. However, an advantage will also belong to the pilot who may enter the fight at a lower energy level but can gain more energy than his opponent during the course of the battle. This is merely possessing more excess thrust than an opponent at given Mach number, altitude, and load factor combinations.

This introduces the basic term in energy-maneuverability theory, specific excess power (P_s) or energy rate.

4.1.3.2 Specific Excess Power. P_s is that power above the amount required to maintain level unaccelerated flight, and is shown in feet/second. The P_s equation is the equation for computing rate of climb, acceleration, or turn. It is defined as:

$$P_s = \frac{(T\text{-}D)V \text{ (in feet per second)}}{W}$$

or

$$P_s = 1.6878V \frac{(T\text{-}D) \text{ (in knots)}}{W}$$

where:

T = Engine thrust at a given power setting.

D = Total aircraft drag at a given angle of attack or load factor.

V = Velocity.

W = Aircraft Weight.

1.6878 = Conversion factor from knots to feet per second.

Specific excess power can also be displayed in units of knots per second in which all contours displayed are contours of longitudinal acceleration. P_s in units of knots per second is derived from P_s in feet per second via the following derivation:

$$P_s = \frac{(T\text{-}D)V}{W} = \frac{(T\text{-}D)V}{mg}$$

where:

g = acceleration due to gravity ($\approx$ 32.2 feet per second^2)

V = true airspeed (feet per second)

m = aircraft mass

rearranging the terms:

$$\frac{P_s\, g}{V} = \frac{T\text{-}D}{m} = \text{acceleration,}$$

if g is expressed in knots per second

$$g = (32.2 \text{ feet per second}^2)\ \frac{(0.59206 \text{ knots})}{\text{feet per second}}$$

then, acceleration = $\frac{19.05}{V}\ P_s$

and the contours displayed on an H-M or E-M diagram are contours of constant acceleration. See Figures 4-7 and 4-8.

Recall the conversion:

V (feet per second) = 1.689 V (knots)

thus, $$P_{s\ KTS/SEC} = \frac{19.05\ P_s}{1.689\ V \text{ (knots)}}$$

or

$$P_{s\ KTS/SEC} = \frac{11.27\ P_s}{V \text{ (knots)}} = \text{Long. Accel.}$$

where P_s is still in units of feet per second.

The excess power can be used to increase airspeed, altitude, or g-loading. When P_s curves are plotted with E_s contours, it can be determined (for each particular altitude/velocity combination and g-loading) whether the aircraft was

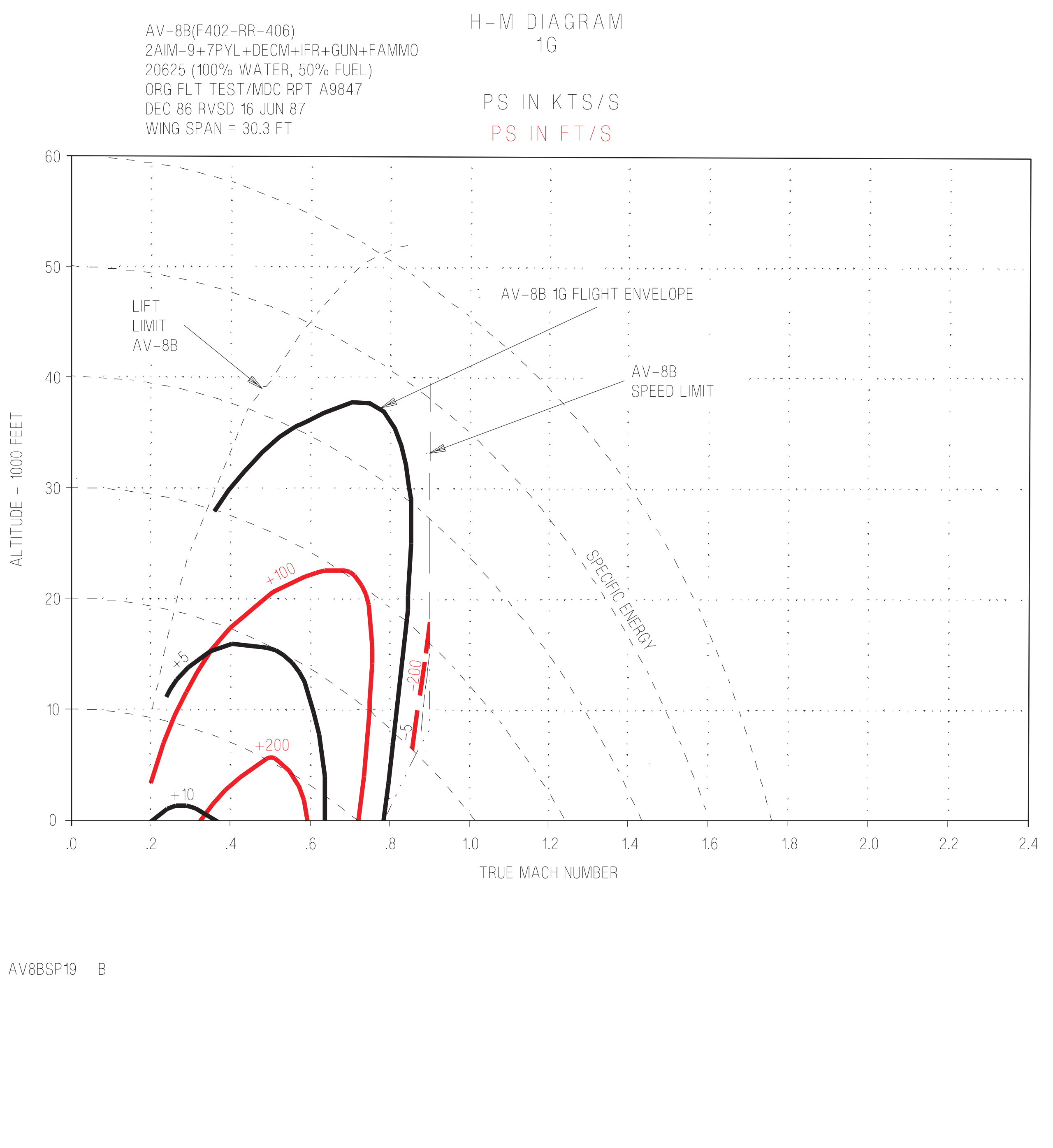

Figure 4-7. Height-Mach Diagram - Units Comparison

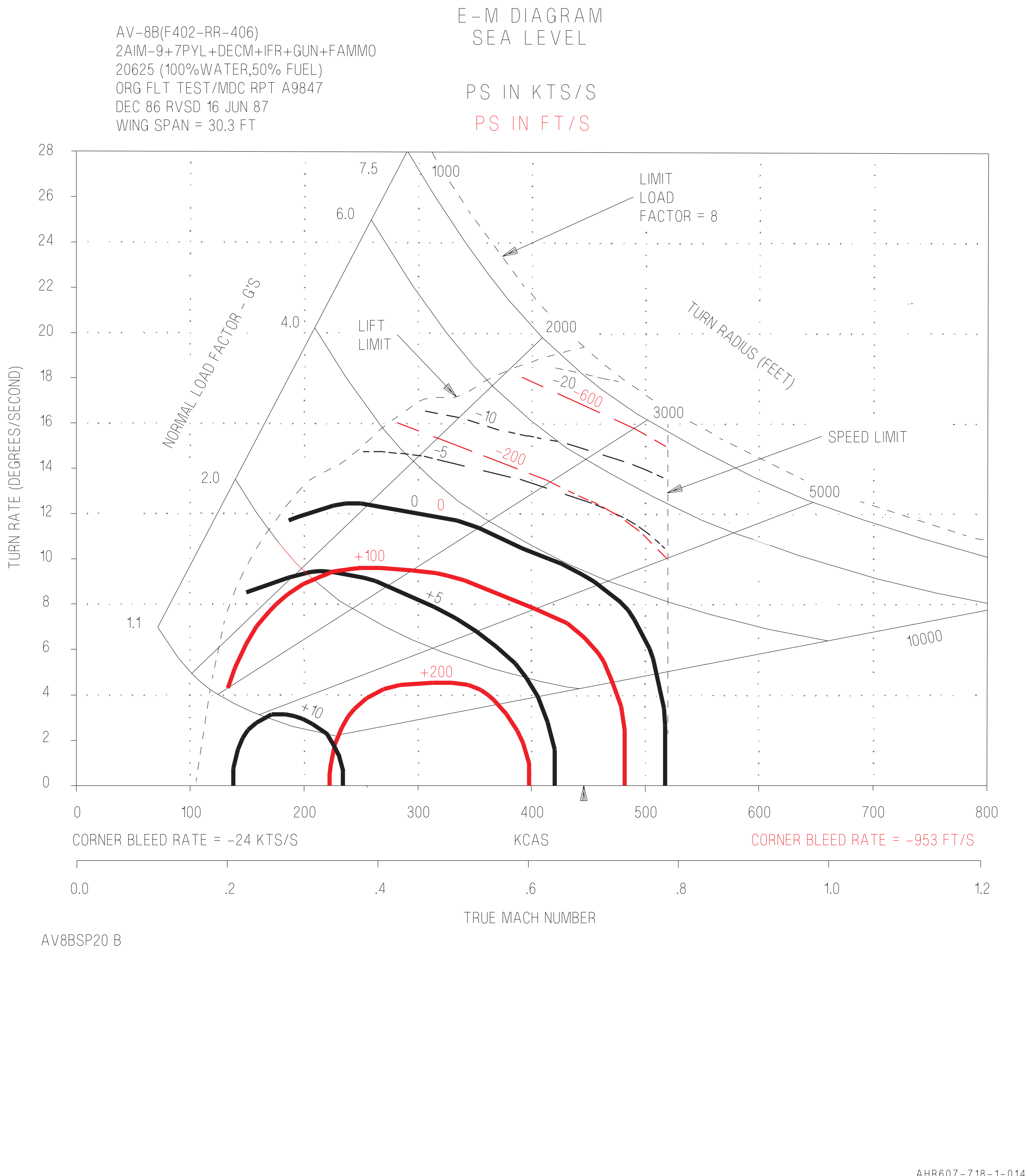

Figure 4-8. Energy Maneuverability Diagram - Units Comparison

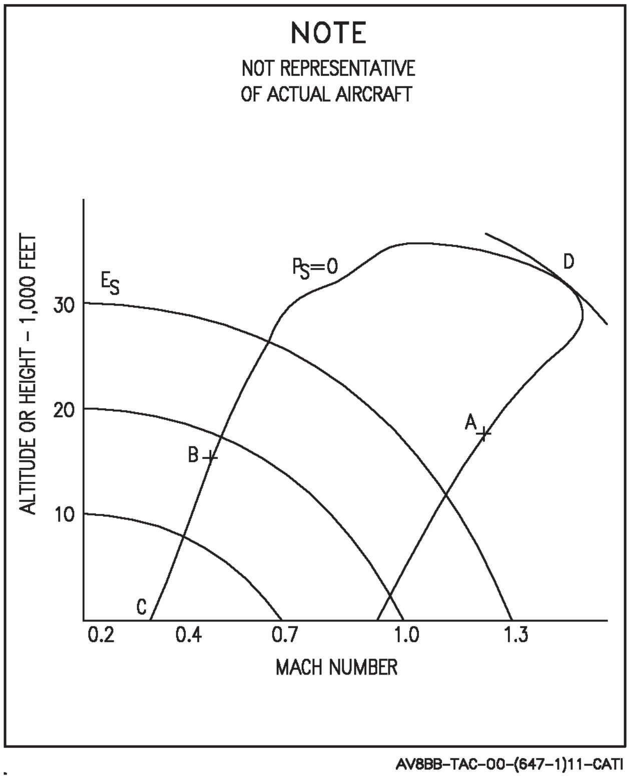

Figure 4-9. Height-Mach Diagram ($P_s = 0$)

losing energy at that point, or whether it was gaining energy at that point. If it was losing energy, the aircraft would either be decelerating or descending or both, and could not operate at the point in steady state. The point where $P_s = 0$, is the steady state operating boundary for the specific combinations of altitude/velocity/load factor. When plotted with E_s contours, the combination will provide the following information. See Figure 4-9.

1. Maximum steady state speed for a given altitude (point A).

2. Maximum steady state altitude for a given speed or minimum speed for given altitude (point B).

3. Minimum energy level the aircraft can sustain (point C).

4. Maximum energy level sustainable, (point D), (highest E_s tangent to the $P_s = 0$ boundary). Excess power can enable an aircraft to engage or disengage, gain separation, dominate in the vertical, and aid in maintaining sustained turns. In other words: climb, accelerate, turn.

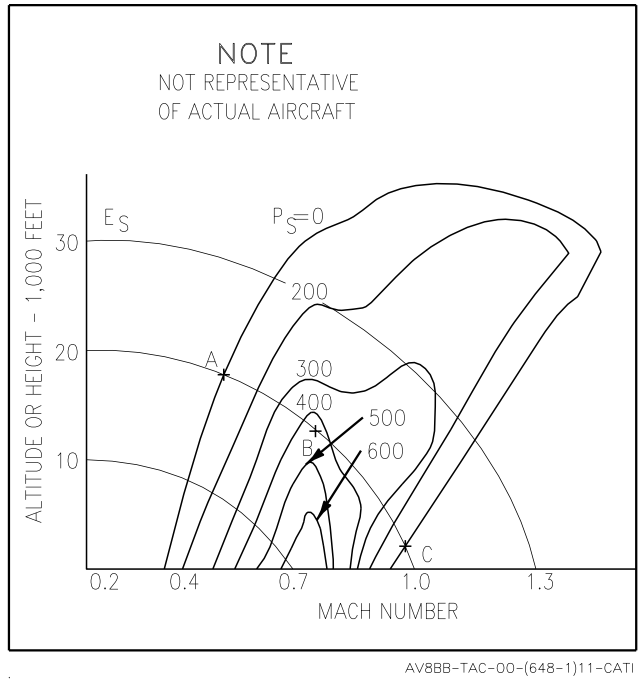

Figure 4-10. Expanded Height-Mach Diagram

An aircraft can operate outside the steady state envelope but generally only to the left of its placard structural limits, and even then it must return to the envelope.

The ability of an aircraft to maneuver within its steady-state envelope may be portrayed by incorporating P_s contours in the E_s diagram. P_s contours provide a method by which the aircraft ability to gain energy (change altitude and airspeed) may be measured anywhere in the envelope for a given g-loading. See Figure 4-10.

Although an aircraft has the same mechanical energy anywhere on the same E_s contour (points, A, B, C), not all points on such a contour are equally desirable. Points near A require such a high angle of attack for 1g flight that drag is relatively high. At point A, drag reduces P_s to zero and no power is available to increase energy. P_s also decreases from B to C because of the increase of drag with airspeed and air density. The most advantageous point to be, is point B, where E_s is 20,000 feet. Point B is a point where the E_s contour is tangent with a P_s contour.

Study of the diagram shows that no other point on the chosen E_s curve has such a high P_s available for increasing energy.

From this diagram it follows, that this aircraft should operate between Mach 0.7 and 1.0, and between 20,000 feet and the deck.

For an offensive maneuvering advantage, an aircraft must be at a higher energy level, or be able to gain energy more quickly than his adversary. A good approximation of the best flightpath to gain total energy can be obtained by following the optimum points on the E_s contours. These points will define a Mach/altitude schedule which will place the aircraft at its optimum E_s level during its climb. See Figure 4-11.

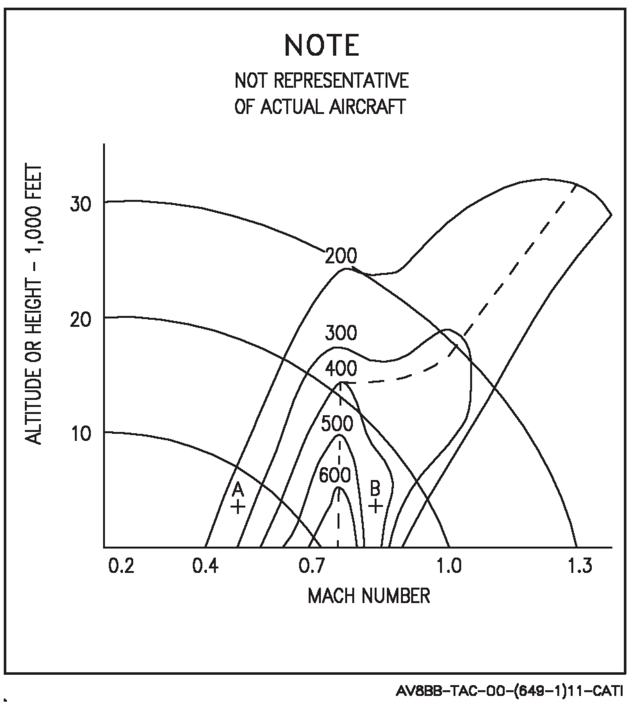

Figure 4-11. Optimum Flightpath for Gaining Energy

An optimum climb schedule from point A for the aircraft in Figure 4-11 would be to select full power and accelerate to 0.75 Mach, then ease the nose up to maintain 0.75 until 15,000 feet. Level the nose at 15,000 feet and accelerate to 1.0, then climb while accelerating. From point B, select full power and raise the nose to decelerate to 0.75 Mach and continue on the climb schedule.

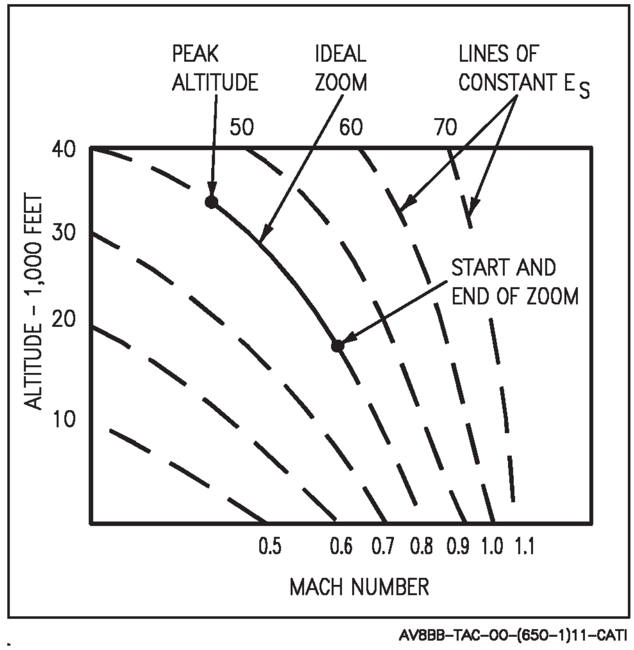

Figure 4-12. General Specific Energy Graph

P_s denotes acceleration, whereas E_s shows a constant state; e.g., feet per second versus feet for measurement.

4.1.4 Height-Mach Diagrams. Any energy system, defined by a combination of potential and kinetic energy can be diagramed on a specific energy graph. The basic graph is constructed by plotting lines of constant specific energy on a Height-Mach diagram. Any total energy point on this diagram is defined by a combination of potential energy (height axis) and kinetic energy (Mach axis). Any constant energy system can change positions on the diagram, but must remain on a constant specific energy line. As an example, an ideal zoom climb is shown on Figure 4-12.

Information available on a Height-Mach Diagram (plotted on Figure 4-13):

1. Lift Limit. For a given Mach number and altitude, the lift limit can be increased (by increasing the angle of attack) to a maximum before stall, control departure, or intolerable buffet occurs. This lift limit capability (C_L max) is represented on the Height-Mach diagram as the left hand boundary of the aircraft

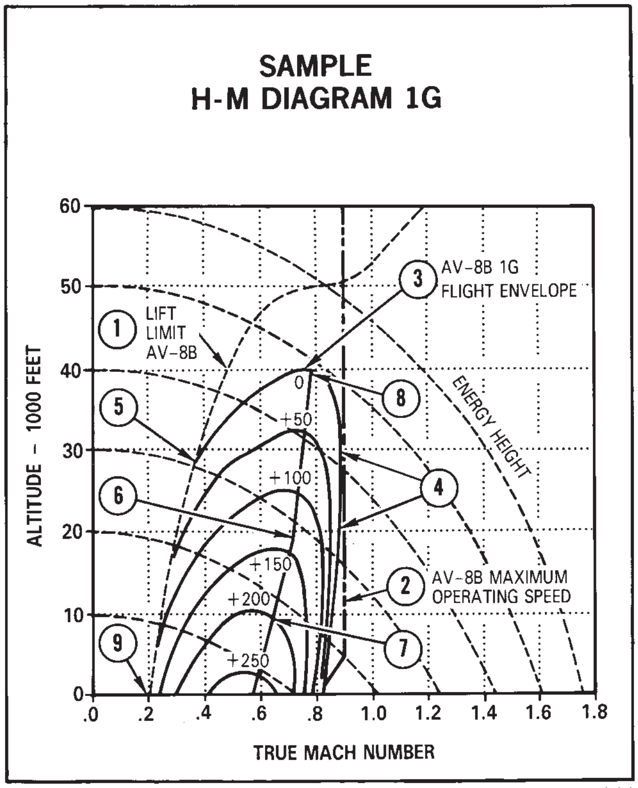

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Figure 4-13. Height-Mach Diagram - 1g

envelope. In this region, the load factor capability is aerodynamically limited.

2. Maximum Operating Limits. The right hand boundary of the aircraft envelope is determined by design limitations: structural and aerodynamic limitations. Structural limits set the maximum load factor available prior to structural failure. Aerodynamic limits are based on the airframe design and configuration with respect to total air pressure, (referred to as max Q).

3. Maximum Altitude. The maximum altitude achievable by an aircraft is the altitude where P_s = 0. The point at which the P_s contour touches the maximum altitude also defines the Mach number required to hold the altitude (maximum/minimum Mach).

4. Maximum Operating Mach. The maximum operating Mach for a given altitude is defined by the right side of the P_s = 0 contour.

5. Minimum Operating Mach. The minimum Mach to sustain a given altitude is defined by the left side of the P_s = 0 contour.

6. Optimum Climb Schedule. The optimum climb schedule from sea level to the operational ceiling is defined by the Mach subtended from a line connecting the points where the P_s contours are tangent to the E_s contours (for charts in feet per second only). A 1 percent increase in Mach number is added to insure the climb schedule remains on the positive side of the power curve. This line also approximates the maximum rate of climb, minimum time to climb, minimum fuel climb and is referred to as the Rotowski Path (best/optimum energy path).

7. Climb Rate. The rate of climb available at a given altitude can be determined by intersecting the P_s contour at a given altitude and Mach and converting feet/second to feet/minute. Comparing climb rates for max thrust and combat thrust for the AV-8B, the effects of the combat plug can be measured.

8. Maximum Energy Level. The maximum energy level is located at the point where the specific energy (E_s) contour is tangent to the steady state envelope. Similarly, the maximum energy level for a given altitude is the Mach defined where the P_s = 0 contour intersects the highest E_s curve for the given altitude.

9. Minimum Energy Level. Conversely, the minimum energy level available is at zero altitude and minimum airspeed.

Height-Mach graphs are portrayed for a given thrust level, weight, g (load factor), and drag (configuration) and are used to portray an aircraft's ability to climb or accelerate vs the rate/radius diagram's portrayal of turn or acceleration.

Changing the load factor from 1g to 2, 3, or more g's demonstrates the maneuverability of an aircraft in relation to its ability to regain energy. Energy rate diagrams of more than 1g can be helpful in determining the best tactics to employ in the maneuver and counter-maneuver portions of the flight. These diagrams contain both positive and negative energy rate (P_s) contours within the steady state envelope. These diagrams portray the ability to maintain energy while pulling g's; hence, they provide a measure of sustained maneuverability as a function of g. If an aircraft can gain energy more quickly or lose it less rapidly than another aircraft in a maneuvering fight, it has offensive maneuvering advantage. If the energy values are reversed, although forced into the defensive, the aircraft may utilize energy loss maneuvers to its advantage. In either case the 3g and 5g energy rate diagrams graphically portray capabilities and limitations in the maneuver and counter-maneuver portions of the flight.

4.1.5 Turn Rate/Radius Versus Mach Versus Load Factor (Rate Radius or Maneuver Diagrams). To develop engagement tactics for given altitudes, turn rate/radius information is required.

Excess lift is necessary to obtain g loads greater than 1.0g and thus obtain a turn rate. This increase in lift results in an increase in drag. Since at a constant power setting, Mach number, altitude, and weight, the P_s value depends on the drag produced. Therefore a relationship between P_s and turn rate can be developed. P_s may be traded for turn rate and vice versa; when one is increased, the other decreases. The greater the P_s value, the more the sustained turn rate can be increased within the limits of the envelope.

Characteristics of the aircraft which are considered in maneuver (turn rate/radius) diagrams are: the maximum lift capability of the wing, aerodynamic drag, structural limits, thrust of the engines(s), and total weight. Each diagram is applicable to only one altitude, configuration, weight, and power setting. Also these diagrams consider turning in only a horizontal plane. However, while they are limited in scope, they are still very useful in determining maneuvering performance. See Figure 4-14.

The following items are plotted on Figure 4-14.

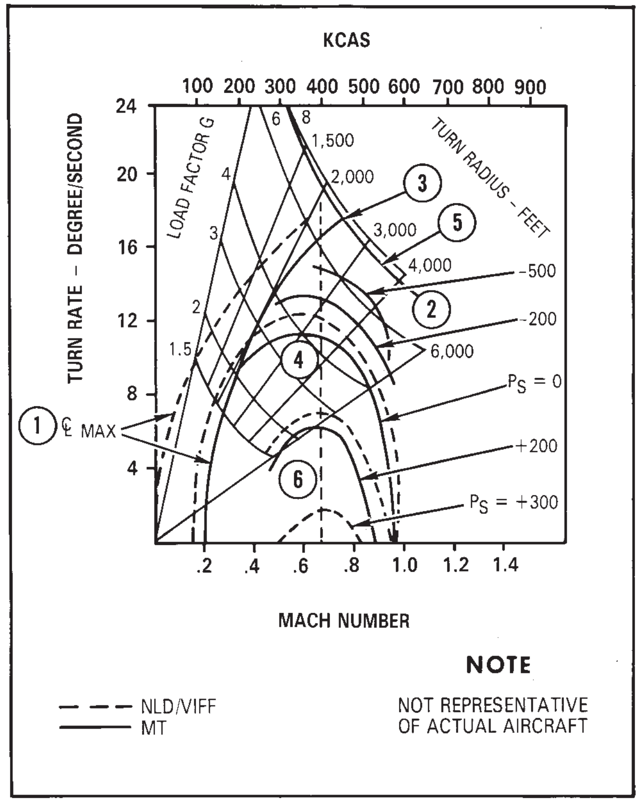

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Figure 4-14. Turn Rate vs Mach vs Load Factor

(1) Aerodynamic Limits. For a given Mach number, the lift can be increased (by increasing the angle of attack) to a maximum before stall, control departure, or intolerable buffet occurs. This limit lift capability (C_L max) is represented on the maneuver diagram as the left hand boundary of the aircraft envelope. In this region, the load factor capability is aerodynamically limited.

(2) Structural Limits. The available load factor is also limited by the structural (or maximum g) capability of the aircraft. Structural limits are established to limit the load factor to prevent fatigue/stress damage.

(3) Corner Velocity. The minimum velocity at which maximum g can be obtained is defined a corner velocity. Below this speed, buffet or stall will be encountered first. At the corner velocity, the aircraft attains its highest instantaneous rate of turn. This is sometimes referred to as the quickest/tightest turn, since above this speed turn rate decreases and turn radius increases.

NOTE

The caret on the KCAS scales of the Energy Maneuverability Diagrams denote the corner velocity speed.

(4) Sustained Corner Velocity. Sustained corner velocity is the speed at which a maximum sustained rate of turn can be achieved for a given power setting. Maximum sustained turning performance is a function of thrust, since it occurs where g is the maximum attainable without an accompanying loss of speed and/or altitude (P_s = 0). A maximum sustained turn for a particular weight, altitude, and airspeed is achieved by applying the amount of g necessary to use all of the excess power available, thereby generating zero fps specific excess power. The maximum sustained load factor can be used to determine the maximum sustained rate of turn which, when compared with airspeed (KTAS), will determine radius of turn. Tactically, rate of turn tells how fast the nose will cover a certain number of degrees of turn while radius of turn will tell the radius of the circle over the ground. For example, if the aircraft is capable of sustaining a turn rate of 10° per second, it will take 9 seconds to turn 90°.

The turn rate and true airspeed required to generate the turn rate will define the turn radius of the aircraft.

(5) Best Energy Rate at Maximum G. If the P_s values are noted all along the maximum loadfactor line, they will be highest at one point. This occurs at a higher Mach and lower turn rate than corner velocity but will produce the best energy rate for maneuvers at maximum g.

(6) Maximum Instantaneous Turning Performance. This term refers to maximum instantaneous g, which gives a maximum instantaneous turn rate; giving a minimum instantaneous turn radius. The relationship of turn rate and turn radius to g remain as they were when discussing sustained turn performance. The maximum instantaneous load factor refers to the absolute maximum g that the aircraft will produce at the given weight, airspeed and altitude. The important thing to remember is that this is only a momentary capability, and that the aircraft is not capable of sustaining such performance without giving up something to satisfy the conditions necessary to produce the g. For example, if an aircraft, at 400 KIAS, is both aerodynamically and structurally capable of producing 10g at 10,000 feet, but has a deficiency of power measured at a rate of minus 100,000 fpm in order to sustain that airspeed at that load factor, then it could hold 10g and 400 KIAS for only 6 seconds before it ran out of altitude. In this case, altitude was given up to sustain the instantaneous performance. If the aircraft was already at sea level when the 10g were applied, it would have to sacrifice airspeed, thereby changing the maximum instantaneous turn performances (since one of the constants had to be changed in the original equation). It should be noted that the maximum instantaneous load factor may be limited in either of two ways. Either the aerodynamic limits are met (i.e. the wing on the aircraft will not sustain any more g at that particular airflow), or structural limits are met (i.e. even though the wing is capable of aerodynamically producing more g, its composition causes structural failure first).

(7) Maximum Maneuverability Energy Gain Mach. By noting the average Mach at which the apexes of the energy contours occur, the best maneuvering Mach for the given altitude may be determined. Maintaining this Mach will provide approximately the best energy rate for that altitude regardless of g-loading.

4.1.6 Maneuvering Comparison Diagrams. Success in combat depends on the ability to exploit an adversary's weakness. This, in turn depends on a knowledge of those weaknesses, which can only come from a comparative study of the adversary against oneself. By superimposing like diagrams of two different aircraft over each other, areas of advantage and disadvantage can be determined quickly. The AV-8B Energy Maneuverability Diagrams presented in Figures 4-15 through 4-17 are in the exact format as the MCM 3-1 and are designed to be used as overlays. This will allow the pilot to make a direct comparison to other aircraft. The following nine configurations will allow a more precise comparison of the aircraft performance:

	CLEAN	AIR-TO-AIR	AIR-TO-GROUND
DAY ATTACK	Figure 4-15, Sheet 1	Figure 4-15, Sheet 2	Figure 4-15, Sheet 3
NIGHT ATTACK	Figure 4-16, Sheet 1	Figure 4-16, Sheet 2	Figure 4-16, Sheet 3
RADAR ATTACK	Figure 4-17, Sheet 1	Figure 4-17, Sheet 2	Figure 4-17, Sheet 3

4.1.7 Configuration Description. The configurations presented on these diagrams are as follows:

	CLEAN	AIR-TO-AIR	AIR-TO-GROUND
FUEL	50 %	50 %	50 %
WATER	50 %	50 %	50 %
PROBE	YES	YES	YES
GUN	YES + 300 RDS	YES + 300 RDS	YES + 300 RDS
ORDNANCE	NONE	2 AIM-9 + DECM	6 Mk 82 LDGP + DECM

Caution must be exercised when attempting to determine operational capabilities based purely on these sources. Operational capabilities are best determined from prolonged observation and analysis of adversary training, readiness, and tactics.

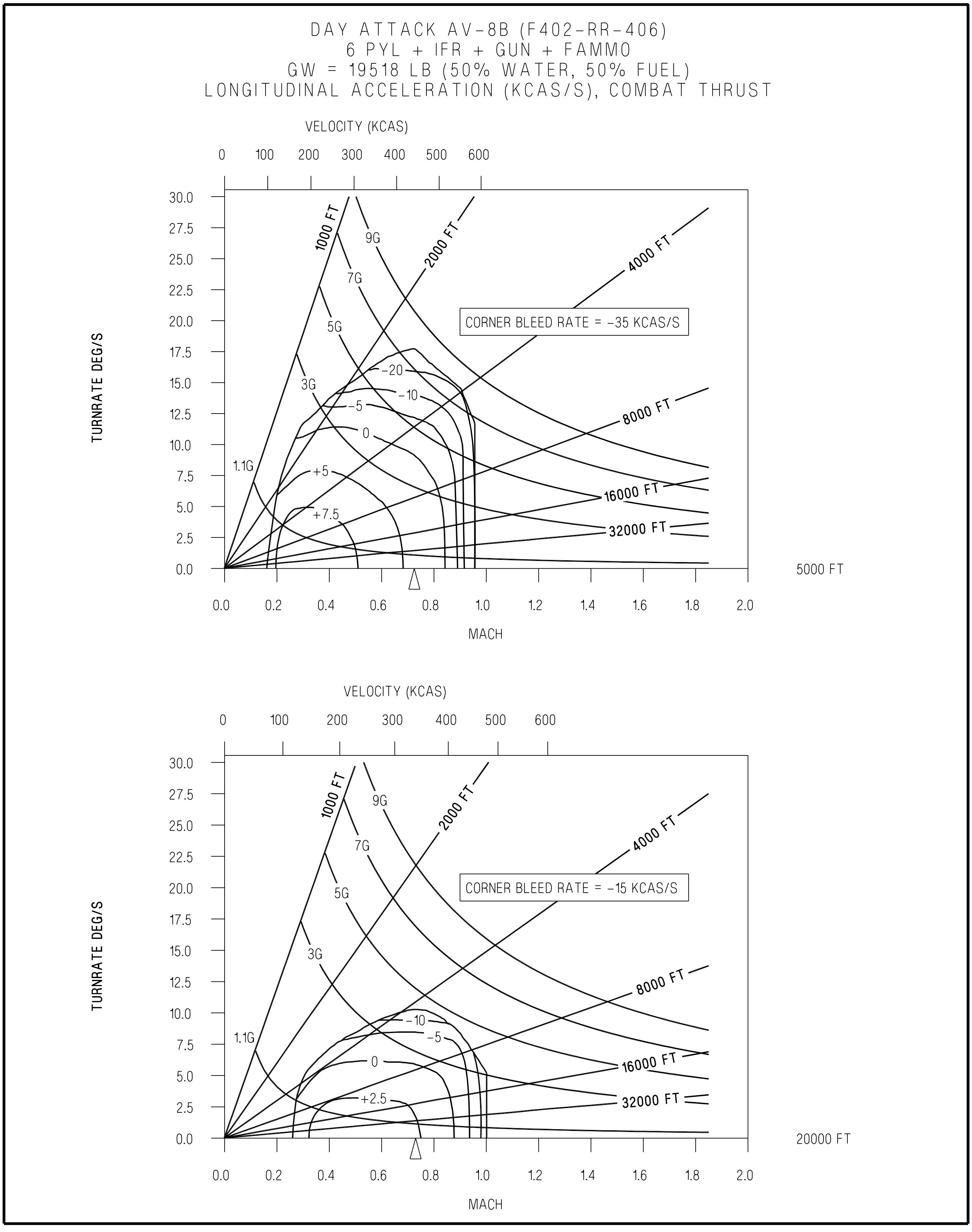

Figure 4-15. Day Attack Energy Maneuverability Diagram (Sheet 1 of 3)

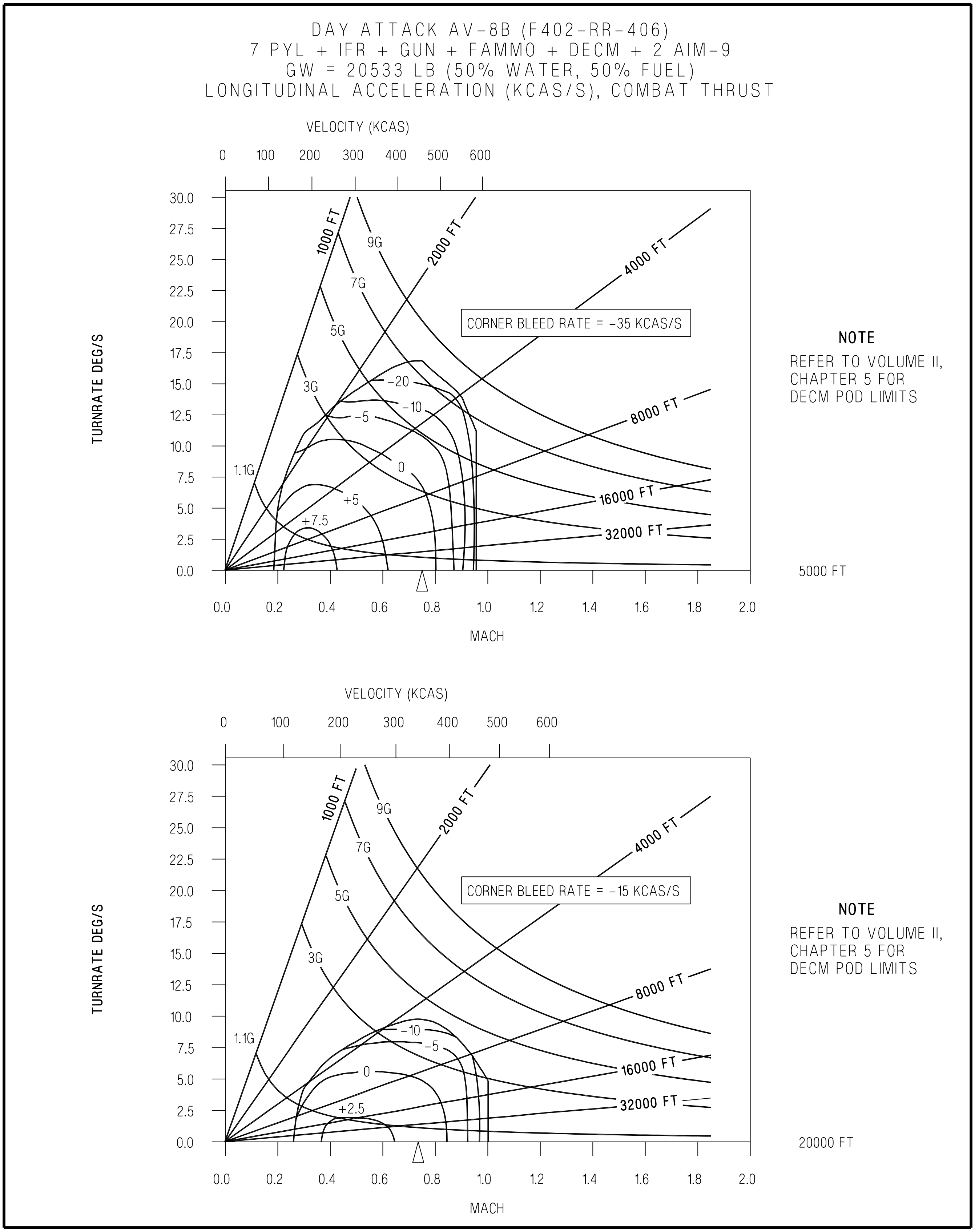

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Figure 4-15. Day Attack Energy Maneuverability Diagram (Sheet 2 of 3)

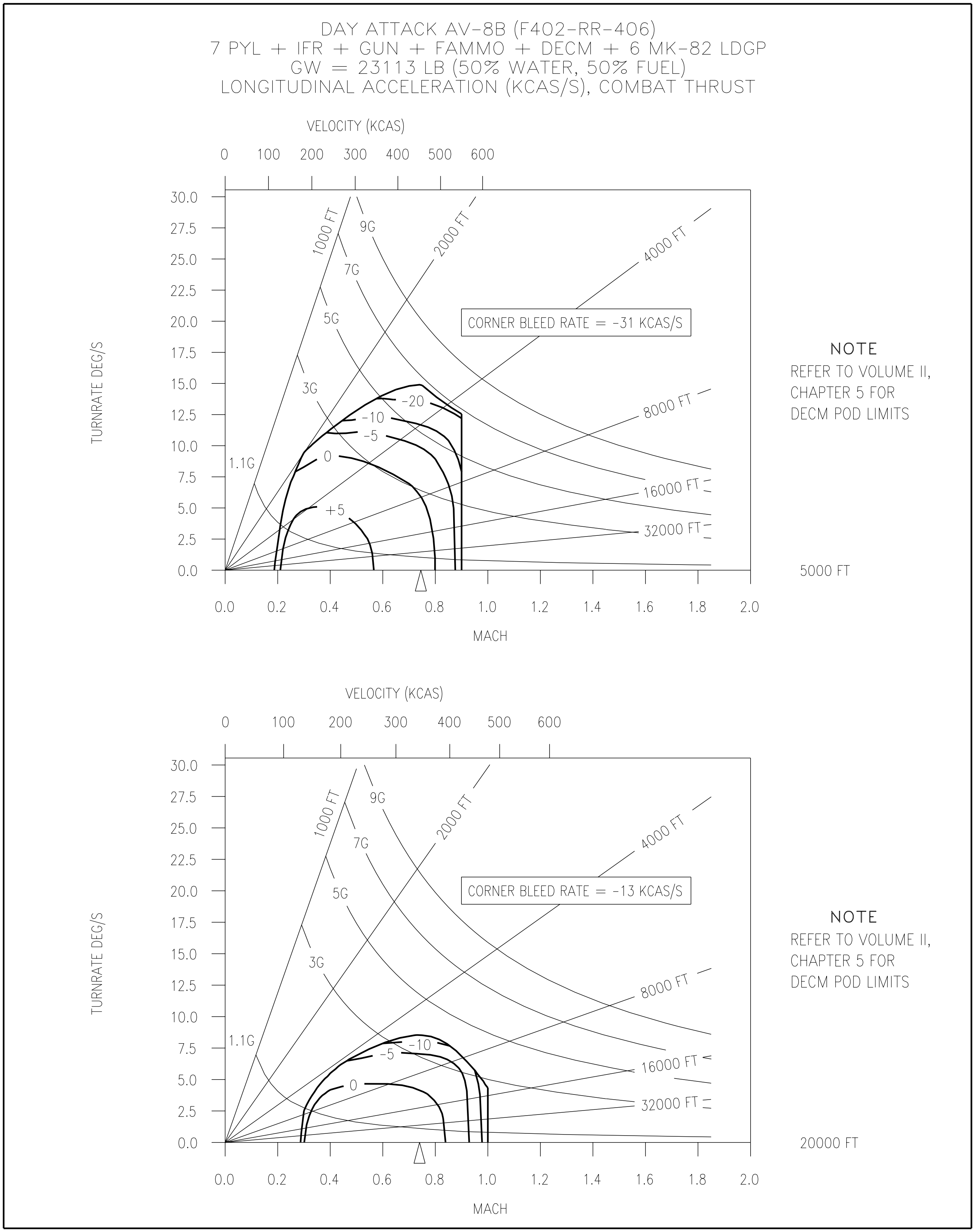

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Figure 4-15. Day Attack Energy Maneuverability Diagram (Sheet 3 of 3)

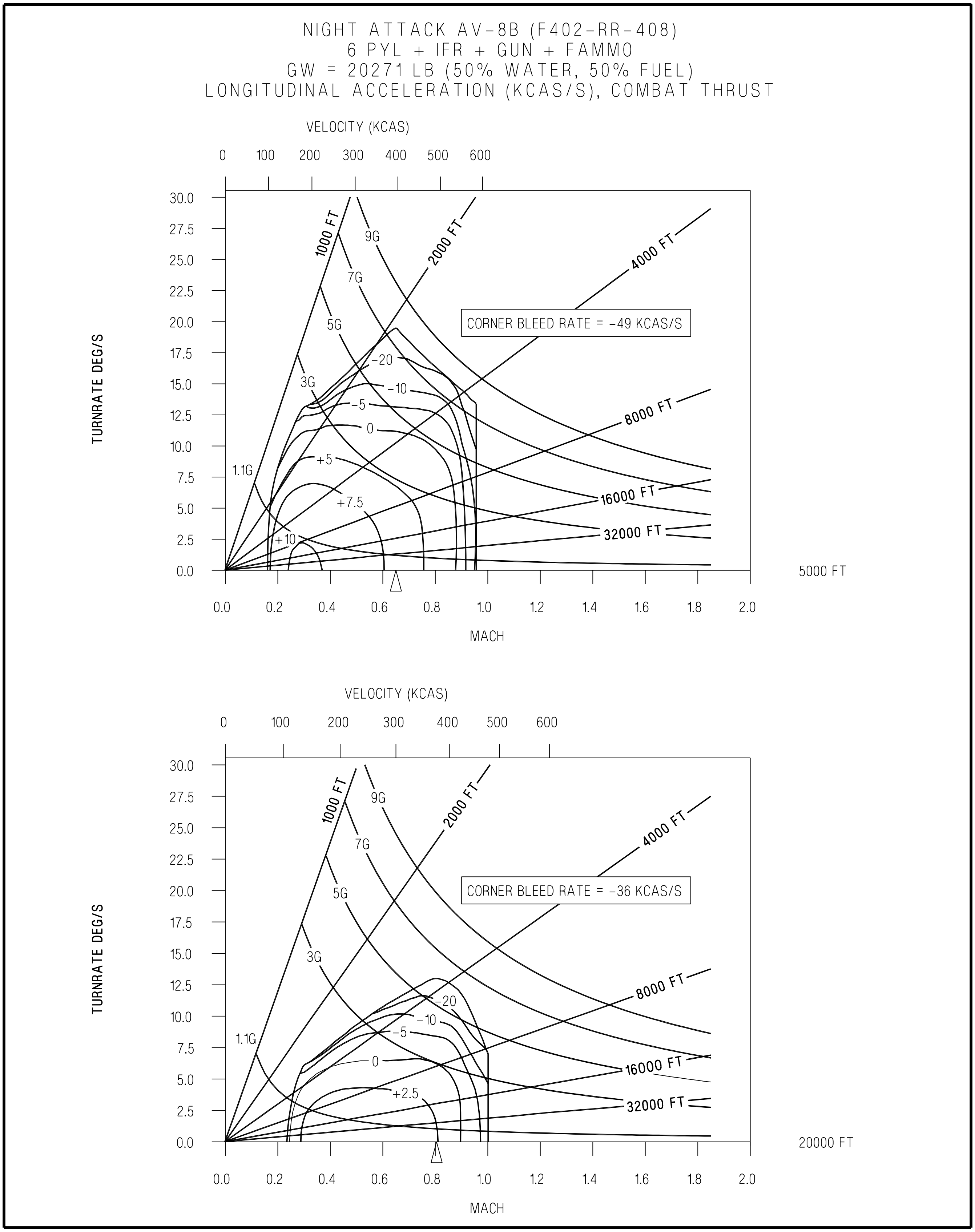

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Figure 4-16. Night Attack Energy Maneuverability Diagram (Sheet 1 of 3)

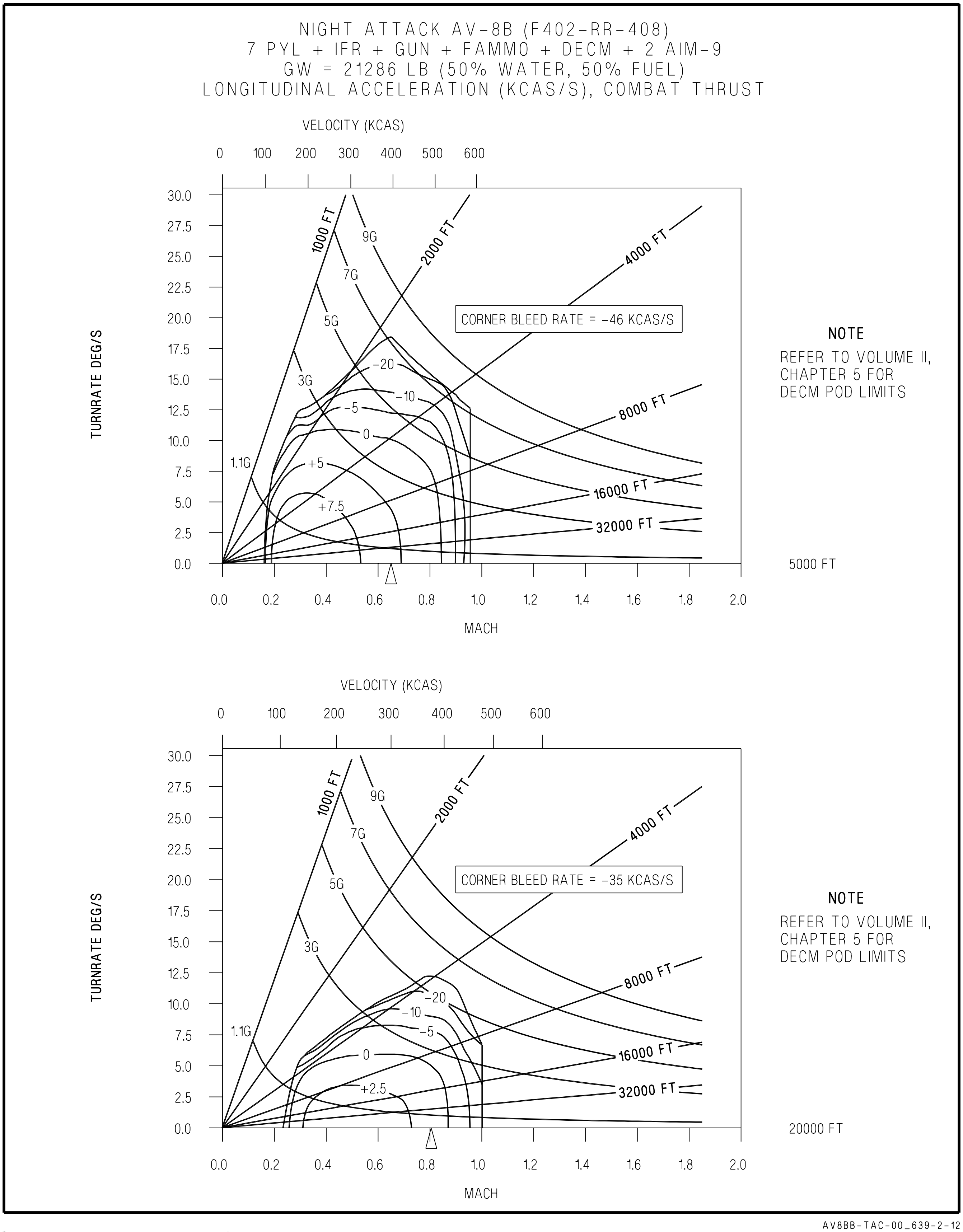


Figure 4-16. Night Attack Energy Maneuverability Diagram (Sheet 2 of 3)

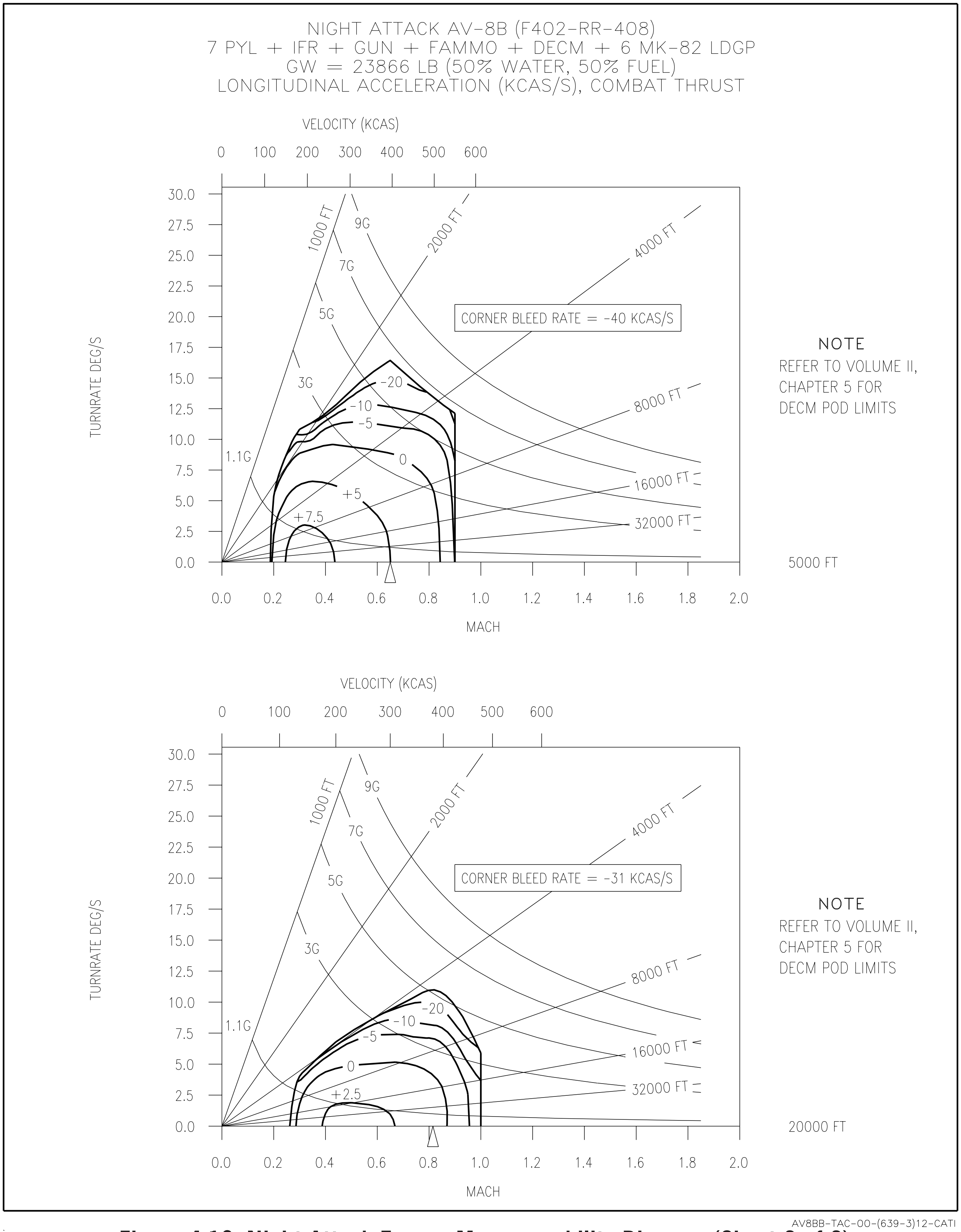


Figure 4-16. Night Attack Energy Maneuverability Diagram (Sheet 3 of 3)

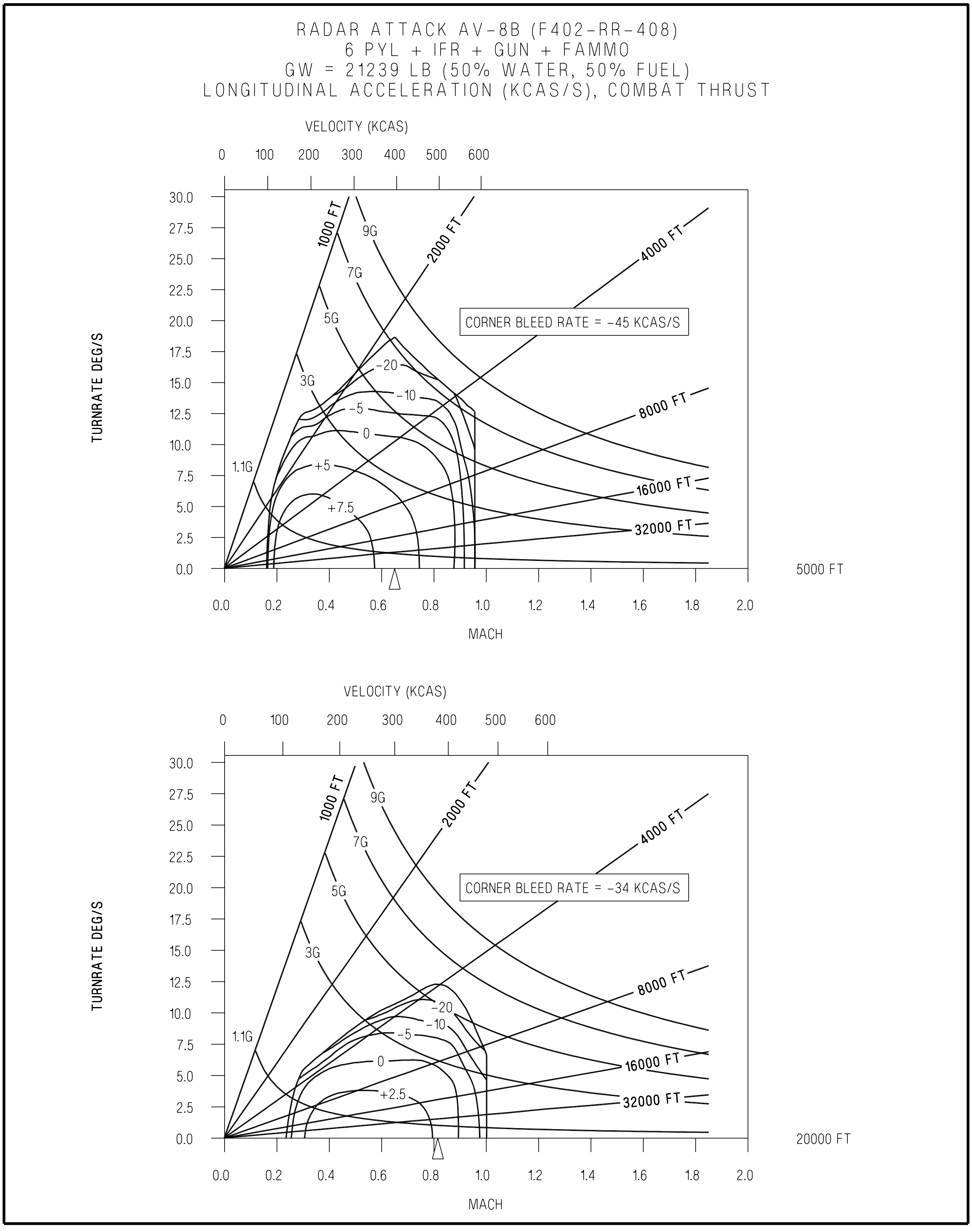


Figure 4-17. Radar Aircraft Energy Maneuverability Diagram (Sheet 1 of 3)

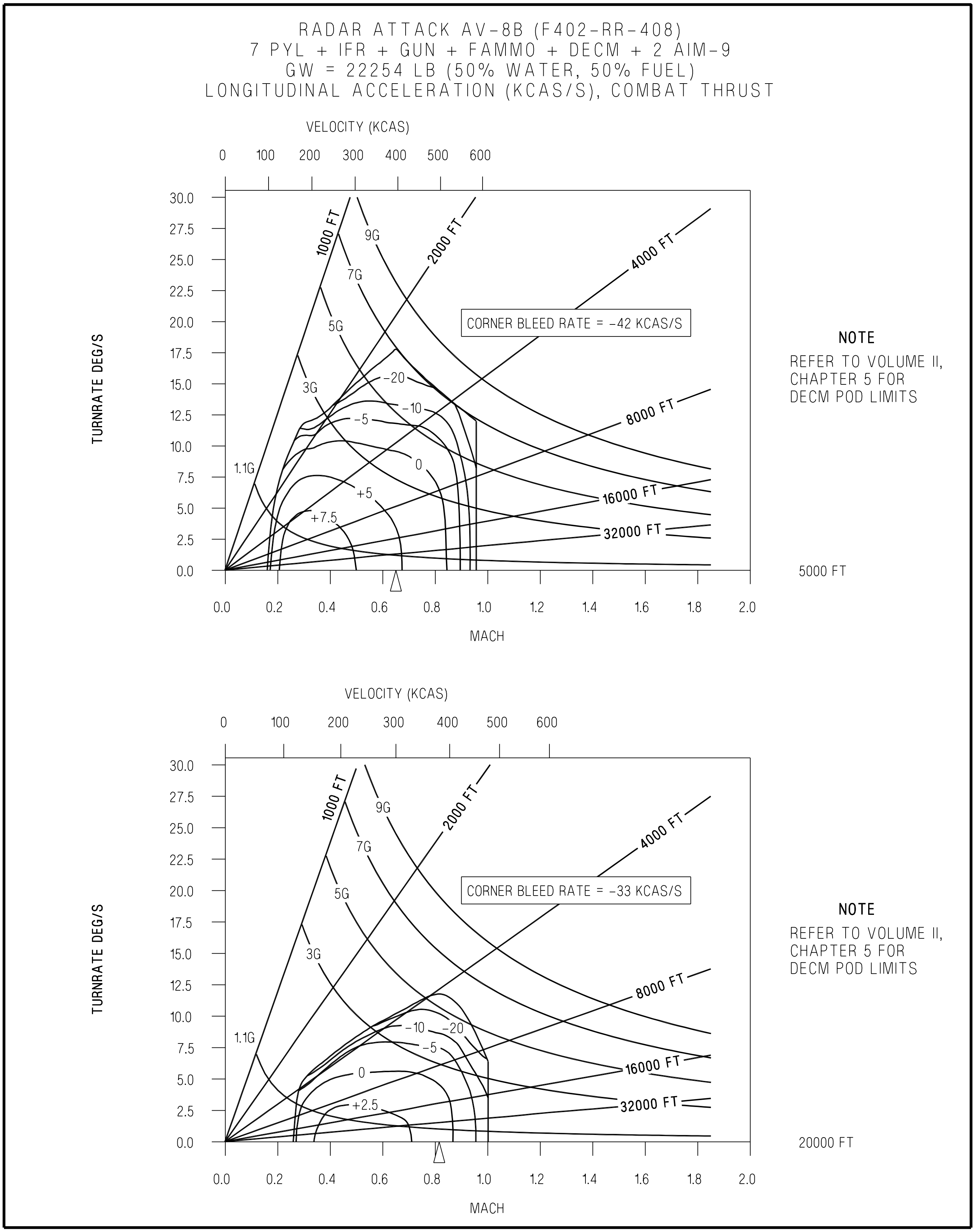


Figure 4-17. Radar Aircraft Energy Maneuverability Diagram (Sheet 2 of 3)

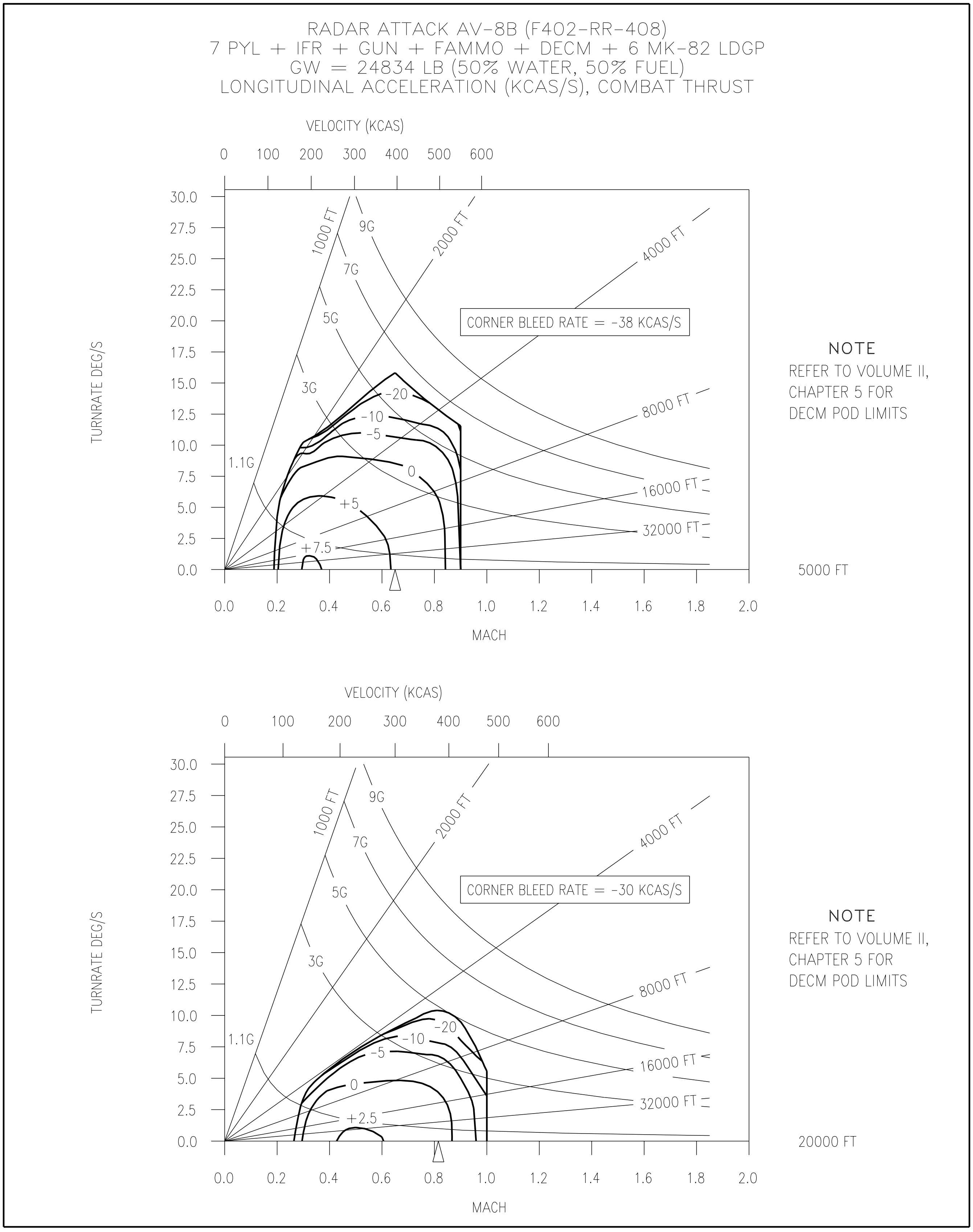


Figure 4-17. Radar Aircraft Energy Maneuverability Diagram (Sheet 3 of 3)

4.1.8 Other Applications of Performance Charts. See Figures 4-18 thru 4-20. By mathematical interpretation of P_s contours overlayed on E_s contours, charts depicting maximum range profiles, fuel consumption profiles, and descent profiles can be developed. These charts, while interesting are more readily interpreted and developed in the format used in the NATOPS Flight Manual.

4.1.9 Summary. The measure of a pilot's achievement is still how well he takes advantage of his aircraft capabilities, whatever they may be. It is here that energy maneuverability analysis makes a second great contribution: it tells the pilot what his aircraft capabilities are in many tactical situations. Pilots study energy maneuverability (E-M) profiles of their aircraft and the enemy's to learn which flight regimes give them the advantage and which do not.

NOTE

The caret on the KCAS scales of the Energy Maneuverability Diagrams denote the corner velocity speed.

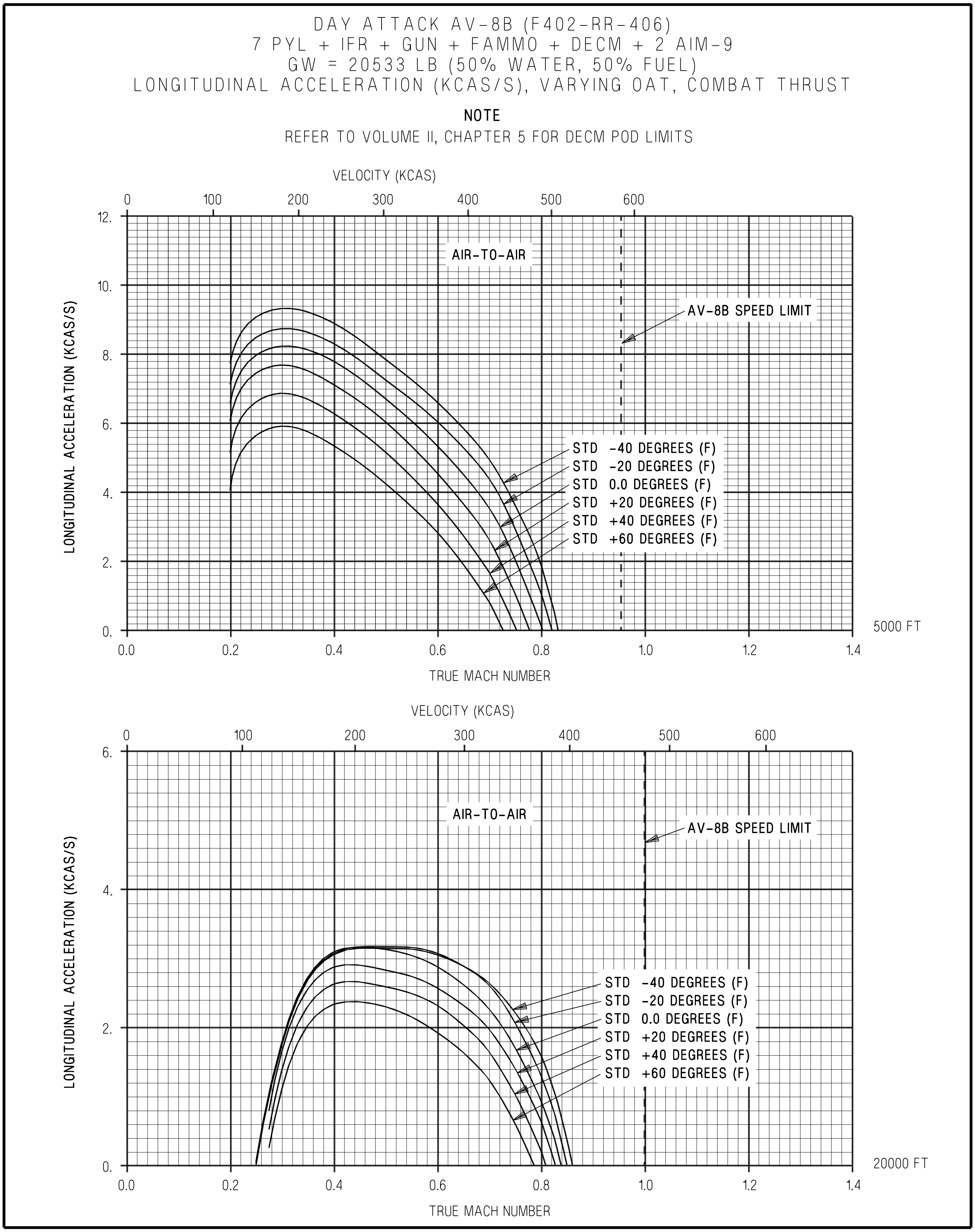


Figure 4-18. Day Attack Longitudinal Acceleration - Varying OAT (Sheet 1 of 2)

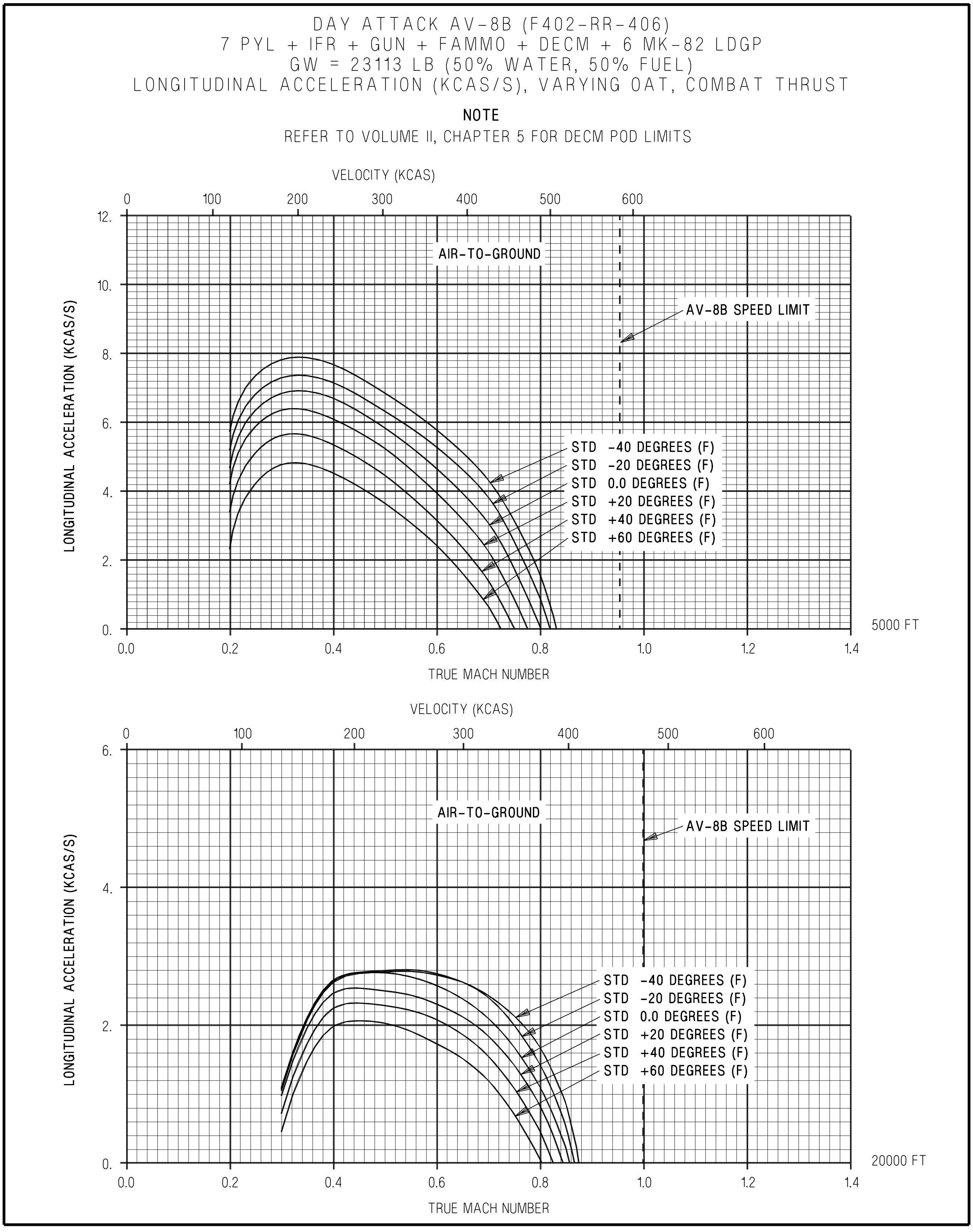


Figure 4-18. Day Attack Longitudinal Acceleration - Varying OAT (Sheet 2 of 2)

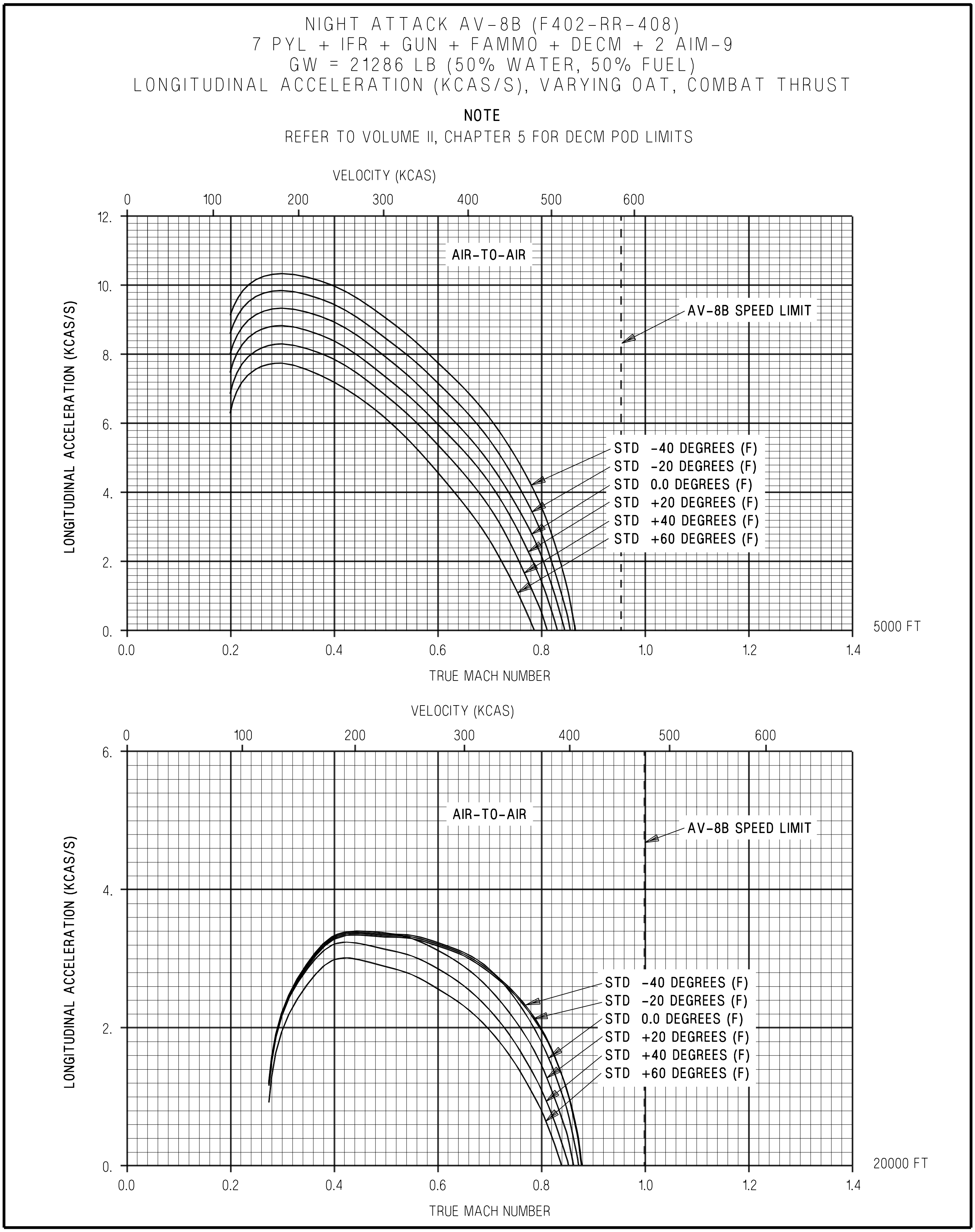
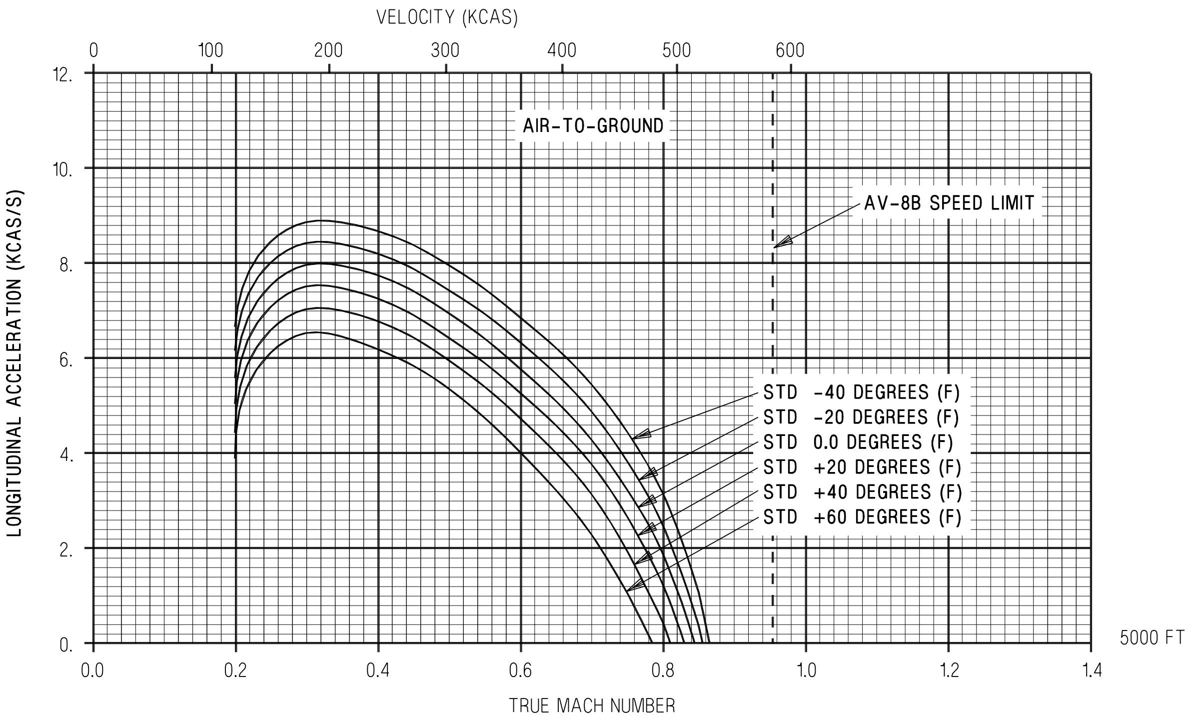


Figure 4-19. Night Attack Longitudinal Acceleration - Varying OAT (Sheet 1 of 2)

NIGHT ATTACK AV-8B (F402-RR-408)
7 PYL + IFR + GUN + FAMMO + DECM + 6 MK-82 LDGP
GW = 23866 LB (50% WATER, 50% FUEL)
LONGITUDINAL ACCELERATION (KCAS/S), VARYING OAT, COMBAT THRUST

NOTE

REFER TO VOLUME II, CHAPTER 5 FOR DECM POD LIMITS



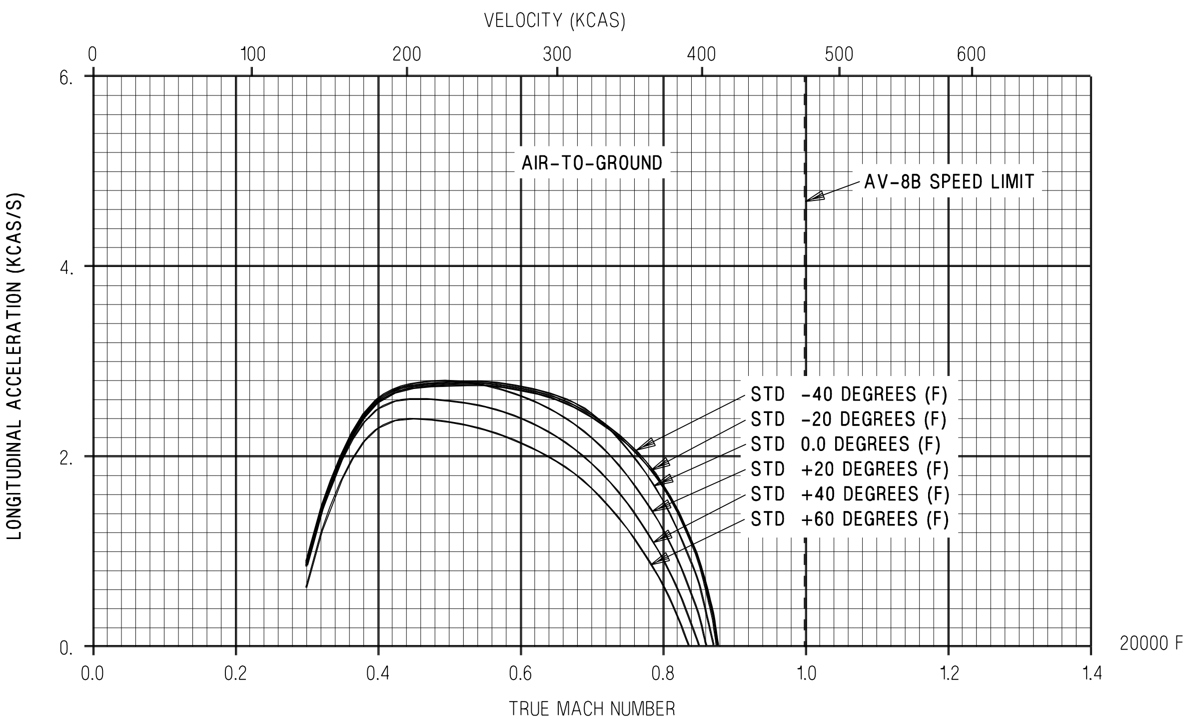


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Figure 4-19. Night Attack longitudinal Acceleration - Varying OAT (Sheet 2 of 2)

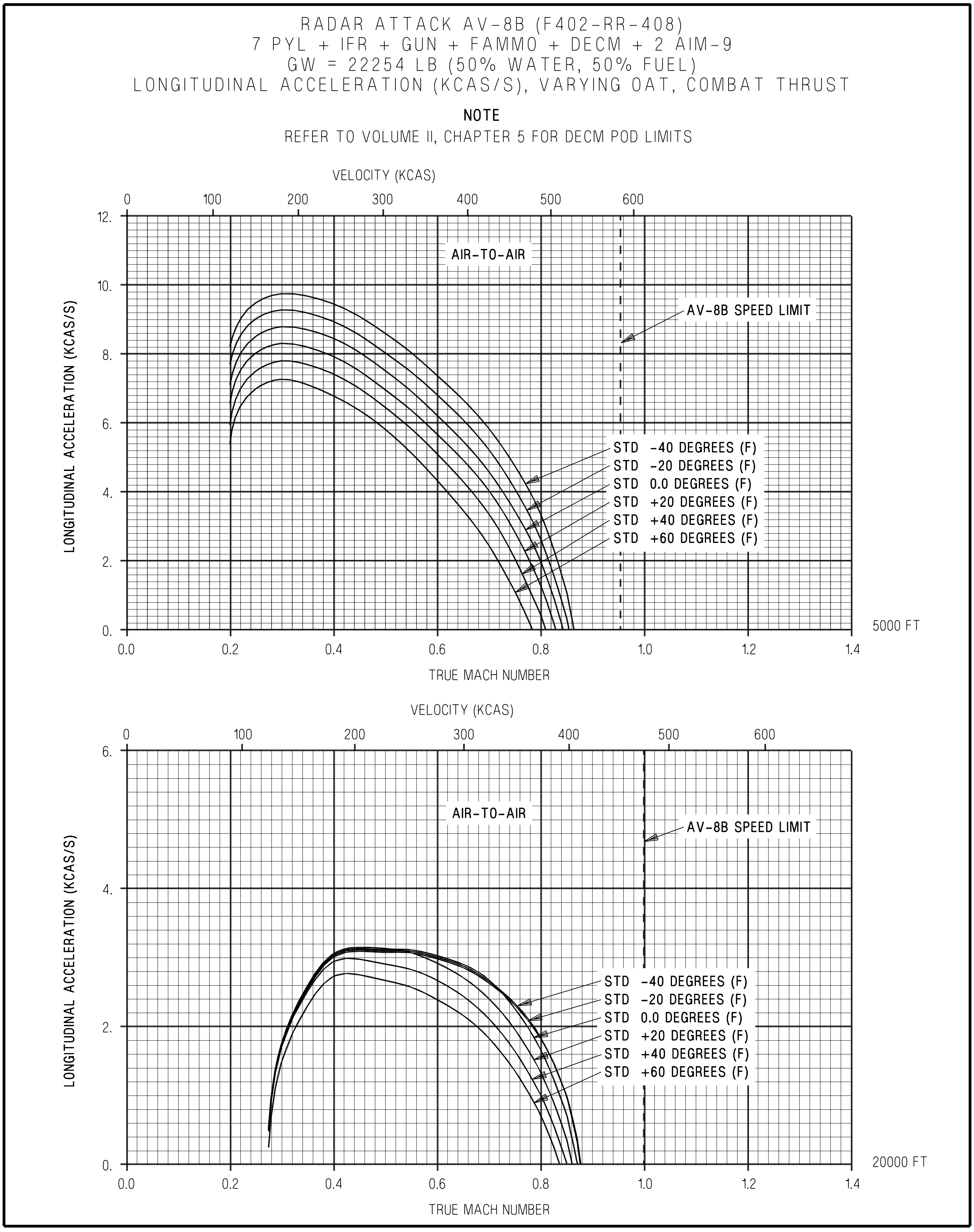


Figure 4-20. Radar Attack longitudinal Acceleration - Varying OAT (Sheet 1 of 2)

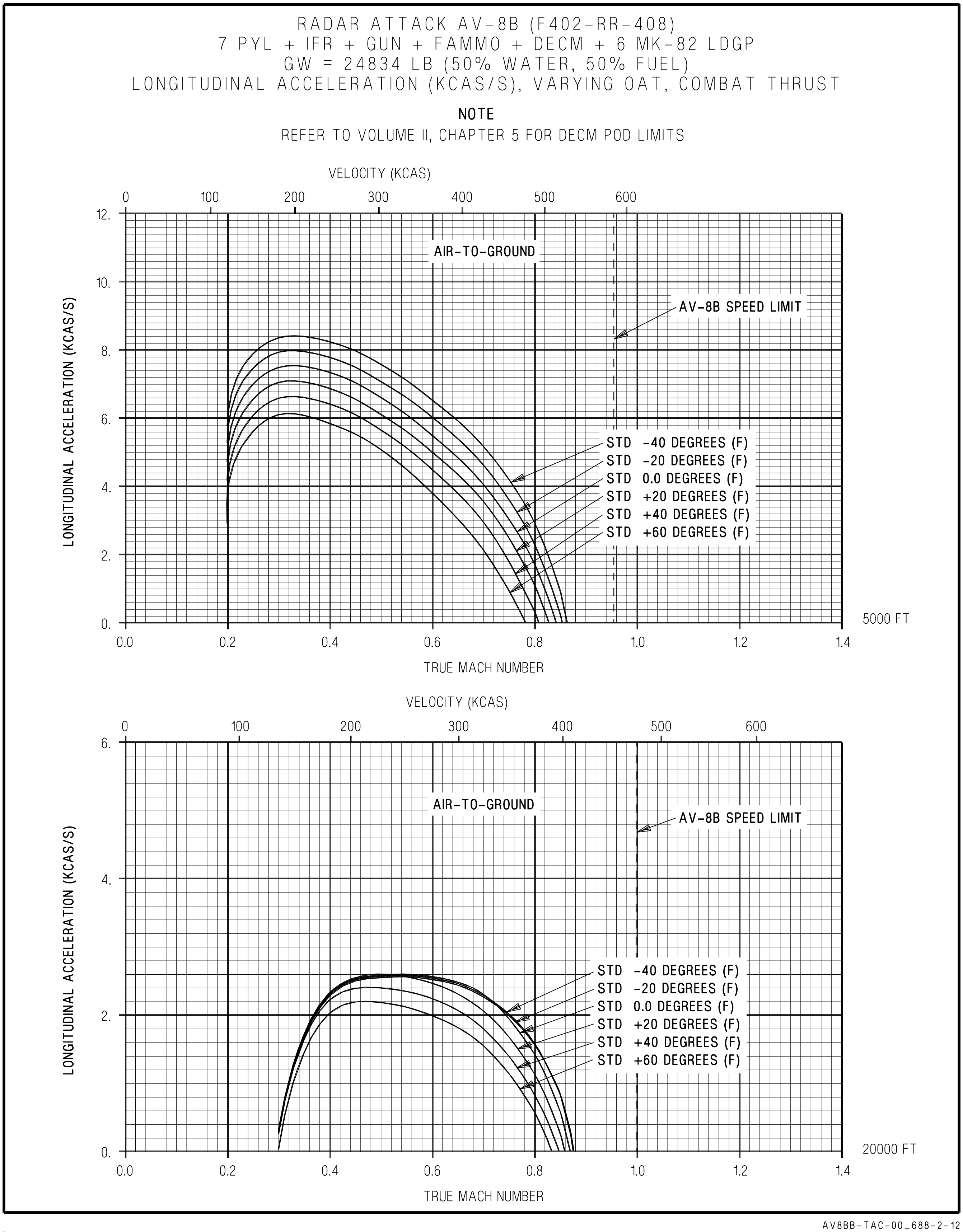


Figure 4-20. Radar Attack Longitudinal Acceleration - Varying OAT (Sheet 2 of 2)

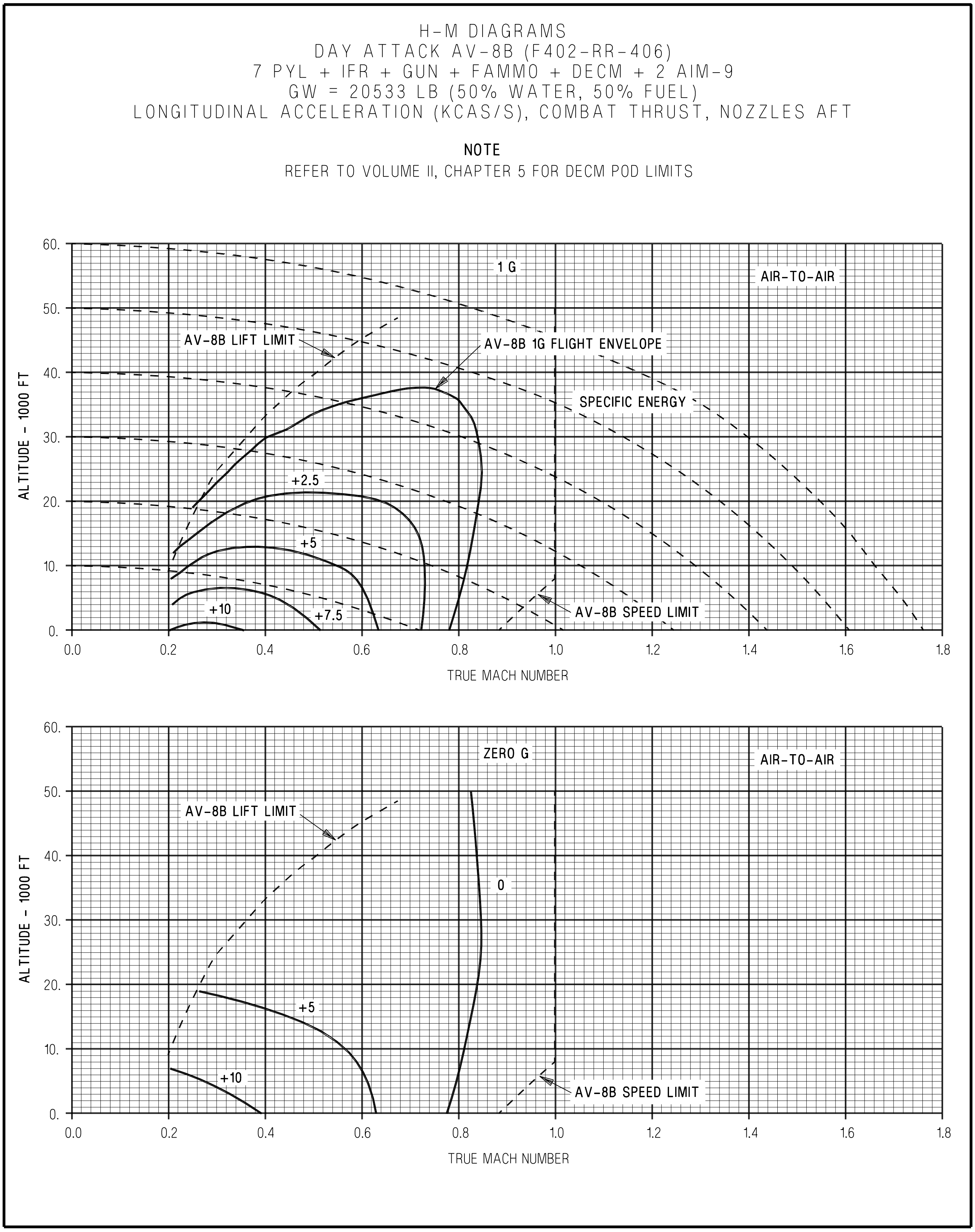
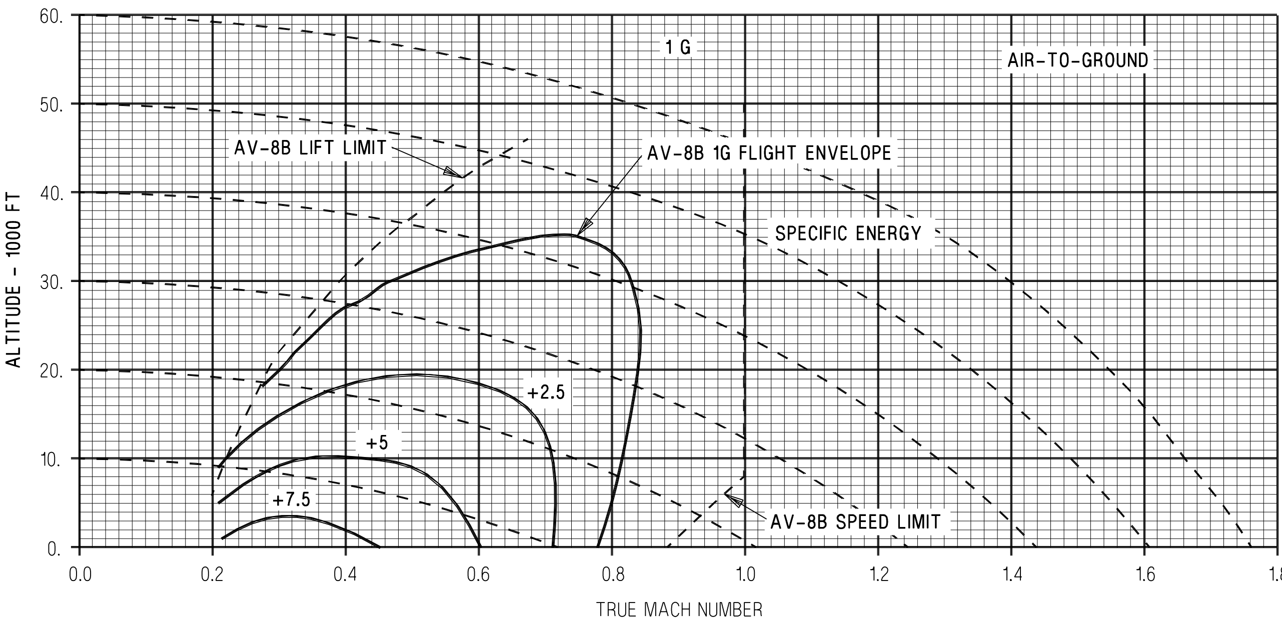


Figure 4-21. Day Attack Height-Mach Diagram (Sheet 1 of 2)

H-M DIAGRAMS
DAY ATTACK AV-8B (F402-RR-406)
7 PYL + IFR + GUN + FAMMO + DECM + 6 MK-82 LDGP
GW = 23113 LB (50% WATER, 50% FUEL)
LONGITUDINAL ACCELERATION (KCAS/S), COMBAT THRUST, NOZZLES AFT

NOTE

REFER TO VOLUME II, CHAPTER 5 FOR DECM POD LIMITS



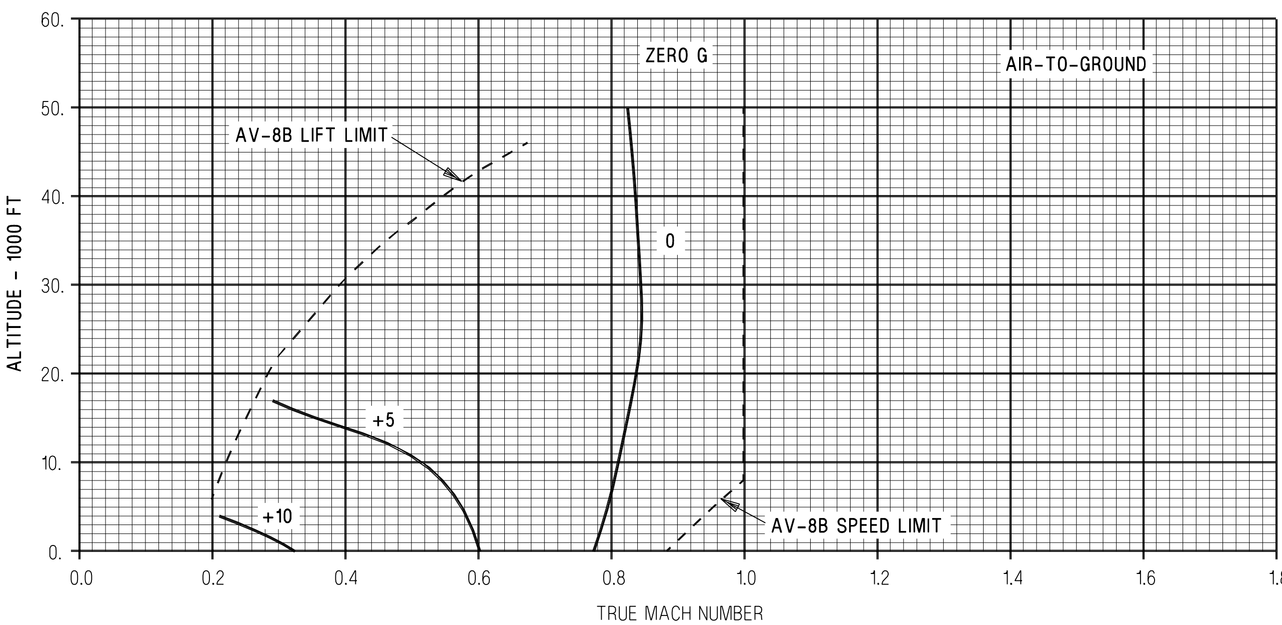


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Figure 4-21. Day Attack Height-Mach Diagram (Sheet 2 of 2)

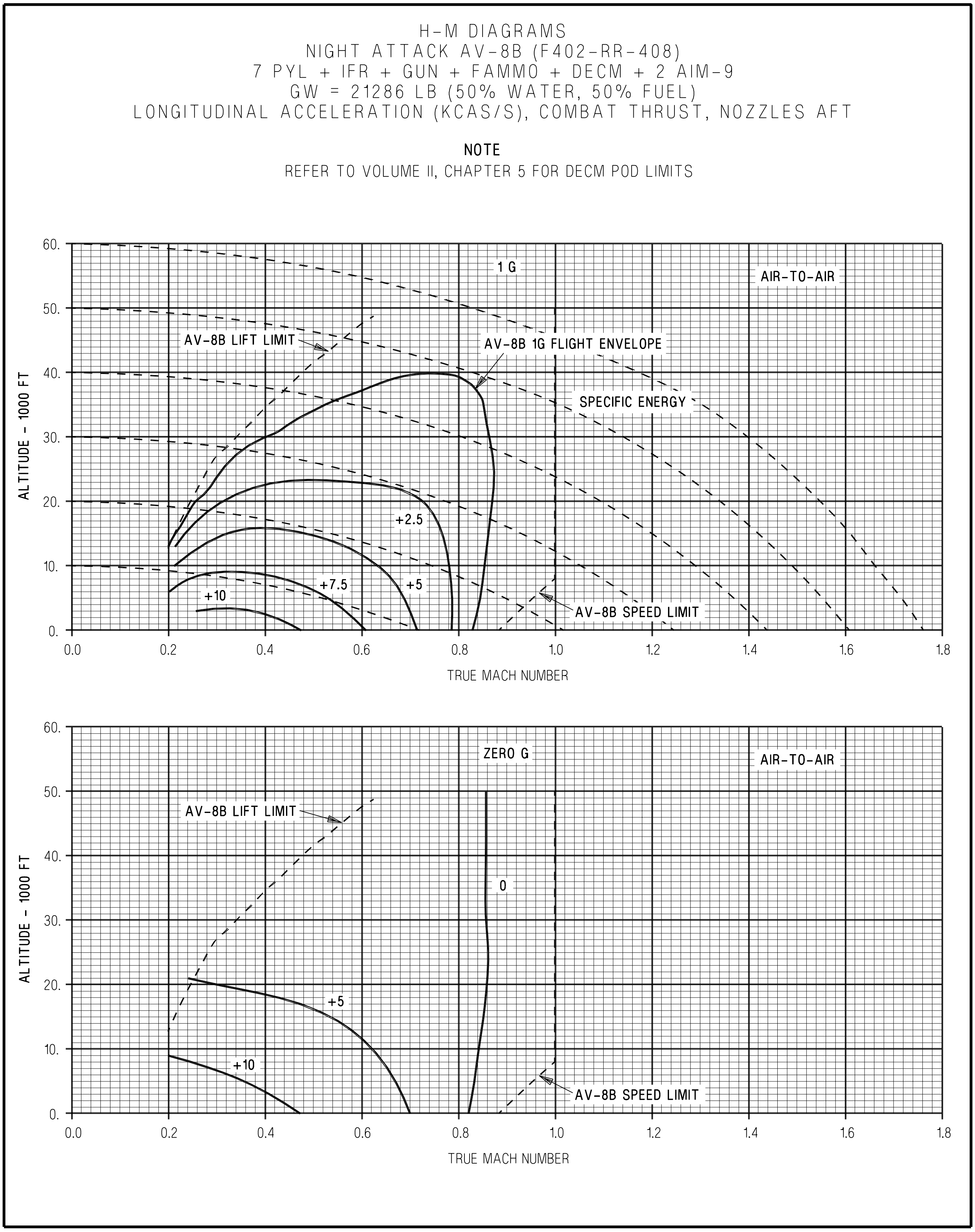
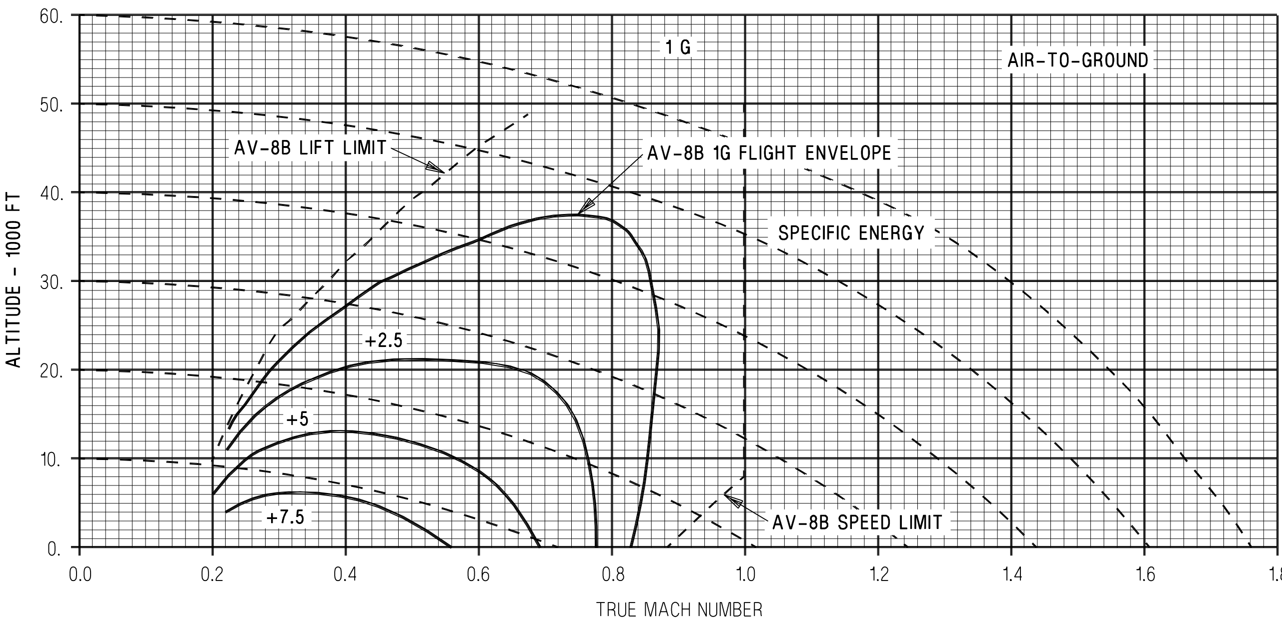


Figure 4-22. Night Attack Height-Mach Diagram (Sheet 1 of 2)

H–M DIAGRAMS
NIGHT ATTACK AV–8B (F402–RR–408)
7 PYL + IFR + GUN + FAMMO + DECM + 6 MK–82 LDGP
GW = 23866 LB (50% WATER, 50% FUEL)
LONGITUDINAL ACCELERATION (KCAS/S), COMBAT THRUST, NOZZLES AFT

NOTE

REFER TO VOLUME II, CHAPTER 5 FOR DECM POD LIMITS



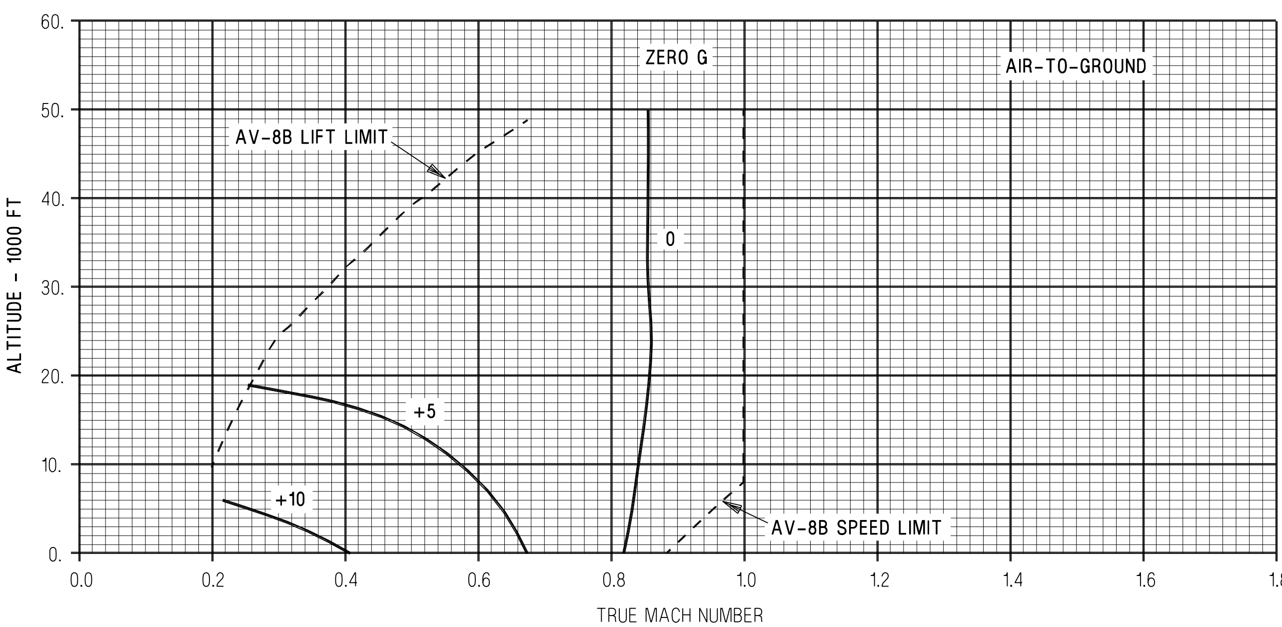


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Figure 4-22. Night Attack Height-Mach Diagram (Sheet 2 of 2)

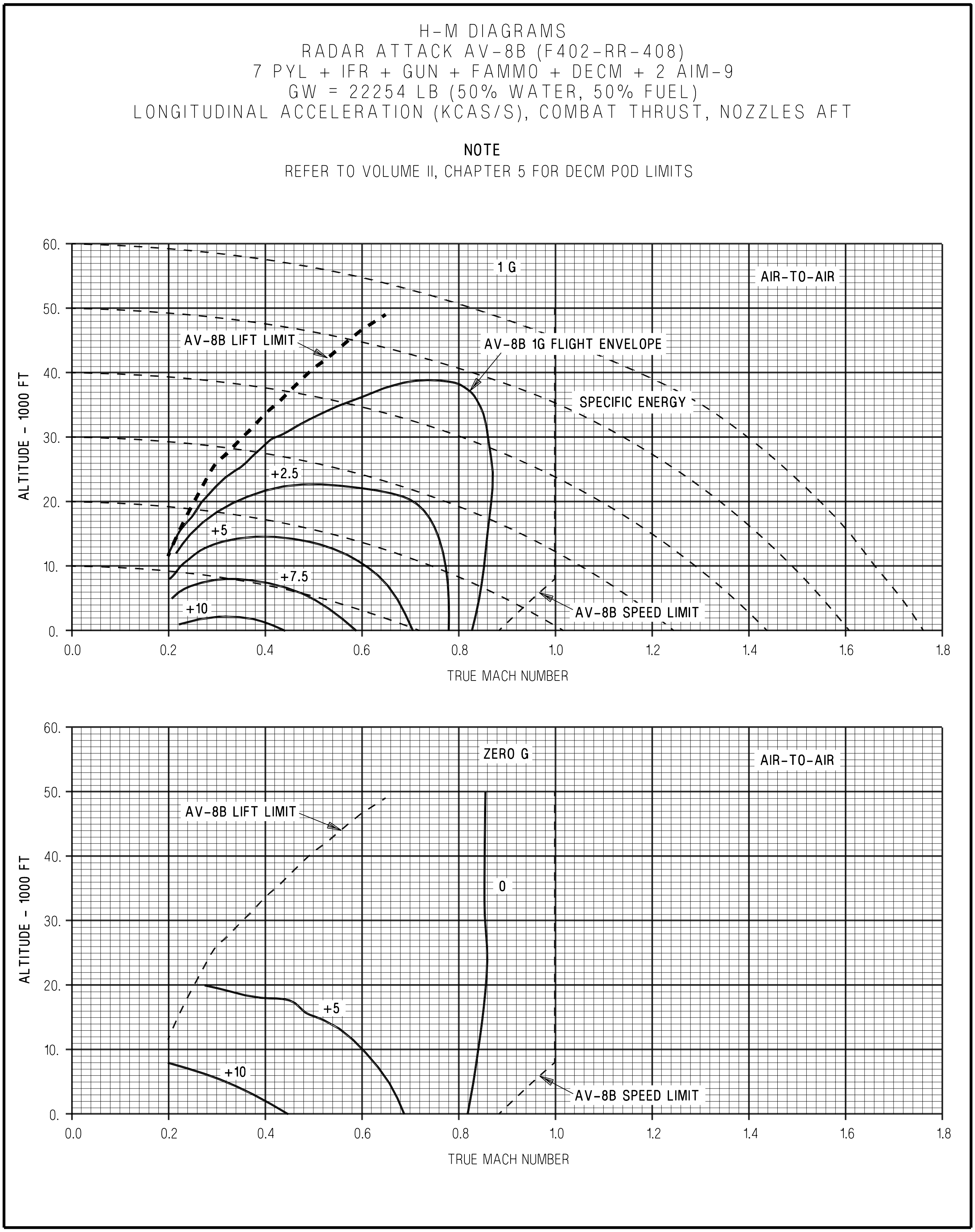
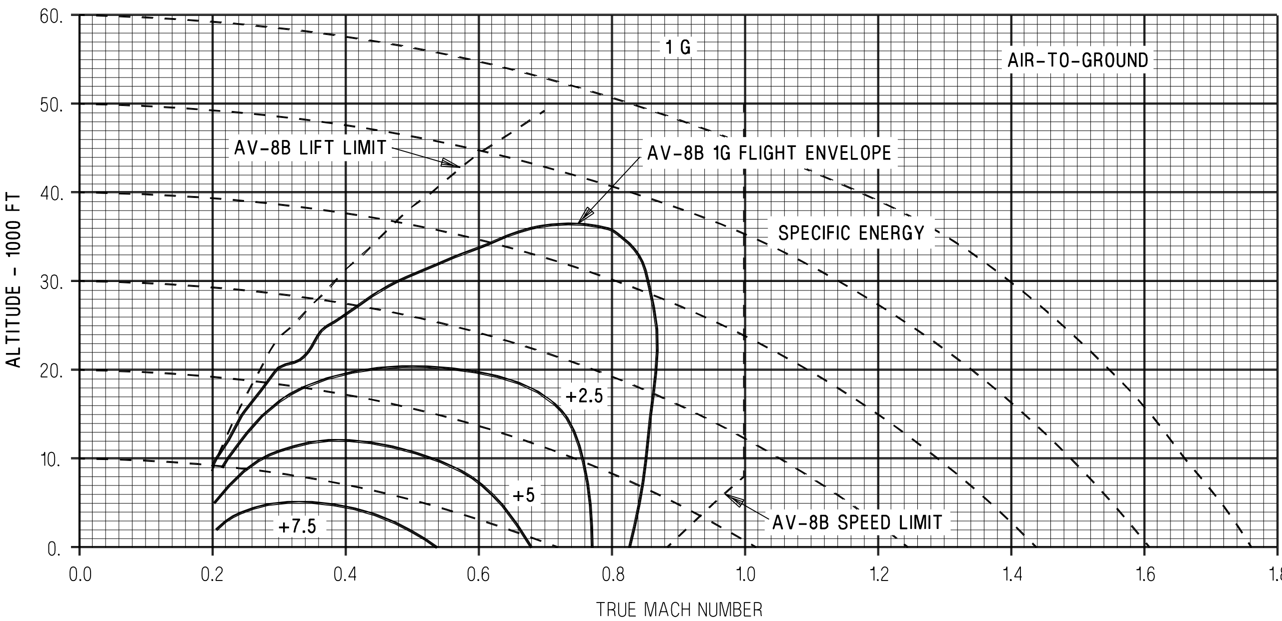


Figure 4-23. Radar Attack Height-Mach Diagram (Sheet 1 of 2)

H-M DIAGRAMS
RADAR ATTACK AV-8B (F402-RR-408)
7 PYL + IFR + GUN + FAMMO + DECM + 6 MK-82 LDGP
GW = 24834 LB (50% WATER, 50% FUEL)
LONGITUDINAL ACCELERATION (KCAS/S), COMBAT THRUST, NOZZLES AFT

NOTE
REFER TO VOLUME II, CHAPTER 5 FOR DECM POD LIMITS



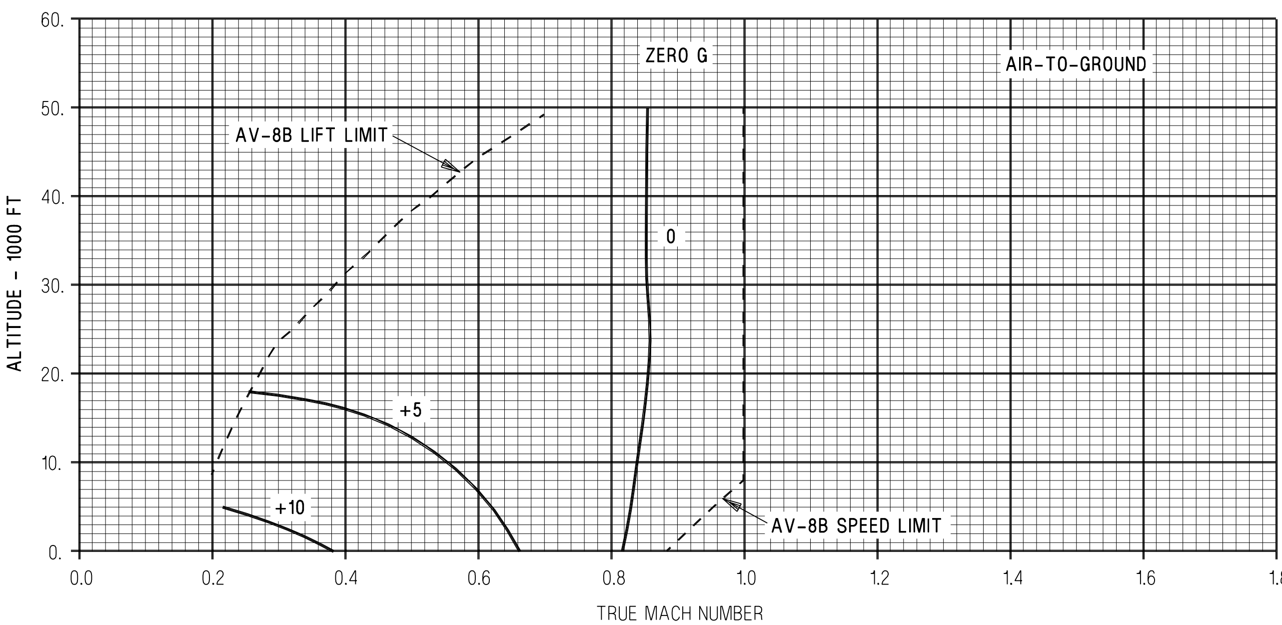


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Figure 4-23. Radar Attack Height-Mach Diagram (Sheet 2 of 2)

4.2 MISSION PROFILES

″What's your range?″ ″What's your time on station?″ These questions are frequently asked of the AV-8B pilot by the FAC's, MEU staff, GCE commanders, and other aircraft communities. They are, at best, difficult questions to answer. The variables of weather, mission, loadout, threat, and tactics all have a drastic affect on the final answer. The exact answer is determined from detailed mission planning. There are times, however, when a more generic profile and loadout can provide an acceptably accurate answer. It is advantageous to all concerned if the capabilities of the aircraft are briefed correctly and accurately each time; this requires that the same set of assumptions be used throughout the AV-8B fleet.

This section contains eight different AV-8B mission profile charts (see Figure 4-24). Each chart is labeled with a specific set of assumptions and flight parameters to allow the operator to evaluate their usefulness for his particular purpose. The purpose of these charts is to provide the fleet user with a detailed, accurate, and consistent reference from which a generic capabilities brief can be developed. This should eliminate inconsistencies that may arise from one briefer to the next, inconsistencies that invariably arise when different assumptions are used. A consistent and accurate presentation of AV-8B capabilities will go far in dispelling many of the myths that exist regarding this aircraft's capabilities.

All of these charts are based on an AV-8B Radar aircraft with the -408 engine, thus they can be considered ″worst case″ when employing Day Attack or Night Attack aircraft. The following general loading and profile rules apply:

4.2.1 General Loading Rules

1. JP-5 fuel
2. 500 pounds water
3. 120 flares and 60 chaff
4. IFR probe
5. 25 mm GAU-12 gun with 300 rounds
6. Seven pylons

4.2.2 General Profile Rules

1. Start, taxi, takeoff, and acceleration to 300 KCAS uses 250 pounds of water and 500 pounds of JP-5 fuel.

2. Climb at 300 KCAS to Mach for best rate of climb at maximum rated thrust.

3. No fuel, time, or distance is credited for the descent inbound to target. Fuel, time, and distance is credited for descent to base.

4. Reserve of 800 pounds JP-5 and 245 pounds of water.

The mission profiles provided here pertain to CAS, AI, AAW, and ferry missions. They are designed to answer both the ″how far″ and ″how long″ question, showing the trade-off between distance traveled and time on station. They also portray different profiles, loadouts, and combat time (time in the target area) for the varying missions. One important piece of information not provided is launch capability. Will you be able to get airborne off the ship or a 600 foot EAF carrying these loads? That answer is easily determined by the planner through use of The ALSO or NAMPS mission planning system.

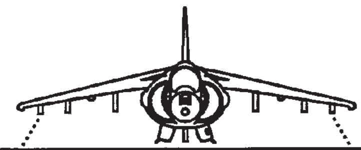
The following mission profiles are provided:

1. Close Air Support, high-medium-high
2. Close Air Support, high-medium-high with tanks
3. Close Air Support, low-low-low
4. Air Interdiciton, high-high-high-high
5. Air Interdiction, high-low-low-high
6. Deck Launch Intercept
7. Combat Air Patrol
8. Ferry

RADAR ATTACK AV-8B
OPERATIONAL COMBAT AIR PATROL (CAP) PROFILE
(7) Pylons + Gun + 300 Rounds 25mm Ammo + IFR Probe + Full Water (495 lb)
Expendables: (120) Flares + (60) Chaff

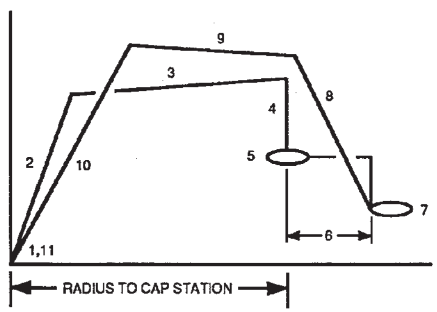
PROFILE DEFINITION

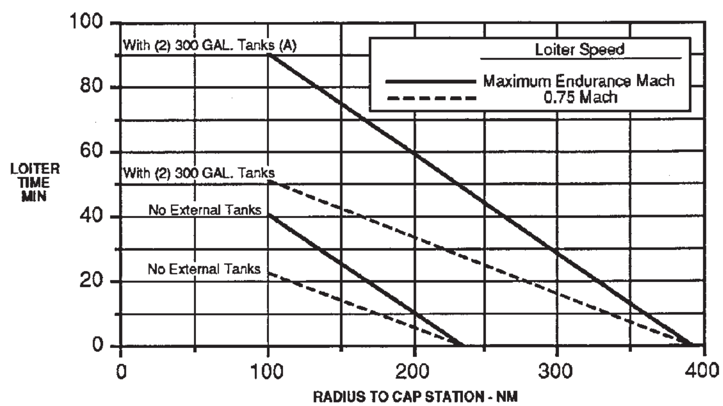
1. WARM-UP, TAKEOFF, AND ACCELERATE: To 300 KCAS using 500 pounds fuel and 250 pounds water.
2. CLIMB: On course to optimum cruise altitude at 300 KCAS to NATOPS specified Mach at Maximum Rated Thrust.
3. CRUISE OUT: At speed and altitude for maximum range.
4. DESCENT: To 20,000 feet. No fuel, time, or distance credited.
5. LOITER AT CAP STATION: At 20,000 feet and speed for maximum endurance.
6. INTERCEPT: Dash 30 nautical miles at 20,000 feet at Maximum Rated Thrust Vmax. Credit distance outbound.
7. COMBAT: (5) minutes at Maximum Rated Thrust Vmax at 10,000 feet. Retain missiles. Release (40) flares and (20) chaff. Retain ammo.
8. CLIMB: On course from 10,000 feet to optimum cruise altitude at 300 KCAS to NATOPS specified Mach at Maximum Rated Thrust.
9. CRUISE BACK: At speed and altitude for maximum range.
10. DESCENT: To sea level at idle power at NATOPS specified Mach for maximum range descent or 230 KCAS, whichever is less. Credit fuel, time, and distance.
11. RESERVE: 800 pounds fuel plus 245 pounds water.



EXTERNAL STORES	STATION LOADING						
	7	6	5	4	3	2	1
DECM + (4) AIM-9	X	X		O		X	X
DECM + (4) AIM-9 + (2) 300 GAL. TKS	X	X	TK	O	TK	X	X

EXTERNAL STORES	MISSION WEIGHTS - LB		
	TAKEOFF	FUEL INTERNAL	FUEL EXTERNAL
DECM + (4) AIM-9	27,253	7,759	--
DECM + (4) AIM-9 + (2) 300 GAL. TKS	31,640	7,915	3,835





Note: (A) External fuel tanks retained

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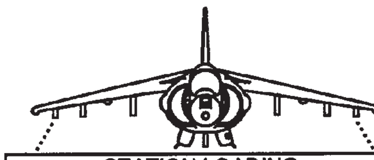
Figure 4-24. Mission Profiles (Sheet 1 of 8)

RADAR ATTACK AV-8B
OPERATIONAL CLOSE AIR SUPPORT (H-M-H) PROFILE
(7) Pylons + Gun + 300 Rounds 25mm Ammo + IFR Probe + Full Water (495 lb)
Expendables: (120) Flares + (60) Chaff

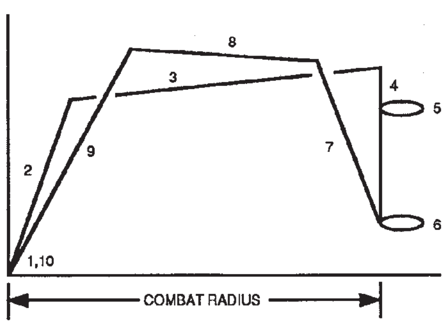
PROFILE DEFINITION

1. WARM-UP, TAKEOFF, AND ACCELERATE: To 300 KCAS using 500 pounds fuel and 250 pounds water.
2. CLIMB: On course to optimum cruise altitude at 300 KCAS to NATOPS specified Mach at Maximum Rated Thrust.
3. CRUISE OUT: At speed and altitude for maximum range.
4. DESCENT: To optimum loiter altitude. No fuel, time, or distance credited.
5. LOITER: At optimum loiter altitude and speed for maximum endurance.
6. COMBAT: (10) minutes at Maximum Rated Thrust Vmax at 10,000 feet. Drop stores after combat. Release (40) flares and (20) chaff. Fire all ammo.
7. CLIMB: On course from 10,000 feet to optimum cruise altitude at 300 KCAS to NATOPS specified Mach at Maximum Rated Thrust.
8. CRUISE BACK: At speed and altitude for maximum range.
9. DESCENT: To sea level at idle power at NATOPS specified Mach for maximum range descent or 230 KCAS, whichever is less. Credit fuel, time, and distance.
10. RESERVE: 800 pounds fuel plus 245 pounds water.



EXTERNAL STORES	STATION LOADING 7	6	5	4	3	2	1
(6) MK-82LD	●	●	●		●	●	●
(10) MK-82LD		▽	▽		▽	▽	

EXTERNAL STORES	MISSION WEIGHTS - LB TAKEOFF	FUEL INTERNAL	FUEL EXTERNAL
(6) MK-82LD	28,812	7,759	--
(10) MK-82LD	31,412	7,759	--



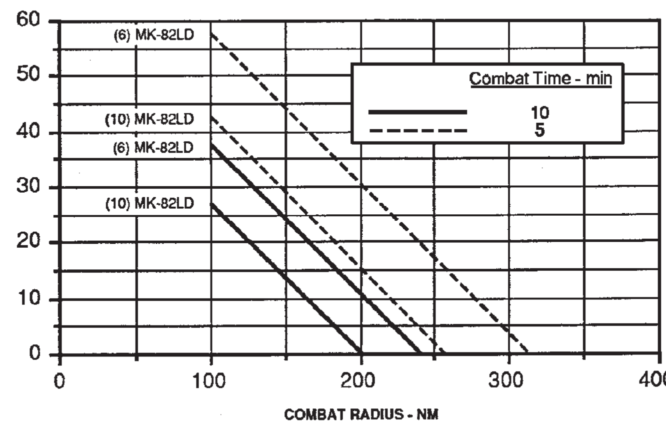


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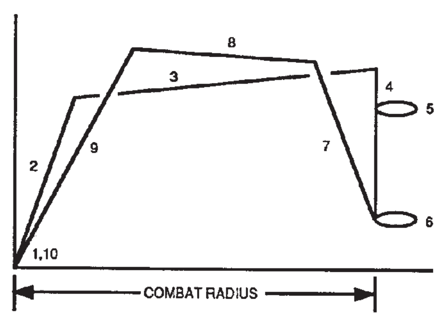
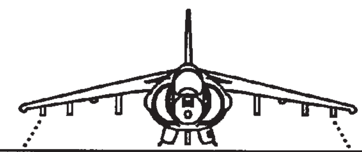
Figure 4-24. Mission Profiles (Sheet 2 of 8)

RADAR ATTACK AV-8B
OPERATIONAL CLOSE AIR SUPPORT (H-M-H WITH TANKS) PROFILE
(7) Pylons + Gun + 300 Rounds 25mm Ammo + IFR Probe + Full Water (495 lb)
Expendables: (120) Flares + (60) Chaff

PROFILE DEFINITION

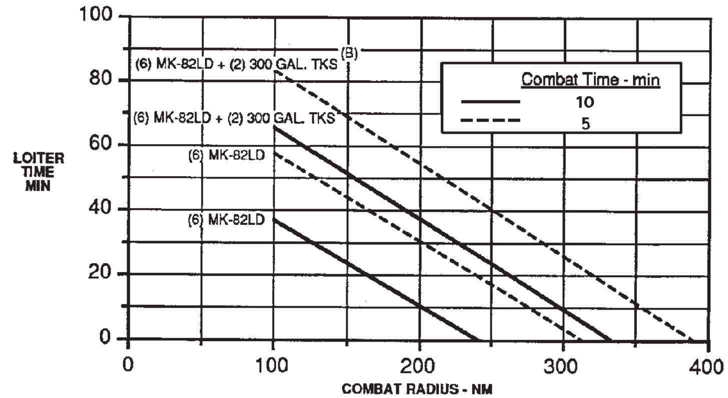
1. WARM-UP, TAKEOFF, AND ACCELERATE: To 300 KCAS using 500 pounds fuel and 250 pounds water.
2. CLIMB: On course to optimum cruise altitude at 300 KCAS to NATOPS specified Mach at Maximum Rated Thrust.
3. CRUISE OUT: At speed and altitude for maximum range.
4. DESCENT: To optimum loiter altitude. No fuel, time, or distance credited.
5. LOITER: At optimum loiter altitude and speed for maximum endurance.
6. COMBAT: (10) minutes at Maximum Rated Thrust Vmax at 10,000 feet. Drop stores after combat. Release (40) flares and (20) chaff. Fire all ammo.
7. CLIMB: On course from 10,000 feet to optimum cruise altitude at 300 KCAS to NATOPS specified Mach at Maximum Rated Thrust.
8. CRUISE BACK: At speed and altitude for maximum range.
9. DESCENT: To sea level at idle power at NATOPS specified Mach for maximum range descent or 230 KCAS, whichever is less. Credit fuel, time, and distance.
10. RESERVE: 800 pounds fuel plus 245 pounds water.





EXTERNAL STORES	STATION LOADING						
	7	6	5	4	3	2	1
(6) MK-82LD	•	•	•		•	•	•
(6) MK-82LD + (2) 300 GAL. TKS	•	▽	TK		TK	▽	•

EXTERNAL STORES	MISSION WEIGHTS - LB		
	TAKEOFF	FUEL INTERNAL	FUEL EXTERNAL
(6) MK-82LD	28,812	7,759	–
(6) MK-82LD + (2) 300 GAL. TKS	32,000	7,915	2,382 (A)



Notes: (A) Requires off loading 1,453 pounds of fuel to maintain 32,000 pound TOGW limit
(B) External fuel tanks retained

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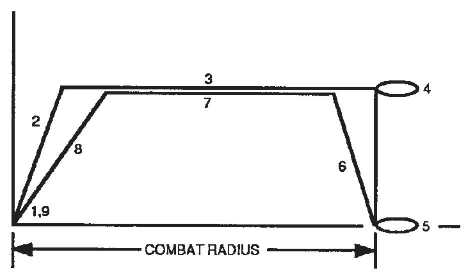
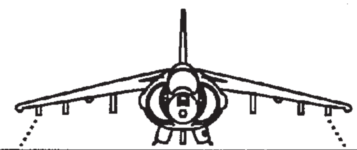
Figure 4-24. Mission Profiles (Sheet 3 of 8)

RADAR ATTACK AV-8B
OPERATIONAL CLOSE AIR SUPPORT (L-L-L) PROFILE
(7) Pylons + Gun + 300 Rounds 25mm Ammo + IFR Probe + Full Water (495 lb)
Expendables: (120) Flares + (60) Chaff

PROFILE DEFINITION

1. WARM-UP, TAKEOFF, AND ACCELERATE: To 300 KCAS using 500 pounds fuel and 250 pounds water.
2. CLIMB: On course to 3,000 feet altitude at 300 KCAS to NATOPS specified Mach at Maximum Rated Thrust.
3. DASH OUT: At 3,000 feet and 300 KCAS or maximum range speed, whichever is higher.
4. LOITER: At 3,000 feet and 300 KCAS or maximum range speed, whichever is higher.
5. COMBAT: (10) minutes at Maximum Rated Thrust Vmax at sea level. Drop stores after combat. Release (40) flares and (20) chaff. Fire one-half ammo.
6. CLIMB: On course from sea level to 3,000 feet altitude at 300 KCAS to NATOPS specified Mach at Maximum Rated Thrust.
7. DASH BACK: At 3,000 feet and 300 KCAS or maximum range speed, whichever is higher.
8. DESCENT: To sea level at idle power at NATOPS specified Mach for maximum range descent or 230 KCAS, whichever is less. Credit fuel, time, and distance.
9. RESERVE: 800 pounds fuel plus 245 pounds water.





	STATION LOADING						
EXTERNAL STORES	7	6	5	4	3	2	1
DECM + (6) MK-82HLD	●	●	●	○	●	●	●

	MISSION WEIGHTS - LB		
		FUEL	
EXTERNAL STORES	TAKEOFF	INTERNAL	EXTERNAL
DECM + (6) MK-82HLD	29,467	7,759	--

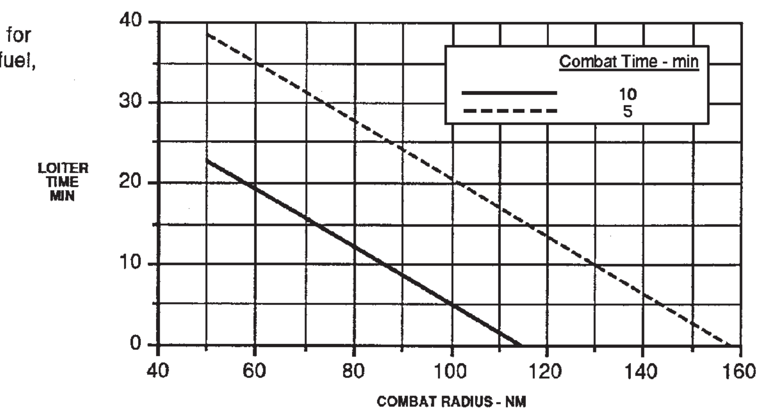


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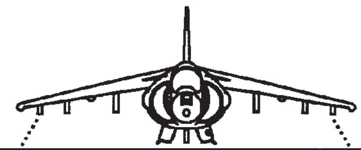
Figure 4-24. Mission Profiles (Sheet 4 of 8)

RADAR ATTACK AV-8B
OPERATIONAL DECK LAUNCHED INTERCEPT (DLI) PROFILE
(7) Pylons + Gun + 300 Rounds 25mm Ammo + IFR Probe + Full Water (495 lb)
Expendables: (120) Flares + (60) Chaff

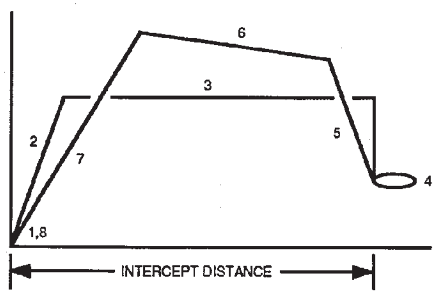
PROFILE DEFINITION

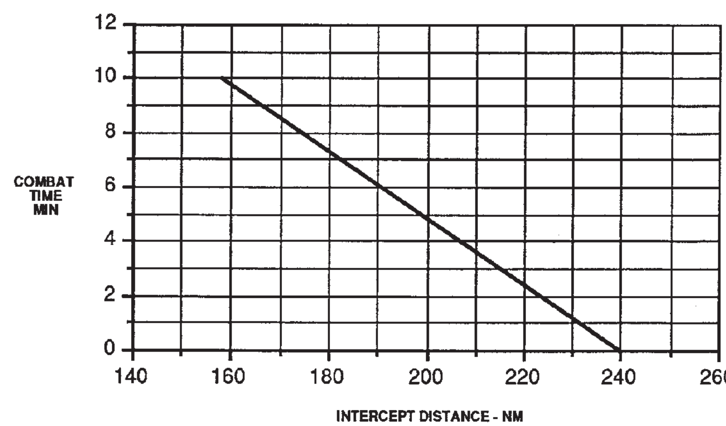
1. WARM-UP, TAKEOFF, AND ACCELERATE: To 300 KCAS using 500 pounds fuel and 250 pounds water.
2. CLIMB: On course to 20,000 feet altitude at 450 KTAS at Maximum Rated Thrust.
3. INTERCEPT: Dash at 20,000 feet at Maximum Rated Thrust Vmax.
4. COMBAT: (5) minutes at Maximum Rated Thrust Vmax at 10,000 feet. Retain missiles. Release (40) flares and (20) chaff. Retain ammo.
5. CLIMB: On course from 10,000 feet to optimum cruise altitude at 300 KCAS to NATOPS specified Mach at Maximum Rated Thrust.
6. CRUISE BACK: At speed and altitude for maximum range.
7. DESCENT: To sea level at idle power at NATOPS specified Mach for maximum range descent or 230 KCAS, whichever is less. Credit fuel, time, and distance.
8. RESERVE: 800 pounds fuel plus 245 pounds water.



EXTERNAL STORES	STATION LOADING 7	6	5	4	3	2	1
DECM + (4) AIM-9	X	X		O		X	X

EXTERNAL STORES	MISSION WEIGHTS - LB TAKEOFF	FUEL INTERNAL	FUEL EXTERNAL
DECM + (4) AIM-9	27,253	7,759 (A)	--





Note: (A) Maximum internal fuel. Shipboard operating limits may apply.

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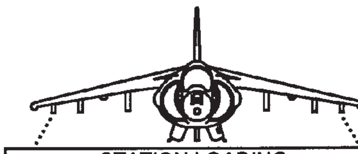
Figure 4-24. Mission Profiles (Sheet 5 of 8)

RADAR ATTACK AV-8B
OPERATIONAL FERRY PROFILE
(7) Pylons + IFR Probe + Full Water (495 lb)

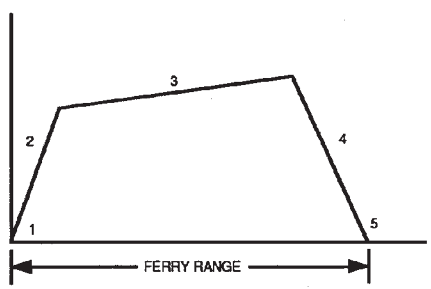
PROFILE DEFINITION

1. WARM-UP, TAKEOFF, AND ACCELERATE: To 300 KCAS using 500 pounds fuel and 250 pounds water.
2. CLIMB: On course to optimum cruise altitude at 300 KCAS to NATOPS specified Mach at Maximum Rated Thrust.
3. CRUISE: At speed and altitude for maximum range.
4. DESCENT: To sea level at idle power at NATOPS specified Mach for maximum range descent or 230 KCAS, whichever is less. Credit fuel, time, and distance.
5. RESERVE: 800 pounds fuel plus 245 pounds water.



EXTERNAL STORES	STATION LOADING 7	6	5	4	3	2	1
GUN + 300 Rounds 25mm Ammo + (2) 300 GAL. TKS			TK		TK		
GUN + 300 Rounds 25mm Ammo + (4) 300 GAL. TKS		TK	TK		TK	TK	
FUSELAGE STRAKES + (2) 300 GAL. TKS			TK		TK		
FUSELAGE STRAKES + (4) 300 GAL. TKS		TK	TK		TK	TK	

EXTERNAL STORES	MISSION WEIGHTS - LB TAKEOFF	FUEL INTERNAL	FUEL EXTERNAL
GUN + 300 Rounds 25mm Ammo + (2) 300 GAL. TKS	29,851	7,915	3,835
GUN + 300 Rounds 25mm Ammo + (4) 300 GAL. TKS	32,000	7,915	5,588 (A)
FUSELAGE STRAKES + (2) 300 GAL. TKS	28,633	7,915	3,835
FUSELAGE STRAKES + (4) 300 GAL. TKS	32,000	7,915	6,806 (B)



EXTERNAL STORES	FERRY RANGE - NM 300 ROUNDS 25mm AMMO	FUSELAGE STRAKES
(2) 300 GAL. TKS (C)	1,217	1,325
(4) 300 GAL. TKS (C)	1,248	1,460

Notes: (A) Requires off loading 2,327 pounds of fuel to maintain 32,000 pound TOGW limit
(B) Requires off loading 1,109 pounds of fuel to maintain 32,000 pound TOGW limit
(C) External fuel tanks retained

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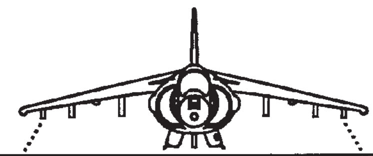
Figure 4-24. Mission Profiles (Sheet 6 of 8)

RADAR ATTACK AV-8B
OPERATIONAL INTERDICTION (H-H-H-H) PROFILE
(7) Pylons + Gun + 300 Rounds 25mm Ammo + IFR Probe + Full Water (495 lb)
Expendables: (120) Flares + (60) Chaff

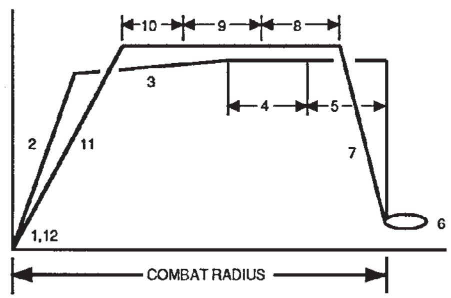
PROFILE DEFINITION

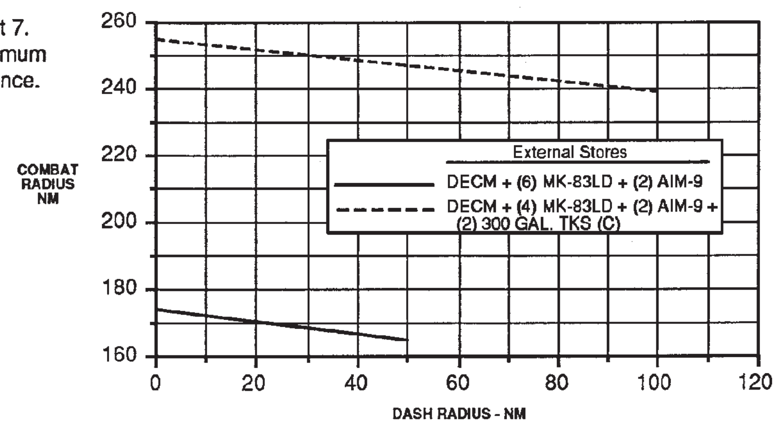
1. WARM-UP, TAKEOFF, AND ACCELERATE: To 300 KCAS using 500 pounds fuel and 250 pounds water.
2. CLIMB: On course to optimum cruise altitude at 300 KCAS to NATOPS specified Mach at Maximum Rated Thrust.
3. CRUISE OUT: At speed and altitude for maximum range.
4. DASH OUT: At final altitude from segment 3 for (X) nautical miles at 450 KTAS or Maximum Rated Thrust Vmax, whichever is less.
5. DASH OUT: At final altitude from segment 3 for (X) nautical miles at 540 KTAS if possible, otherwise at 510 KTAS or Maximum Rated Thrust Vmax, whichever is less.
6. COMBAT: (5) minutes at Maximum Rated Thrust Vmax at 10,000 feet. Drop stores after combat. Retain missiles. Release (40) flares and (20) chaff. Retain ammo.
7. CLIMB: On course at Maximum Rated Thrust from 10,000 feet to optimum cruise altitude at 500 KTAS if possible, otherwise at 450 KTAS.
8. DASH BACK: At final altitude from segment 7 for (X) nautical miles at 540 KTAS if possible, otherwise at 510 KTAS or Maximum Rated Thrust Vmax, whichever is less.
9. DASH BACK: At final altitude from segment 7 for (X) nautical miles at 450 KTAS or Maximum Rated Thrust Vmax, whichever is less.
10. CRUISE BACK: At speed for maximum range at final altitude from segment 7.
11. DESCENT: To sea level at idle power at NATOPS specified Mach for maximum range descent or 230 KCAS, whichever is less. Credit fuel, time, and distance.
12. RESERVE: 800 pounds fuel plus 245 pounds water.



EXTERNAL STORES	STATION LOADING 7	6	5	4	3	2	1
DECM + (6) MK-83LD + (2) AIM-9	X	•	▽	O	▽	•	X
DECM + (4) MK-83LD + (2) AIM-9 + (2) 300 GAL. TKS	X	TK	▽	O	▽	TK	X

	MISSION WEIGHTS - LB		
		FUEL	
EXTERNAL STORES	TAKEOFF	INTERNAL	EXTERNAL
DECM + (6) MK-83LD + (2) AIM-9	32,000	6,948 (A)	--
DECM + (4) MK-83LD + (2) AIM-9 + (2) 300 GAL. TKS	32,000	7,915	607 (B)





Notes: (A) Requires off loading 811 pounds of fuel to maintain 32,000 pound TOGW limit
(B) Requires off loading 3,228 pounds of fuel to maintain 32,000 pound TOGW limit
(C) External fuel tanks retained

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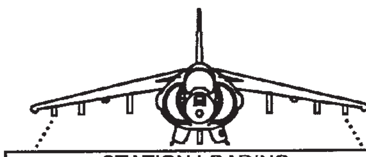
Figure 4-24. Mission Profiles (Sheet 7 of 8)

All data on pages 4-48 thru 4-50 deleted.

RADAR ATTACK AV-8B
OPERATIONAL INTERDICTION (H-L-L-H) PROFILE
(7) Pylons + Gun + 300 Rounds 25mm Ammo + IFR Probe + Full Water (495 lb)
Expendables: (120) Flares + (60) Chaff

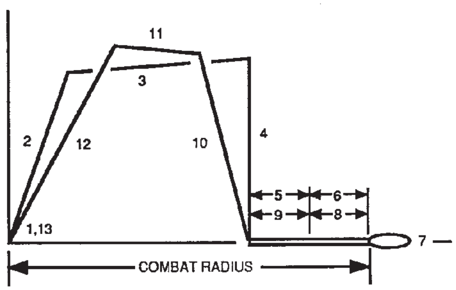
PROFILE DEFINITION

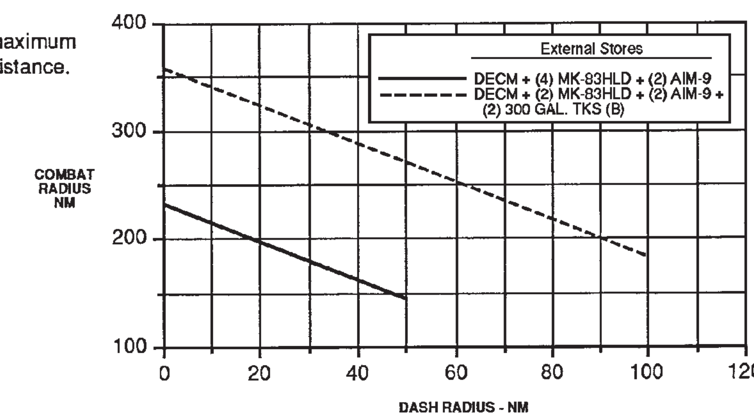
1. WARM-UP, TAKEOFF, AND ACCELERATE: To 300 KCAS using 500 pounds fuel and 250 pounds water.
2. CLIMB: On course to optimum cruise altitude at 300 KCAS to NATOPS specified Mach at Maximum Rated Thrust.
3. CRUISE OUT: At speed and altitude for maximum range.
4. DESCENT: To sea level. No fuel, time, or distance credited.
5. DASH OUT: At sea level for (X) nautical miles at 420 KTAS.
6. DASH OUT: At sea level for (X) nautical miles at 540 KTAS if possible, otherwise at 510 KTAS or Maximum Rated Thrust Vmax, whichever is less.
7. COMBAT: (5) minutes at Maximum Rated Thrust Vmax at sea level. Drop stores after combat. Retain missiles. Release (40) flares and (20) chaff. Retain ammo.
8. DASH BACK: At sea level for (X) nautical miles at 540 KTAS if possible, otherwise at 510 KTAS or Maximum Rated Thrust Vmax, whichever is less.
9. DASH BACK: At sea level for (X) nautical miles at 420 KTAS.
10. CLIMB: On course from sea level to optimum cruise altitude at 300 KCAS to NATOPS specified Mach at Maximum Rated Thrust.
11. CRUISE BACK: At speed and altitude for maximum range.
12. DESCENT: To sea level at idle power at NATOPS specified Mach for maximum range descent or 230 KCAS, whichever is less. Credit fuel, time, and distance.
13. RESERVE: 800 pounds fuel plus 245 pounds water.



EXTERNAL STORES	STATION LOADING 7	6	5	4	3	2	1
DECM + (4) MK-83HLD + (2) AIM-9	X	•	•	O	•	•	X
DECM + (2) MK-83HLD + (2) AIM-9 + (2) 300 GAL. TKS	X	•	TK	O	TK	•	X

EXTERNAL STORES	MISSION WEIGHTS - LB TAKEOFF	FUEL INTERNAL	FUEL EXTERNAL
DECM + (4) MK-83HLD + (2) AIM-9	30,779	7,759	--
DECM + (2) MK-83HLD + (2) AIM-9 + (2) 300 GAL. TKS	32,000	7,915	2,735 (A)





Notes: (A) Requires off loading 1,100 pounds of fuel to maintain 32,000 pound TOGW limit
(B) External fuel tanks retained

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Figure 4-24. Mission Profiles (Sheet 8 of 8)

PART VII

AIRCRAFT TACTICAL PLANNING AND EMPLOYMENT

(Refer to Volume III)

PART VIII

LAND-BASED AND SHIPBORNE THREAT SYSTEMS

(Refer to MCM 3-1)

PART IX

DEFENSIVE ELECTRONIC WARFARE SYSTEMS

(Refer to Volume III)

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