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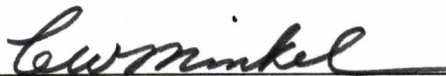


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Date 23 May 1989

MISSION SYSTEMS EVALUATION
OF THE
AH-64A HELICOPTER

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Stephen A. Kracinovich
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DISCLAIMER

The technical data included in this thesis are actual flight test data collected by the author during a limited scope mission systems evaluation of the United States Army AH-64A helicopter. However, all enhancing characteristics and deficiencies attributed to this aircraft, the aircraft systems, and/or the aircraft subsystems are the sole opinion of the author and do not necessarily represent the official position of the Rotary Wing Aircraft Test Directorate, the Naval Air Test Center, the Naval Air Systems Command, or the United States Navy. Similarly, the recommended corrections to the documented deficiencies are presented for the sole purpose of fulfilling the requirements of this thesis, and are not attributable to any of the aforementioned authorities.

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Most of all I am grateful to my beautiful wife Jeannie, who continued to provide her support through Test Pilot School and Graduate School.

ABSTRACT

The purpose of this evaluation was to determine the suitability of the AH-64A helicopter systems for the helicopter escort and anti-armor missions. The evaluation consisted of three flights totalling 4.4 hours and eight hours of ground tests at the Army Aviation Developmental Test Activity (ADTA), Ft. Rucker, Alabama. The testing revealed a series of Part I, II and III deficiencies as defined in appendix B. Two of the most severe deficiencies (Part I) found must be corrected prior to operational deployment of the helicopter. These deficiencies were as follows:

a. The failure of the Image Auto Tracker to reestablish track of a target which is momentarily obstructed. This will permit targets to break lock of the Image Auto Tracker and prevent target kill.

b. The inability of the XM-130 countermeasures dispenser, as installed in the AH-64A helicopter, to use flares. This will result in a lack of defense against the destruction of AH-64A aircraft by infrared missiles.

In addition, 14 Part II deficiencies, which should be corrected as soon as practicable, and 8 Part III deficiencies, which should be avoided in future designs, were documented. The AH-64A helicopter also demonstrated two enhancing characteristics which should be incorporated in future designs. These enhancing characteristics were as follows:

a. The ability to slew the Target Acquisition Designation Sight line of sight to the pilot's line of sight. This will increase the target detection and identification range and provide for a greater standoff distance.

b. The color image provided by Direct View Optics will provide the Copilot Gunner with additional visual cueing. This will assist in detection and identification of targets and increase the AH-64A standoff range.

Overall, the AH-64A weapon system demonstrated excellent potential for the helicopter escort and anti-armor missions and should be satisfactory upon correction of the Part I deficiencies.

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1 INTRODUCTION

1.1 BACKGROUND

The United States Marine Corps has identified a need to counter the land based armored threat to assault helicopters with a night capable, heavily armed, and highly survivable attack helicopter. This thesis investigates the possibility of utilizing the Army AH-64A Apache as a candidate for this role. The Army began the full scale engineering development program of the AH-64 on 10 December 1976. The first production delivery of the AH-64 occurred 26 January 1986. The Army anticipates a total of 675 aircraft to be built. The Apache was designed to be an adverse weather night capable aircraft. Specific design emphasis was placed on the high survivability, low susceptibility, and front line deployment capability. A more detailed background of the AH-64A helicopter can be found in reference 1. This evaluation was conducted using Naval Air Test Center initial qualitative Developmental Test Phase A (DT-IIA) planning, testing and reporting guidelines.

1.2 PURPOSE

The purpose of this evaluation was to determine the suitability of the AH-64A helicopter systems for the helicopter escort and anti-armor missions.

2 TEST PROCEDURES

2.3 DESCRIPTION OF TEST AIRCRAFT

The AH-64A helicopter, illustrated in appendix E, figure 1, is a twin engine, tandem seat, night capable attack helicopter manufactured by McDonnell Douglas Helicopter Company. The two General Electric T700 engines are rated at 1694 SHP at sea level standard day conditions. The Apache has a four bladed, fully articulated main rotor and a four bladed teetering tail rotor. The pilot sits in the back and the Copilot Gunner (CPG) sits in the front seat. The maximum mission gross operating weight is 17,650 lbs. The overall length is 57 ft 8 in. and the principal aircraft dimensions are given in appendix E, figure 2. The general external arrangement is presented in appendix E, figure 3. The aircraft uses conventional helicopter flight controls in both cockpits and incorporates digital automatic stabilization equipment. The Apache is equipped with a 30 mm gun, can carry 2.75 in. Folding Fin Aerial Rockets (FFAR), and laser guided Hellfire (AGM-114A) anti-armor missiles on the four stores stations. A detailed description of the AH-64A Apache helicopter is contained in references 2 and 3. The test aircraft SN 8424216, was representative of production AH-64A helicopters for the purposes of this evaluation.

2.4 DESCRIPTION OF TEST EQUIPMENT

The AH-64A Apache helicopter is an adverse weather anti-armor attack aircraft. Major mission systems include data handling, communication, navigation, armament, countermeasures, external sensors, and integrated controls and displays. The Apache systems were representative of production equipment for the purposes of this evaluation. A detailed description of the AH-64A weapon systems is presented in appendix C, and in references 2 and 3.

2.5 SCOPE OF TESTS

The evaluation consisted of three flights totalling 4.4 hours and eight hours of ground tests at the Army Aviation Developmental Test Activity (ADTA), Ft. Rucker, Alabama. Tests and test conditions are presented in appendix D, tables I and II. Meteorological conditions for the flights are presented in appendix D, tables III through V. All testing was conducted with full internal fuel, 619 rounds of dummy 30 mm ammunition, two crew members, and with external stores presented in table I.

Table I
TEST LOADINGS

STATION 1	STATION 2	STATION 3	STATION 4
Pylon + 1 AGM-114A trainer + 3 AGM-114A dummies + 2 pair AGM-114A launchers	Pylon + 1 M261 rocket pod + 19 dummy 2.75 in. rockets	Pylon + 1 M261 rocket pod + 19 dummy 2.75 in. rockets	Pylon + 1 AGM-114A trainer + 3 AGM-114A dummies + 2 pair AGM-114A launchers

The test gross weight varied between 14,200 lb and 16,000 lb.

2.6 METHOD OF TEST

2.6.1 General

Test methods and procedures were conducted using the United States Naval Test Pilot School (USNTPS) model test plan for mission systems testing known as VAX (reference 6) with applicable paragraphs and exceptions presented in appendix D, tables VI and VII. In general, flight test instrumentation and ground truth data systems were not available; however, alternate, but less elaborate test methods were sufficient to perform a good qualitative evaluation. All testing was performed using the sensor baseline settings given in appendix D, tables XIII, IX, and

X. The system was tested against the standards presented in references 4, 5, and 7. The definition of deficiencies assigned throughout this report is presented as appendix B.

2.6.2 Cockpit Evaluation

The cockpit evaluation was conducted using the normal and emergency procedures prescribed in reference 2. All measurements were made with a tape measure and protractor. The seat position was selected for optimum comfort except for Field Of View (FOV), which was performed from the Design Eye Position (DEP). The seat harness was locked for all take off and landing procedures. The evaluator's anthropometric measurements are presented in appendix D, table XI.

2.6.3 Weapon System Integration

Integration of all weapons were tested in conjunction with sensor system testing. The evaluation was conducted using various targets, such as small buildings and trucks. The integration testing was performed using simulated weapon releases at the maximum identification range of the selected sensor and noting the time to perform the procedure, the clarity of the procedure, and the integration between the sensor and the weapon. These simulated attacks took place at 20 to 200 ft AGL to utilize terrain masking. Target acquisition took place at 40 KIAS and weapon release was simulated at 0 KIAS. All Hellfire

attacks were conducted using a Hellfire trainer missile.

2.6.4 Integrated Helmet and Display Sight System

Testing of the Integrated Helmet and Display Sight System (IHADSS) was conducted in hovering flight and during air taxi around the airfield. The IHADSS was qualitatively evaluated for utility, integration with sensors and weapons, and adequacy of display symbology.

2.6.5 Data Recording and Reduction

Data were recorded on kneeboard cards and a tape recorder. Times were measured with a hand held digital stopwatch and distances were measured with a tape measure. Navigation accuracy data were processed using version 1.3 of USNTPS airborne systems data reduction programs.

3 EVALUATIONS AND RECOMMENDATIONS

3.1 COCKPIT EVALUATION

3.1.1 Entry/Egress

3.1.1.1 General. Entry and egress of the CPG station were evaluated with full flight gear including helmet, flight suit, gloves and survival vest. Entry and egress were performed with engines off and rotors still.

3.1.1.2 Normal entry and egress. Entry into the CPG cockpit required 30 seconds, including strapping in. Normal egress required 15 seconds. Entry and egress were performed without inadvertently damaging aircraft equipment. Handholds and footholds were readily available at all stages. The CPG will be able to perform expeditious entry and egress without injury or damage to aircraft equipment. Normal entry and egress are satisfactory.

3.1.1.3 Emergency egress. Emergency egress was performed by simulating canopy jettison, releasing the single point restraint and rolling out of the aircraft on to the ground. Emergency egress required 7 seconds with the CPG cyclic control stowed, and 9 seconds with the cyclic control extended. Emergency egress was accomplished in a upright position without injury. The CPG will be able to rapidly exit the aircraft in the event of an emergency. Emergency

egress is satisfactory.

3.1.2 Functional Reach

The functional reach required to actuate all controls in the CPG cockpit was evaluated on the ground with full flight gear including helmet, flight suit, gloves, and survival vest. Evaluator anthropometric measurements are provided in appendix D, table XI. Data are presented in appendix E, figures 4 and 5. All controls could be actuated with the shoulder harness locked if stretching against the restraint was permitted (zone 2 defined by reference 4). All flight controls could be actuated throughout their operating range without stretching against the restraints (zone 1). The accessibility of the controls will allow the CPG to actuate controls without releasing his harness, affording maximum protection from the restraint system. The functional reach to CPG controls is satisfactory for the helicopter escort and anti-armor missions and met the specification (reference 4).

3.1.3 Internal Field of View

3.1.3.1 General. Internal Field Of View (FOV) was evaluated from the Design Eye Position (DEP) for an unobstructed Line Of Sight (LOS) to all CPG instruments and indicators.

3.1.3.2 RPM gage. The CPG rotor RPM gage (appendix C, enclosure 1, figure 2) LOS was obstructed by the right Optical Relay Tube (ORT) control handle. Head movements of 8 inches right were required to see the rotor RPM gage. Head movements required to see the rotor RPM gage, while backing up the pilot, will contribute to CPG fatigue. The obstructed Line Of Sight of the CPG rotor RPM gage is a Part III deficiency which should be avoided in future designs. The RPM gage was not visible from the design eye position and failed to meet the specification (paragraph 4.2 of reference 7).

3.1.3.3 Selectable digital display. The selectable digital display (appendix C, enclosure 1, figure 2) LOS was obstructed by the right ORT handle. The selectable digital display was used to determine fuel, engine oil pressure, engine temperature, and turbine RPM. Head movements of six inches were required to see the selectable digital display. Head movements required to see the selectable digital display, while backing up the pilot, will contribute to CPG fatigue. The obstructed Line Of Sight of the selectable digital display is a Part III deficiency which should be avoided in future designs. The selectable digital display was not visible from the design eye position and failed to meet the specification (paragraph 4.2 of reference 7).

3.1.4 External Field of View

External Field of View was evaluated from the DEP. A FOV envelope plot from the CPG cockpit is presented in appendix E, figure 6. The over the nose FOV was limited to 17 deg depression between +/- 33 deg azimuth. The restricted over the nose FOV will prevent the CPG from visually clearing the landing zone during nose up aircraft deceleration, increasing the likelihood of aircraft damage on landing. The restricted over the nose Field Of View is a Part II deficiency which should be corrected as soon as practicable. External FOV met the specification of reference 5. Raising the CPG DEP is not an option because it would interfere with the pilot external FOV. It is recommended that methods of lowering the CPG instrument panel be investigated. This could be accomplished by combining the airspeed indicator, remote attitude indicator, stabilator position indicator, Radio Magnetic Indicator, Vertical Speed Indicator, altimeter, and engine instruments in a multi-function display. Since these are backup instruments to allow the CPG to relieve the pilot, there need not be a mechanical backup. This would also allow an unobstructed LOS to all of these instruments while saving weight. Additionally, switches on the fire control panel (appendix C, enclosure 1, figure 4) which are not used in the arming or attack phases of the mission, such as the Fire Control Computer (FCC) and Multiplex Bus (MUX)

power switches, Boresight switches, IHADSS, TADS, and symbol generator power switches could be moved to a lower console.

3.2 TARGET ACQUISITION DESIGNATION SIGHT

3.2.1 Preflight

Target Acquisition Designation Sight (TADS) preflight procedures were evaluated considering time to complete, thoroughness, logical sequencing and clarity. TADS preflight took 10 seconds to complete and involved turning the TADS on, then selecting the desired acquisition and sighting. The clarity allowed preflight to be conducted without error. The timeliness and clarity of TADS preflight will contribute to the orderly flow of the remaining CPG preflight checks. TADS preflight is satisfactory for the helicopter escort and anti-armor missions.

3.2.2 Built in Test

TADS Built In Test (BIT) was evaluated for operator interface required and time to execute. TADS BIT had two modes of operation: a continuous BIT, which ran automatically while TADS was turned on; and command initiate BIT, which was intended to isolate faults once they were detected. No faults were detected by either the automatic or the command initiate BIT. The TADS command

initiate BIT was activated through the Data Entry Keyboard (DEK). Command initiated TADS BIT required 75 seconds to complete. This mode prompted the operator to activate various switches and allowed the evaluator to complete the BIT with no external checklists. BIT will notify the CPG of TADS failures while he is performing his regular duties and will permit fault isolation procedures to be completed in a timely fashion. Within the scope of this test, TADS BIT is satisfactory for the helicopter escort and anti-armor missions. The author recommends further tests of the Target Acquisition Designation Sight Built In Test with fault insertion techniques.

3.2.3 Slew Limits

The TADS slew limits were measured on the ground and qualitatively evaluated in the air. The azimuth limits were +/- 120 deg, and the elevation limits were +30 and -60 deg. The limits allowed coverage of all targets within the external FOV of the CPG. The TADS slew limits will permit target detection within the field of fire of all AH-64A weapons. The TADS slew limits are satisfactory for the helicopter escort and anti-armor missions.

3.2.4 Slew Rates

TADS slew rates were measured on the ground and qualitatively evaluated in the air. Maximum slew rates were measured using the manual tracker to slew the TADS. Data are presented in table II.

Table II
TADS MAXIMUM SLEW RATES

SENSOR/FOV	SLEW RATE (deg/sec)
FLIR	
wide	50
medium	35
narrow	1.0
zoom	1.0
Daylight Television	
wide	12
narrow	1.0
zoom	1.0
Direct view Optics	
wide	9.3
narrow	1.5

Slew rates were proportional to the force applied to the tracker button. Maximum slew rates were sufficient to allow acquisition and automatic tracking of a target moving perpendicular to the helicopter nose at 60 mph and 0.5 nmi range. TADS slew rates will permit the CPG to track fast moving targets, thus providing target position data to the Fire Control Computer. The TADS slew rates are

satisfactory for the helicopter escort and anti-armor missions.

3.2.5 Stabilization

TADS stabilization was evaluated in bank angles up to ± 80 deg, pitch angles up to ± 30 deg, and in yaw angles up to ± 120 deg from the original heading to the target. The maximum roll rate was 30 deg/sec, the maximum pitch rate was 10 deg/sec, the maximum yaw rate was 20 deg/sec, and the maximum 'g' level achieved was 2.0. Stabilization was evaluated with the Image Auto Tracker (IAT) on and off. The TADS was designed to be aircraft stabilized. No degradation of image of any TADS sensor was noted with or without the IAT engaged. The IAT maintained track on the target throughout all maneuvers. TADS stabilization will permit the aircrew to maneuver the aircraft throughout the full range of attack maneuvers, without encountering the TADS stabilization limits. TADS stabilization is satisfactory for the helicopter escort and anti-armor missions.

3.2.6 Line of Sight Indication

Indication of the TADS LOS was evaluated for accuracy of presentation. TADS LOS was presented by the relative position of the FOV indicator in the field of regard box located on the lower portion of the selected display as illustrated in appendix C, enclosure 1, figure

12. When the FOV indicator was centered on the right side of the field of regard box, the sensor was at the right azimuth limit; however, as the sensor approached the left azimuth limit, the FOV indicator passed beyond the left side of the field of regard box and jumped to the right side of the field of regard box. This faulty indication at the left azimuth limit will mislead the CPG and cause him to loose track of the target. The faulty indication of the Target Acquisition Designation Sight left azimuth limit is a Part II deficiency which should be corrected as soon as practicable. The author recommends a software change to more accurately represent the actual TADS Line of Sight.

3.2.7 Field of View Indication

TADS FOV indication was evaluated for clarity of presentation. The coverage of the next smaller FOV was represented by an imaginary rectangle around the LOS reticle. No indication of the selected FOV was provided. Since the selected FOV was unknown, the wrong FOV was frequently selected when attempting to change FOV's. This increased the time required to acquire a target by up to 2 to 3 seconds. The insufficient indication of FOV will cause the CPG to select the incorrect FOV; thereby, detracting from the time dedicated to operation of other systems. The insufficient indication of Target Acquisition Designation Sight Field Of View is a Part III deficiency

which should be avoided in future designs.

3.2.8 Line of Sight Slaving

Integration between pilot and CPG sensors was evaluated during target search and acquisition tasks. The TADS LOS could be slewed manually; or it could be slaved to a preprogrammed waypoint, the pilot LOS, or the CPG LOS. When the pilot identified a target before the CPG, the CPG placed the ACQ SEL switch on the fire control panel in the PHS (Pilot Head Set) position and the TADS LOS was slewed to the pilot's LOS. The ability to use the pilot's eyes or Pilot Night Vision System (PNVS) effectively provided a second simultaneous searching sensor to that of the CPG. The ability to slew the TADS LOS to the pilot's LOS will increase the target detection and identification range and provide for a greater standoff distance. The ability to slew Target Acquisition Designation Sight Line Of Sight to the pilot's Line of Sight is an enhancing characteristic which should be incorporated in future designs.

3.2.9 Forward Looking Infrared

3.2.9.1 Cool down time. Forward Looking Infrared (FLIR) cool down time was evaluated on the ground prior to takeoff with an ambient air temperature of 73 deg Fahrenheit. FLIR cool down required 17.75 minutes. The cool down was not complete until 8 minutes after takeoff. During night

operations the FLIR provided the CPG with his only independent night vision capability; therefore, cool down was required prior to takeoff. The FLIR cool down time will delay takeoff and decrease the probability that targets will be in their previously reported positions. The excessive FLIR cool down time is a Part II deficiency which should be corrected as soon as practicable. FLIR cool down time is a function of the capacity of the cooling system, the ambient temperature and the cooling requirements of the sensor. Since the ambient temperature cannot be controlled and changing the characteristics of the sensor (size or material) would involve prohibitive cost, the best solution would be to increase the capacity of the cooling system. Although a larger compressor and associated hardware would add weight and cost, the increase in readiness (especially on hot days) would be a favorable tradeoff. The author recommends that the cooling system be redesigned to decrease TADS FLIR cool down time.

3.2.9.2 Field Of View. FLIR FOV was measured on the ground and qualitatively evaluated in the air. FLIR FOV's are presented in table III.

Table III
FLIR FIELDS OF VIEW

SCALE	FIELD OF VIEW (AZIMUTH)
Zoom	1.7 deg
Narrow	3.4 deg
Medium	9.5 deg
Wide	43.0 deg

The range of FOV's was sufficient to allow identification of the target area and to select progressively narrower FOV's for target identification. The range of FLIR FOV's will permit the AH-64A crew to achieve target identification immediately following detection, and maintain standoff range for weapons release. The range of FLIR Field Of Views is satisfactory for the helicopter escort and anti-armor missions and met the specification (reference 5).

3.2.9.3 Temperature resolution. FLIR temperature resolution was qualitatively evaluated in hovering flight during the conditions described in appendix D, table IV. During daylight conditions, the resolution was sufficient to discern the character of the terrain due to shadows. Idle vehicles, buildings and pedestrians were easily resolved. During twilight conditions, recently tilled ground was resolved five minutes after it was tilled. It

was possible to turn the gain down so that a tractor appeared as the sole bright spot on the display. The temperature resolution will allow the CPG to discriminate targets from the background. The FLIR temperature resolution is satisfactory for the helicopter escort and anti-armor missions.

3.2.9.4 Vibration Effects On Spacial Resolution. A qualitative evaluation of the degradation the FLIR resolution due to vibration (LOS jitter) was conducted by observing a UH-1 helicopter at approximately 300 yards in the medium FOV during the conditions described in appendix D, table IV. Data are presented in table IV.

Between 30 and 40 KIAS, the reduction in resolution decreased the maximum detection range of an automobile size target by approximately 2 km. The low resolution caused by airframe vibration will reduce the maximum detection and standoff ranges and increase exposure to enemy fire. The low FLIR dynamic spacial resolution due to airframe vibration is a Part II deficiency which should be corrected as soon as practicable. In order to correct this deficiency, further testing of the Forward Looking Infrared is recommended to quantify static and dynamic resolution,

Table IV
FLIR IMAGE QUALITY WITH VIBRATION

AIRSPPEED (KIAS)	VIBRATION LEVEL (1)	IMAGE QUALITY
50-100	4	Side number illegible, target clearly recognizable.
40 target clearly	5	Side number illegible, recognizable.
20	7	Target virtually unrecognizable.
Hover	3	Side number almost legible.
Static (ground power)	0	Side number clearly legible.

note: (1) vibration levels assigned in accordance with appendix D, table XII.

as well as line of sight jitter. A detailed description of a procedure to determine combined angular and thermal resolution is presented in section 4.2.20 of reference 8. This test determines the Spacial Cutoff Frequency (SF_{CO}) on the ground and in flight. The SF_{CO} is the maximum spacial frequency which can be detected by a sensor, as illustrated in appendix E, figure 7. These frequencies can be applied to the empirically derived Philco-Ford curve presented in appendix E, figure 8, to determine the value of LOS jitter. The LOS jitter can be used to determine the effectiveness of various corrections. Since the temperature resolution was determined to be satisfactory in paragraph 3.2.9.3 and table IV indicates that the resolution is satisfactory with no vibration, the best way to increase resolution is to decrease vibration effects. Various methods for decreasing vibration are detailed in chapters 30 thru 37 of reference 9. Two of the most promising methods are servo-controlled vibration suppression devices and vibration isolation. Suppression devices sense an acceleration and impose a force 180 deg out of phase to cancel the vibration. An example of this is the vibration suppression system in the AH-1W helicopter as described in reference 10. Although, the use of this system would result in a weight penalty, the decreased vibration would not only increase FLIR resolution, but would also increase the life of aircraft and mission systems hardware, and decrease crew fatigue.

The author recommends the incorporation of a vibration suppression system to decrease degradation of FLIR resolution. Another potential method is to mount FLIR hardware to the airframe using mounts which are designed to isolate the hardware from aircraft vibration at a specific frequency. This would be a lightweight low cost solution which could be implemented quickly and would enhance the benefits from the vibration suppression system. The use of vibration isolation mounts on FLIR hardware to decrease degradation of FLIR resolution is also recommended.

3.2.9.5 Maximum detection/identification range. FLIR maximum detection and identification range was evaluated using various targets during the conditions presented in appendix D, tables III and IV. Target detection and identification was performed by slewing the FLIR to the navigation coordinates of the target, approaching the target at 40 KIAS and 200 ft AGL in medium FOV until detection, and then selecting narrow FOV to perform target identification. Data are presented in table V.

Table V

FLIR MAXIMUM DETECTION/IDENTIFICATION RANGE

TARGET	FLIGHT/ RUN	RANGE ⁽¹⁾ (km)	REMARKS
House	1a	5.2	Daylight Target was approx. 60 x 40 x 25 ft high. Approached from rear.
	b	5.6	
Fire Truck	1c	3.1	Dusk.
	d	3.4	
UH-1 Helicopter	1e	5.0	Dark. Target on ground in middle of airfield, rotors still.
Small Building	2a	4.1	Daylight target was approx. 40 x 30 x 15 ft high. Approached from corner.
	b	3.9	

note: (1) Target detection and identification ranges are the same, because target identification immediately followed target detection, upon selection of a narrower FOV.

The maximum detection/identification range was on the edge of the maximum range of typical anti-helicopter weapons. The helicopter crew will be forced to mask the aircraft to avoid enemy fire, reducing the time for acquisition and weapon firing and decreasing weapon effectiveness. The insufficient Forward Looking Infrared maximum detection/identification range is a Part II deficiency

which should be corrected as soon as practicable. Maximum detection/identification range is a function of a number of variables including FLIR temperature and spacial resolution, target properties, system integration, environmental conditions, and crew experience. The effects of vibration on FLIR performance were previously described in paragraph 3.2.9.4. This deficiency is likely to improve if the effects of vibration are addressed.

3.2.9.6 Level and gain adjustments. The amount of operator interface required during FLIR acquisition tasks were evaluated. FLIR level and gain adjustments were required to maintain the optimum image approximately every 30 to 45 seconds. Adjustments were required with changes in FOV, changes in heading, or just as time progressed. When attention was diverted to other systems, it was necessary to accept a less than optimum FLIR image which will reduce the effective target acquisition range. The requirement to make constant Forward Looking Infrared level and gain adjustments is a Part II deficiency which should be corrected as soon as practicable. The author recommends that an automatic feedback loop be incorporated in the FLIR to decrease the number of required level and gain adjustments.

3.2.10 Daylight Television

3.2.10.1 Field Of View. Daylight TV FOV was measured on the ground and qualitatively evaluated in the air. Daylight TV FOV's are presented in table VI.

Table VI

DAYLIGHT TV FIELDS OF VIEW

SCALE	FIELD OF VIEW (AZIMUTH)
Zoom	0.57 deg
Medium	1.1 deg
Wide	4.0 deg

Target detection was performed using Direct View Optics (DVO) and Daylight TV was used for target identification and acquisition. The range of FOV's was sufficient to allow target acquisition and identification. The range of Day TV FOV's coupled with DVO FOV's will provide the CPG with sufficient FOV latitude for daylight target detection and identification. The range of Daylight Television Fields Of View is satisfactory for the helicopter escort and anti-armor missions and met the specification (reference 5).

3.2.11 Direct View Optics

3.2.11.1 Field Of View. DVO FOV was measured on the ground and qualitatively evaluated in the air. DVO FOV's are presented in table VII.

Table VII

DIRECT VIEW OPTICS FIELDS OF VIEW

SCALE	FIELD OF VIEW (AZIMUTH)
Narrow	4.0 deg
Wide	18.0 deg

The range of DVO FOV's was sufficient to allow target area identification and target detection for hand off to the Day TV for target identification. The range of DVO FOV's will provide the CPG with the required daylight target search capability. The range of DVO FOV'S are satisfactory for the helicopter escort and anti-armor missions and met the specification (reference 5).

3.2.11.2 Airspeed effects on resolution. Degradation of DVO resolution caused by vibration due to airspeed was evaluated using a 60 ft X 40 ft X 25 ft high house at a range of 4.5 km during the conditions described in appendix D, table III. Data are presented in Table VIII.

Table VIII

DVO IMAGE QUALITY WITH VIBRATION

AIRSPEED (KIAS)	VIBRATION LEVEL (1)	IMAGE QUALITY
50-100	4	Details (windows, doors, gutters) evident.
40	5	Details slightly blurred.
20	7	Image unusable.
0	3	Details evident.

note: (1) vibration levels assigned in accordance with appendix D, table XII.

Acquisition tasks were performed at or above 40 KIAS or at 0 KIAS, to minimize resolution reductions. The severe degradation of DVO resolution at low airspeeds will restrict target detection and identification during nap of the earth profiles, and zero ground speed hover during moderate to high wind conditions. The severe degradation of Direct View Optics resolution at low airspeeds is a Part II deficiency which should be corrected as soon as practicable. Although DVO operates in the visible light spectrum and FLIR operates in the infrared spectrum, both are subject to LOS jitter. It is recommended that the same techniques employed to decrease FLIR resolution degradation due to vibration be used to correct DVO resolution

degradation.

3.2.11.3 Color image. The color image provided by DVO was evaluated during target search tasks. DVO provided a magnified color image of the world. Target identification with DVO in the narrow FOV was achieved approximately 0.5 km further than with daylight TV in the wide FOV. It was possible to search the area faster with DVO than with monochrome presentations, because recognition was easier. The DVO color image will provide the CPG with additional visual cueing, which will assist in detection and identification of targets and increase the AH-64A standoff range. The DVO color image is an enhancing characteristic which should be incorporated in future designs.

3.2.12 Day Maximum Detection/Identification Range

The daylight maximum detection and identification range was evaluated using various targets during the conditions presented in appendix D, tables III and IV. Target detection and identification was performed by slewing the DVO to the navigation coordinates of the target and approaching the target at 40 KIAS and 200 ft AGL in wide FOV until the target area was identified. After target detection, DVO narrow FOV and daylight TV narrow FOV were used to identify the target. Detection/Identification ranges are presented in table IX.

Table IX

DAY SENSORS MAXIMUM DETECTION/IDENTIFICATION RANGE

TARGET	FLIGHT/ RUN	RANGE ⁽¹⁾ (km)	REMARKS
House	1a	6.0	Daylight. Target was approx. 60 x 40 x 25 ft high. Approached from rear.
	b	6.0	
Fire Truck	1a	3.2	Daylight.
	b	3.8	
Fire Truck	1a	1.2	Dusk.
	b	1.0	
Small building	2a	5.2	Daylight. Target was approx. 40 x 30 x 15 ft high. Approached from corner.
	b	5.1	

note: (1) Target Detection and identification ranges are the same, because target identification immediately followed target detection, upon selection of a Daylight TV narrow FOV.

The maximum detection/identification range was on the edge of the effective range of typical anti-helicopter weapons. The helicopter crew will be forced to mask the aircraft to avoid enemy fire, reducing the time for acquisition and weapon firing and decreasing weapon effectiveness. The insufficient maximum detection range of the daylight sensors is a Part II deficiency which should be corrected as soon as practicable. As stated in paragraph 3.2.9.5,

the first logical step to increase maximum detection range is to decrease the effects of LOS jitter. Therefore, this deficiency is likely to improve if the effects of vibration are addressed.

3.2.13 Image Auto Tracker

3.2.13.1 Tracking ability. The Image Auto Tracker (IAT) was evaluated while tracking automobiles moving at 60 mph on a highway at 0.5 nmi range and perpendicular to the helicopter nose. Establishing target track required an average of 3 seconds. Once the target track had been established, the track was maintained unless the target passed behind an obstruction. If the target became more than half obstructed, the IAT began an erratic search pattern that slewed the FOV away from the target and target track was lost 100% of the time. After the target cleared the obstruction, the IAT failed to reacquire the target, even though the target continued along an unaccelerated straight line track. When track was lost, it was necessary to disengage the IAT and manually search for and acquire the target. This was successfully accomplished less than 50% of the time, with successful acquisition requiring a minimum of 3 seconds to achieve. Momentarily obstructed targets will be able to break the lock of the IAT, preventing target kill. The failure of the Image Auto

Tracker to reestablish track of a target which is momentarily obstructed is a Part I deficiency which must be corrected prior to operational deployment. It is recommended that Image Auto Tracker software be modified to search for a target along its last track when lock is broken.

3.2.13.2 Field of View changes. The IAT was evaluated while approaching targets to determine the level of effort required to maintain target lock. As the range to the target decreased, the target grew in size relative to the display. When the target occupied approximately 80% of the display, the IAT would break lock and go into an erratic search pattern. It was necessary to be attentive of the target image size and to manually change FOV when the target image became too large. The requirement to ensure that the proper FOV is selected, will add an unnecessary step to the CPG weapons delivery procedures. The failure of the Image Auto Tracker to automatically change Field Of View and maintain target track is a Part III deficiency which should be avoided in future designs.

3.2.14 Linear Motion Compensator

The Linear Motion Compensator (LMC) was evaluated while tracking automobiles moving at 60 mph on a highway at 0.5 nmi range and perpendicular to the helicopter nose. The LMC was designed to be an aide in manually acquiring

targets for hand off to the IAT. The evaluator placed the TADS reticle on the target and attempted to track the target with smooth inputs. The LMC was then engaged to automatically continue the track in the same direction; however, when the LMC was engaged, it initially attempted to follow a completely different track. The evaluator was required to apply rapid inputs to bring the LMC on to the desired track. An average of three attempts were required to establish an adequate track, during which time several targets passed behind cover and were lost all together. The LMC can not be used by the operator to decrease the acquisition workload as intended by the design. This will cause a decrease in the probability of successful target acquisition. The initial tendency of the Linear Motion Compensator to establish an erroneous track is a Part II deficiency which should be corrected as soon as practicable. The author recommends that Linear Motion Compensator software be modified to more accurately follow the track established when it is engaged.

3.3 PILOT NIGHT VISION SENSOR

3.3.1 Preflight

Pilot Night Vision Sensor (PNVS) preflight procedures were evaluated for time to complete, thoroughness, logical sequencing, and clarity. PNVS preflight required 10 seconds to complete and involved

turning the PNVS on, then selecting the desired acquisition and sighting. The clarity of the procedure allowed preflight checks to be conducted without error. The timeliness and clarity of PNVS preflight will contribute to the orderly flow of the remaining pilot preflight checks. PNVS preflight is satisfactory for the helicopter escort and anti-armor missions.

3.3.2 Built in Test

PNVS BIT was evaluated for operator interface required and time to execute. PNVS BIT had two possible modes of operation: a continuous BIT which ran automatically while the PNVS was turned on, and a command initiate BIT which was intended to isolate faults once they were detected. The PNVS command initiate BIT was activated through the Data Entry Keyboard (DEK) and prompted the evaluator to activate various switches. Command initiated PNVS BIT required 45 seconds to complete. No faults were detected by either the automatic or the command initiate BIT. The prompting from the command initiate BIT allowed the evaluator to complete the BIT with no external checklists. BIT will allow the pilot to be notified of PNVS failures while performing his regular duties and permit fault isolation procedures in a timely fashion. Within the scope of this test, PNVS BIT is satisfactory for the helicopter escort and anti-armor missions. Further

tests of Pilot Night Vision System Built In Test with fault insertion techniques are recommended.

3.3.3 Cool Down Time

PNVS cool down time was evaluated on the ground prior to takeoff with an ambient air temperature of 73 deg Fahrenheit. FLIR cool down required 15.3 minutes. The cool down was not complete until 6 minutes after the helicopter was ready for takeoff. During night operations the PNVS provided the pilot with his only external night vision capability and required the crew to delay takeoff until PNVS cool down was complete. The excessive PNVS cool down will delay takeoff and decrease the probability that targets will be in their previously reported positions. The excessive Pilot Night Vision Sensor cool down time is a Part II deficiency which should be corrected as soon as practicable. The same solutions to decrease the TADS FLIR cool down time apply to the PNVS. The author recommends that the cooling system be redesigned to decrease PNVS cool down time.

3.3.4 Field of View

PNVS FOV was measured on the ground and qualitatively evaluated in the air. PNVS FOV was 42 deg in azimuth. The FOV provided an approximation close enough to the actual visual image to prevent disorientation. The PNVS FOV will provide the pilot with the cues required to

maintain situational awareness. The PNVS FOV is satisfactory for the helicopter escort and anti-armor missions.

3.3.5 Slew Limits

The PNVS slew limits were evaluated in the air from the front cockpit under control of the CPG IHADSS. The azimuth limits were 100 deg left and 90 deg right (the PNVS left stop was further aft for ground stowage). The PNVS slew limits were never encountered during normal head movements. The PNVS slew limits will permit coverage of the pilot's normal visual limits required to fly the aircraft and clear the flight path. The PNVS slew limits are satisfactory for the helicopter escort and anti-armor missions.

3.3.6 Slew Rates

PNVS slew rates were qualitatively evaluated in flight. The slew rates were sufficient to keep up with all head movements well beyond the rate at which it was not possible for the eye to keep up with the changing image. The PNVS slew rates will allow the pilot to make normal head movements in flight without disorientation. The PNVS slew rates are satisfactory for the helicopter escort and anti-armor missions.

3.3.7 Level and Gain Adjustments

The PNVS was evaluated for the amount of operator interface required in flight. At night, the PNVS was the pilot's only external visual reference. The PNVS required level and gain adjustments approximately every minute to maintain the optimum image. Adjustments were required with changes in heading or just as time progressed. The continual adjustments increased the workload, while flying the aircraft such that the adjustments were made only when the aircraft was on the ground or in low workload phases of flight. The pilot will be forced to fly with a less than optimum PNVS image, requiring him to fly higher above the ground, increasing helicopter susceptibility. The requirement to make constant PNVS level and gain adjustments is a Part II deficiency which should be corrected as soon as practicable. It is recommended that an automatic feedback loop be incorporated in the PNVS to decrease the number of level and gain adjustments required.

3.4 WEAPONS PROCEDURES

3.4.1 General

Actual firing of weapons was beyond the scope of this evaluation due to lack of range facilities. Procedures and facilities to test the delivery of gun fire, rockets and laser guided missiles can be found in reference 11. The operator interface procedures of weapons were evaluated

using of dummy ordnance. Weapons procedures for the gun, rockets and missiles were evaluated for time, clarity, and thoroughness during simulated attacks. Target acquisition was performed at 40 KIAS and 200 ft AGL. When the target was identified, the pilot slowed the aircraft to a hover, descended, and attempted to mask the helicopter without losing acquisition of the target. The evaluator acquired the target with the IAT and initialized the desired weapon system for a simulated attack.

3.4.2 Gun Attack

Once the target was acquired a gun attack was performed in 4 seconds, requiring the following five steps:

- a. MASTER/CPG ARM - ARM
- b. GUN select - NORM
- c. Establish target range - Laser or manual
- d. Weapons Action Switch (WAS) - GUN
- e. Trigger - DEPRESS

The procedure was easy to understand and perform. The CPG will be able to rapidly prepare the 30 mm gun for firing, minimizing exposure time to hostile fire. The 30 mm gun procedure is satisfactory for the helicopter escort and anti-armor missions.

3.4.3 Rocket Attack

Once the target was acquired, a rocket attack required the CPG to perform the following steps:

- a. MASTER/CPG ARM - ARM
- b. ROCKET select - NORM
- c. Establish target range - Laser or manual
- d. Weapons Action Switch (WAS) - ROCKET

Before a rocket attack could be completed, the pilot had to select the type (zone), quantity, and penetration from the rocket control panel described in appendix C, paragraph 4.4. Since the pilot was initially occupied with masking the aircraft, the entire procedure required 20 seconds to complete. The requirement for the pilot to operate the rocket control panel will distract the pilot from flying during demanding attacks and delay rocket launch; thereby, increasing exposure time to hostile fire. The requirement for the pilot to operate the rocket control panel is a Part II deficiency which should be corrected as soon as practicable. The author recommends that provisions to select rocket type, quantity, and penetration be provided to the CPG.

3.4.4 Missile Attacks

3.4.4.1 General. Missile attacks were initially attempted using the checklist provided in the AH-64A Operator's Manual (reference 2). It became apparent that the missile

armament procedures were in error. Although numerous combinations of procedures were attempted, a successful simulated launch was never completed. It is recommended that the missile armament procedures in reference 2 be modified to the correct procedures to include but not be limited to the following changes:

- a. MSL - ON
- b. TYPE - LASER
- c. CHAN SEL should take place following MASTER ARM

The failure to perform a successful simulated launch was attributed to suspected hardware failure. Due to the limited time of the evaluation, it was not possible to determine if this was true. It is recommended that further testing of missile launch be performed upon correction of any hardware failures and the establishment of proper procedures. BIT did not indicate any system failures. Since a hardware failure was not confirmed, it was not determined if BIT failed to perform adequately. Further tests of missile BIT with fault insertion techniques are recommend

3.4.4.2 Procedures. The following types of Hellfire (AGM-114A) missile engagements were attempted:

- a. Single Lock On Before Launch (LOBL)
- b. Ripple LOBL
- c. Single Lock On After Launch (LOAL)
- d. Ripple LOAL

Each procedure required a minimum of 13 steps and 30 seconds to complete. The steps were confusing and required the evaluator to go back and forth and make inputs to the DEK, Fire Control Panel, and the Missile Control Panel. Without the checklist, errors were made approximately 20% of the time, even after 30 minutes of ground practice. The numerous and complicated missile procedures will require the CPG to perform these procedures well in advance of engagement, decreasing the flexibility to respond to sudden threats or targets of opportunity. The numerous and complicated missile launch procedures is a Part II deficiency which should be corrected as soon as practicable. The author recommends that the required missile launch procedures be reduced to no more than 5 steps in the attack phase.

3.4.4.3 Prompting. While executing simulated attacks, the missile TYPE switch (appendix C, figure 2) was inadvertently left in the RF/IR position instead of the required LASER position. The Fire Control Computer (FCC)

indicated that there was an "INVALID COMMAND", but did not indicate what the problem was. The problem was resolved after a ten minute period of investigation. The inadequate prompting of missile launch procedures will require the AH-64A crew to mask the helicopter while sorting out input errors, providing the target with an opportunity to escape. The inadequate prompting of missile launch procedures is a Part II deficiency which should be corrected as soon as practicable. The author recommends that a software change be added to inform the CPG as to what steps are required to fire a weapon.

3.4.4.4 Missile type switch. To perform a Hellfire missile launch the missile TYPE switch on the missile control panel (appendix C, paragraph 4.3) was required to be in the LASER position. Because the AH-64A helicopter was not capable of carrying any other type of missiles, this was an unnecessary procedure. The CPG will be required to perform an unnecessary step in the missile launch procedures to avoid setting the missile TYPE switch in the wrong position. The requirement to set the missile TYPE switch for missile launch is a Part III deficiency which should be avoided in future designs.

3.5 OPTICAL RELAY TUBE

3.5.1 General

The Optical Relay Tube (ORT) (appendix C, paragraph 7.1) was used as the integrated control and display unit for TADS operation and laser and weapons firing. The ORT was evaluated for blind operation, operative sense, sensitivity, suitability of display and system integration.

3.5.2 Controls

The ORT controls were arranged in functional groups and all controls were labeled. All target acquisition and tracking tasks which required the use of more than one control at a time had the controls on opposite handles. Although three switches on each handle were exactly alike, different fingers were used to actuate each one and no confusion resulted. The evaluator could operate all ORT controls blindly with minimal mistakes. The ORT controls will permit the CPG to perform target acquisition and weapons release with minimal effort. The Optical Relay Tube controls are satisfactory for the helicopter escort and anti-armor missions.

3.5.3 Head Out Display

The ORT Head Out Display (HOD) was used as the primary daylight display when the CPG was not engaged in targeting tasks. The HOD measured 3 in x 2 in. The small

screen made seeing fine detail difficult. The small HOD display will contribute to CPG eye fatigue. The small Optical Relay Tube Head Out Display is a Part III deficiency which should be avoided in future designs.

3.6 INTEGRATED HELMET AND DISPLAY SIGHT SYSTEM

3.6.1 Preflight/Boresight Procedures

IHADSS preflight/boresight procedures were evaluated for time to complete, thoroughness, logical sequencing and clarity. IHADSS preflight/boresight took 30 seconds to complete. The clarity allowed preflight/boresight to be conducted without error. The timeliness and clarity of IHADSS preflight/boresight will contribute to the orderly flow of the remaining CPG preflight checks. IHADSS preflight is satisfactory for the helicopter escort and anti-armor missions.

3.6.2 Performance

3.6.2.1 General. The Integrated Helmet and Display Sight System (IHADSS) (appendix C, paragraph 7.2) was evaluated in a 0.4 hour flight around the Cairns airfield area during the daylight conditions described in appendix D, table V. Only the symbology was intended for daylight use. To evaluate the TADS and PNVIS video image the evaluator's left eye was closed and the back of the combiner lens on the Helmet Mounted Display (HMD) was covered to simulate night.

The IHADSS was qualitatively evaluated for disorienting effects, image alignment with the real world, integration with other systems, preflight, and quality of display.

3.6.2.2 Boresight. IHADSS video image and the actual visual image appeared to share the same LOS. The IHADSS boresight was accurate enough to prevent confusion and disorientation. The CPG will be able to use any external references near his line of sight to aide in interpreting the IHADSS image. The correlation to the IHADSS image LOS and the CPG LOS (boresight) is satisfactory for the helicopter escort and anti-armor missions.

3.6.2.3 Image quality. The IHADSS presented a far more grainy image than that provided by the ORT. The Daylight TV image of side numbers on aircraft 800 yards away were crisp on the ORT display, but close to illegible in the IHADSS. The CPG will use the ORT while searching for targets and lose the advantage of the situational awareness provided by the IHADSS. The grainy Integrated Helmet And Display Sight System image is a Part II deficiency which should be corrected as soon as practicable. Since the image from the sensors did not appear grainy on the ORT displays, the resolution of the IHADSS display is insufficient. It is recommended that the resolution of the IHADSS be increased to eliminate the grainy image.

3.7 COUNTERMEASURES

3.7.1 Radar Signal Detector

3.7.1.1 Direction Of Arrival. The AN/APR-39V-1 Radar Signal Detector (RSD) (appendix C, paragraph 5.1) Direction Of Arrival (DOA) was evaluated in the Cairns operating area between 7 and 15 nmi from the airfield and it's traffic radars. The RSD detected two signals during the entire evaluation. Both signals were displayed on a direct bearing to the airfield. The DOA of the detected signal was presented in a clear and understandable format. The RSD DOA accuracy will allow the pilot to determine the bearing of a radar threat and initiate the appropriate evasive maneuvers. Within the scope of this test, the RSD DOA accuracy is satisfactory for the helicopter escort and anti-armor missions. Since there was no testing performed with multiple emitters as outlined in reference 12, further tests of the Radar Signal Detector in a high emitter density environment are recommended.

3.7.1.2 Threat identification. The AN/APR-39V-1 RSD was evaluated for threat identification accuracy in the Cairns operating area between 7 and 15 nmi from the airfield. The RSD detected two signals and did not characterize either one as a threat. The radar signals detected corresponded to the location of the local traffic radar. The AH-64A

crew will not be unnecessarily alarmed by false threats from friendly radars. Within the scope of this test, the RSD threat identification is satisfactory for the helicopter escort and anti-armor missions. Since there was no testing with identifiable threats as outlined in reference 12, further tests of the Radar Signal Detector threat identification with hostile emitters are recommended.

3.7.2 Countermeasures Dispenser

The capabilities of the XM-130 countermeasure dispenser installation (appendix C, paragraph 5.2) were evaluated for effectiveness against infrared missiles. The XM-130 as installed in the AH-64A helicopter had the capability to dispense only chaff. The XM-130 was designed to carry chaff or flares, but the location of the dispenser on the left aft tailboom would cause impact of the flares on the tailrotor. The only active infrared countermeasures was the AN/ALQ-144, which was designed to be effective against only a fixed class of infrared seekers. The inability of the XM-130 countermeasures dispenser, as installed in the AH-64A helicopter, to use flares will result a lack of defense against the destruction of AH-64A aircraft by infrared missiles. The inability of the XM-130 countermeasures dispenser, as installed in the AH-64A helicopter, to use flares is a Part I deficiency which must

be corrected prior to operational deployment. Since flares are one of the most effective countermeasures to heat seeking missiles launched against helicopters, as many additional flare dispensers as possible should be added. One possible configuration is mounting an external pod, containing an XM-130, on top of each wing. A similar arrangement is used to mount AN/ALE-39 flare and chaff dispensers on Marine AH-1 helicopters as described in reference 10. This arrangement would involve little structural modification to the aircraft, while placing the dispenser in a position to provide proper deployment of flares. Additionally, this location would allow the crew to see the dispenser in the event one catches fire. The author recommends installation of additional XM-130 dispensers in locations which permit proper deployment of flares.

3.8 DOPPLER NAVIGATION SYSTEM

3.8.1 Preflight

The ASN-128 Lightweight Doppler Navigation Set (LDNS) (appendix C, paragraph 3) preflight was evaluated for clarity of procedures and timeliness of completion. Data entry of waypoints was the primary task during preflight. Data entry was accomplished by selecting the DEST/TGT position on the display switch and UTM or LAT/LONG on the mode switch. The desired waypoint was dialed into

the DEST DISP window and the KYBD pushbutton was depressed. The number of times required to press the KYBD key depended on the data to be entered. No prompts were supplied by the system for the data required. If data were entered incorrectly, the input was rejected but no indication was given. The requirement to memorize the data entry format and to recheck each waypoint for errors became tedious with several waypoints. The confusing data entry procedures will detract from the logical sequence of the CPG preflight checks. The confusing Doppler data entry procedures are a Part III deficiency which should be avoided in future designs.

3.8.2 Doppler/Fire Control Computer Interface

3.8.2.1 Duplicate data entry. The interface between the LDNS and the Fire Control Computer (FCC) was evaluated for navigation data compatibility. The LDNS and the FCC both required target coordinates, if the TADS was to be slewed by means of a navigation designate. No capability existed to directly transfer navigation data between the LDNS and the FCC. The evaluator was forced to enter duplicate data into both systems. The requirement to enter the same data into both the FCC and the LDNS will detract from the time the CPG has to initialize other weapon systems. The requirement to enter duplicate data into both the Doppler

and the Fire Control Computer is a Part III deficiency which should be avoided in future designs.

3.8.2.2 Data entry sequence. The data entry sequence of the LDNS was evaluated for compatibility with the FCC. Data entry into the FCC was accomplished through the Data Entry Keyboard (appendix C, paragraph 7.3). To enter a letter the operator first depressed the appropriate shift key then the appropriate letter key. To enter a letter into the LDNS, the operator first depressed the letter key was and then the appropriate shift. The different data entry sequences were a source of confusion and will add to the overall frustration level of the CPG. The different data entry sequences between the Doppler and the Fire Control Computer are a Part III deficiency which should be avoided in future designs.

3.8.3 Built in Test

LDNS BIT was evaluated for operator interface required and time to execute. BIT was run by placing the MODE switch in the TEST position. After 16 seconds GO was presented in the left display and the operator placed the MODE switch in the appropriate mode. The LDNS also had a malfunction light (MAL) to notify the operator of an in flight failure. No faults were detected either by the initial BIT or inflight, and no faulty operation was observed. The rapid initial BIT and the automatic nature

of the continuous BIT will not interfere with the CPG primary duties. Within the scope of this test, LDNS BIT is satisfactory for the helicopter escort and anti-armor missions. Further tests of Doppler Built In Test with fault insertion techniques are recommended.

3.8.4 Accuracy

LDNS accuracy, as described in section 3.0 of reference 13, was evaluated during a 2.2 hour flight covering 62 nmi. Truth data for the inflight checkpoints were determined from a map, and were subject to errors in map reading of up to 0.4 km and an unknown error in the construction of the map itself. The evaluation was conducted completely over land and was indicative of typical escort and anti-armor mission; including hovering, sideward, rearward, and high speed flight. Data are presented in appendix E, figures 9 and 10. The maximum error was 1.0 nmi; however, the initial error of 0.8 nmi on the first inflight navigation point and the strict correlation of the error with the checkpoints used, indicated that a major portion of the error (80%) was due to determining the truth data from the map. The error at the end of flight was 0.6 nmi and was taken at the system initialization point, which was a surveyed point. This error and the trend of appendix E, figure 10, indicate that the error rate was 0.01 nmi per nmi of flight. Even with

the errors in truth data, the navigation accuracy allowed the evaluator to perform navigation/waypoint slewing of the TADS to locate the target. The navigation accuracy will provide the CPG with a means to locate a target based on its reported coordinates. The accuracy of the Doppler is satisfactory for the helicopter escort and anti-armor missions. Further tests of Doppler accuracy in the backup mode are recommended.

4 SUMMARY

4.1 GENERAL

Within the scope of this test, the AH-64A weapon system demonstrates excellent potential for the helicopter escort and anti-armor missions. It will be satisfactory upon correction of the Part I deficiencies. A final determination of the suitability of AH-64A mission systems should be conducted utilizing thorough and accurate instrumentation and test ranges.

4.2 ENHANCING CHARACTERISTICS

The following enhancing characteristics were identified, which should be incorporated in future designs:

- a. The ability to slew Target Acquisition Designation Sight Line Of Sight to the pilot's Line of Sight (paragraph 3.2.8).
- b. The color image provided by the Direct View Optics (paragraph 3.2.11.3).

4.3 PART I DEFICIENCIES

The following Part I deficiencies were identified which must be corrected prior to operational deployment:

- a. Failure of the Image Auto Tracker to reestablish track of a target which is momentarily obstructed (paragraph 3.2.13.1). The author recommends that Image Auto Tracker software be modified to search for a target along its last track when lock is broken.
- b. Inability of the XM-130 countermeasures dispenser, as installed in the AH-64A helicopter, to use flares (paragraph 3.7.2). The author recommends installation of additional XM-130 dispensers in locations which permit proper deployment of flares.

4.4 PART II DEFICIENCIES

The following Part II deficiencies were identified which should be corrected as soon as practicable:

- a. Restricted over the nose Field Of View (paragraph 3.1.4). It is recommended that methods lowering the CPG instrument panel be investigated.

b. Faulty indication of the Target Acquisition Designation Sight left azimuth limit (paragraph 3.2.6). The author recommends a software change to more accurately represent the actual TADS Line of Sight.

c. Excessive Forward Looking Infrared cool down time (paragraph 3.2.9.1). It is recommended that the cooling system be redesigned to decrease TADS FLIR cool down time.

d. Low Forward Looking Infrared dynamic spacial resolution due to airframe vibration (paragraph 3.2.9.4). The author recommends the incorporation of a vibration suppression system to decrease degradation of FLIR resolution. Also, the use of vibration isolation mounts on FLIR hardware to decrease degradation of FLIR resolution is recommended.

e. Insufficient Forward Looking Infrared maximum detection/identification range (paragraph 3.2.9.5). This deficiency is likely to improve if the effects of vibration are addressed as discussed in paragraph 3.2.9.4.

f. Requirement to make constant Forward Looking Infrared level and gain adjustments (paragraph 3.2.9.6). It is recommended that an automatic feedback loop be incorporated in the FLIR to decrease the number of level and gain adjustments required.

g. Severe degradation of Direct View Optics resolution at low airspeeds (paragraph 3.2.11.2). The author recommends that the same techniques employed to decrease FLIR resolution degradation due to vibration be used to correct DVO resolution degradation.

h. Insufficient maximum detection range of the daylight sensors (paragraph 3.2.12). This deficiency is likely to improve if the effects of vibration are addressed as discussed in paragraph 2.2.9.4.

i. Initial tendency of the Linear Motion Compensator to establish an erroneous track (paragraph 3.2.14). The author recommends that Linear Motion Compensator software be modified to more accurately follow the track established when it is engaged.

j. Excessive Pilot Night Vision Sensor cool down time (paragraph 3.3.3). It is recommended that the cooling system be redesigned to decrease PNVs cool down time.

k. Requirement to make constant Pilot Night Vision System level and gain adjustments (paragraph 3.3.7). The author recommends that an automatic feedback loop be incorporated in the PNVs to decrease the number of level and gain adjustments required.

l. Requirement for the pilot to operate the rocket control panel (paragraph 3.4.3). It is recommended that provisions to select rocket type, quantity, and penetration be provided to the CPG.

m. Numerous and complicated missile launch procedures (paragraph 3.4.4.2). The author recommends that the required missile launch procedures be reduced to no more than 5 steps in the attack phase.

n. Inadequate prompting of missile launch procedures (paragraph 3.4.4.3). The author recommends that a software change be added to inform the CPG as to what steps are required to fire a weapon.

o. Grainy Integrated Helmet And Display Sight System image (paragraph 3.6.2.3). It is recommended that the resolution of the IHADSS be increased to eliminate the grainy image.

4.5 PART III DEFICIENCIES

The following Part III deficiencies were identified, which should be avoided in future designs:

a. Obstructed Line Of Sight of the CPG rotor RPM gauge (paragraph 3.1.3.2).

b. Obstructed Line Of Sight of the selectable digital display (paragraph 3.1.3.3).

- c. Insufficient indication of Target Acquisition Designation Sight Field Of View (paragraph 3.2.7).
- d. Failure of the Image Auto Tracker to automatically change Field Of View and maintain target track (paragraph 3.2.13.2).
- e. Requirement to set the missile TYPE switch for missile launch (paragraph 3.4.4.4).
- f. Small Optical Relay Tube Head Out Display (paragraph 3.5.3).
- g. Confusing Doppler data entry procedures (paragraph 3.8.1).
- h. Requirement to enter duplicate data into both the Doppler and the Fire Control Computer (paragraph 3.8.2.1).
- i. Different data entry sequences between the Doppler and the Fire Control Computer (paragraph 3.8.2.2).

4.6 RECOMMENDATIONS FOR FURTHER TESTING

The requirement for further testing was identified in the following areas:

- a. Target Acquisition Designation Sight Built In Test with fault insertion techniques (paragraph 3.2.2).

- b. Quantify Forward Looking Infrared to determine static and dynamic resolution, as well as line of sight jitter (paragraph 3.2.9.4).
- c. Pilot Night Vision System Built In Test with fault insertion techniques (paragraph 3.3.2).
- d. Missile launch procedures, upon correction of any hardware failures and the establishment of proper procedures (paragraph 3.4.4.1).
- e. Missile BIT with fault insertion techniques (paragraph 3.4.4.1).
- f. Radar Signal Detector in a high emitter density environment (paragraph 3.7.1.1).
- g. Radar Signal Detector threat identification with hostile emitters (paragraph 3.7.1.2)
- h. Doppler Built In Test with fault insertion techniques (paragraph 3.8.3).
- i. Doppler accuracy in the backup mode (paragraph 3.8.4).

4.7 PROCEDURES

The author recommends that the missile armament procedures in reference 2 be modified to the correct procedures to include but not be limited to the following changes:

- a. MSL - ON
- b. TYPE - LASER
- c. CHAN SEL should take place following MASTER ARM (paragraph 3.4.4.1).

4.8 SPECIFICATION CONFORMANCE

The equipment tested met all of the specification requirements against which it was tested (paragraph 2.6.1), except those listed below:

MIL-STD-203F

(1) Paragraph 4.2 in that the following indicators were not visible from the design eye position:

- (a) Copilot Gunner rotor RPM gage (paragraph 3.1.3.2).
- (b) Copilot Gunner selectable digital display (paragraph 3.1.3.3).

LIST OF REFERENCES

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- 2 Operator's Manual for Army AH-64A Helicopter, TM55-1520-238-10, Dated 15 January 1984.
- 3 AH-64A Aircrew Training Student Manual, vols 1-3, Dated September 1983.
- 4 Military Standard, MIL-STD-1333A, "Aircrew Station Geometry for Military Aircraft, Dated 2 June 1969.
- 5 Military Specification, DRC-S-H10000B, "System Specification for the Advanced Attack Helicopter, Dated 15 April 1982.
- 6 "Techeval of the Weapon System Installed in the Advanced Fixed Wing Medium Attack Airplane, VAX Test Plan", Dated 15 February 1983.
- 7 Military Standard, MIL-STD-203F, "Aircrew Station Controls and Displays Assignment, and Actuation of", Dated 28 December 1973.
- 8 Masters, George, USNTPS Textbook, "Electro-Optical Systems Test and Evaluation", October 1981.
- 9 Harris, C., & Crede, C. Shock and Vibration Handbook, second edition. New York: McGraw-Hill Book Company, 1976.
- 10 NATOPS Flight Manual for the AH-1W Helicopter, NAVAIR 01-H1AAC-1, of 3 September 1987.
- 11 Masters, George, USNTPS Textbook, "Integrated Weapon System Test and Evaluation", 26 October 1981.
- 12 Masters, George, USNTPS Textbook, "Electronic Warfare Systems Test and Evaluation", 18 March 1981.
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APPENDICES

GLOSSARY

ADF	Automatic Direction Finder
ALC	Automatic Light Control
ADTA	Army Aviation Test Activity
AGL	Above Ground Level
AND	Alpha Numeric Display
ARCS	Aerial Rocket Control System
AWS	Area Weapons System
BBC	Backup Bus Controller
BIT	Built In Test
BRU	Boresight Reticle Unit
CDU	Computer Display Unit
CPG	Copilot Gunner
DAP	Display Adjust Panel
DASE	Digital Automatic Stabilization Equipment
DEP	Design Eye Position
DEK	Data Entry Keyboard
DEU	Display Electronics Unit
DOA	Direction Of Arrival
DT-IIA	Developmental Test Phase A
DTV	Day Television
DVO	Direct View Optics
FCC	Fire Control Computer
FD/LS	Fault Detection/Location System
FFAR	Folding Fin Aerial Rockets
FLIR	Forward Looking Infrared
FOV	Field Of View
HARS	Heading Attitude Reference System
HDD	Heads Down Display
HDU	Helmet Display Unit
HMD	Helmet Mounted Display
HOD	Head Out Display
HSI	Horizontal Situation Indicator
IAT	Image Auto Tracker
ICS	Intercommunications System
IFF	Interrogation Friend or Foe
IHADSS	Integrated Helmet Display Sight System
IR	Infrared

GLOSSARY

KIAS	Knots Indicated Airspeed
LDNS	Lightweight Doppler Navigation Set
LED	Light Emitting Diode
LF	Low Frequency
LMC	Linear Motion Compensator
LOAL	Lock On After Launch
LOBL	Lock On Before Launch
LOS	Line of Sight
LRF/D	Laser Rangefinder/Designator
LST	Laser Spot Tracker
LTU	Laser Transceiver Unit
MRTU	Multiplex Remote Terminal Units
MUX	Multiplex Bus
ORT	Optical Relay Tube
Part I	The most severe deficiency which adversely effects either safety or successful mission completion
Part II	A deficiency which requires significant compensation to accomplish the mission.
Part III	A deficiency which is an annoyance
PNVS	Pilot Night Vision
System	
RHE	Remote Hellfire Electronics
RMI	Radio Magnetic Indicator
RSD	Radar Signal Detector
RTA	Receiver Transmitter Antenna
SAM	Surface to Air Missile
SDC	Signal Data Converter
SEU	Sight Electronics Unit
SF _{co}	Spacial Frequency Cutoff
SSU	Sight Survey Unit
TADS	Target Acquisition Designation Sight
USNTPS	United States Naval Test Pilot School
UTM	Universal Transverse Mercator
VAX	Test Pilot School model systems test plan
VDU	Video Display Unit
VHF	Very High Frequency
WAS	Weapons Action Switch
WFOV	Wide Field Of View

DEFINITION OF DEFICIENCIES

Part I indicates a deficiency, the correction of which is necessary because it adversely affects:

- a. Airworthiness of the aircraft.
- b. The ability of the aircraft to accomplish its primary or secondary mission.
- c. The effectiveness of the crew as an essential subsystem.
- d. The safety of the crew or the integrity of an essential subsystem. In this regard, a real likelihood of injury or damage must exist. Remote possibilities or unlikely sequences of events shall not be used as a basis for safety items.

PART II indicates a deficiency of lesser severity than a Part I which does not substantially reduce the ability of the aircraft to accomplish its primary or secondary mission, but the correction of which will result in significant improvement in the effectiveness, maintainability, or safety of the aircraft.

Part III indicates a deficiency that appears too impractical or costly to correct in this model, but which should be avoided in future designs.

WEAPON SYSTEM DESCRIPTION

1 GENERAL

The AH-64A Apache helicopter is an adverse weather anti-armor attack aircraft. Major mission systems include data handling, communication, navigation, armament, countermeasures, external sensors, and integrated controls and displays. The general arrangement of the Copilot Gunner (CPG) cockpit is depicted in enclosure 1, figure 1. CPG instrument panel and consoles are depicted in enclosure 1, figures 2 and 3 respectively.

2 DATA HANDLING SYSTEM

2.1 Multiplexer Bus Subsystem (MUX)

The MUX subsystem consists of Multiplex Remote Terminal Units (MRTU) and a redundant 1553 data bus. Three helicopter subsystems; the Digital Automatic Stabilization Equipment (DASE), the Remote Hellfire Electronics (RHE) unit and the symbol generator also function as MRTU's. The data bus consists of two identical bus networks separated down each side of the helicopter and interconnected to minimize data loss in the event of battle damage. The MUX bus system receives power from the No. 1 essential ac bus and the No. 3 essential dc bus.

2.2 Fire Control Computer

The FCC (Fire Control Computer) is the primary bus controller. The FCC controls all data transmissions on the MUX during normal operations. The FCC processes and computes data to all fire control capabilities on board the helicopter. The software version during testing was 8676 000-23. The FCC continuously executes an internal Built In Test (BIT). Power is supplied from the No. 1 ac essential bus and the No. 3 dc essential bus.

2.3 Fault Detection/Location System

The Fault Detection/Location System (FD/LS) resides in the FCC computer program. If the FCC fails no FD/LS function exists. The purpose of the FD/LS is to announce NO-GO subsystem components to the flight crew or the FCC repairman. The Data Entry Keyboard (DEK) is used to access the FD/LS functions. There are two basic FD/LS modes: continuous monitor and command initiated. The continuous monitor systems are:

-30mm gun	-Image Auto Tracker servo
-Rocket system	-FLIR
-Hellfire system	-Daylight TV
-Rounds Counter	-Heading Attitude Reference
-Pilot Night Vision Sensor	-DEK
-CPG Fire Control Panel	-Backup Bus Controller (BBC)
-CPG MRTU	-Symbol Generator
-Laser Rangefinder/Designator	-Laser Spot Tracker
-Target Acquisition Designation Sight (TADS)	
-Integrated Helmet Display And Sight System (IHADSS)	

In addition the following 19 systems can be accessed by the command initiate FD/LS, which can perform a fault isolation function:

-Air Data System	-DASE
-Anti-Ice	-30 mm gun
-Heading Attitude Reference	-IHADSS
-Missiles	-MUX
-Pilot Night Vision System	-External Stores
-Rockets	-Stabilator
-Symbol Generator	-TADS
-BBC	-CPG Fire Control Panel
-DEK	-Auxiliary Power Unit
-Generator	

3 LIGHTWEIGHT DOPPLER NAVIGATION SET

The AN/ASN-128 Lightweight Doppler Navigation Set (LDNS), located on the CPG right console (enclosure 1, figure 3), is designed to determine ground speed from the Doppler shift in the radar return caused by aircraft motion in the longitudinal, lateral, and vertical directions. Current software version tested was CP 125. The system is designed to operate above 10,000 ft and to 45 deg bank and 30 deg pitch. The LDNS consists of:

- a. Computer Display Unit (CDU), CP-1252/ASN-128 (Figure 1)
- b. Signal Data Converter (SDC), CV-3338/ASN-128
- c. Receiver Transmitter Antenna (RTA), RT1193/ASN-128

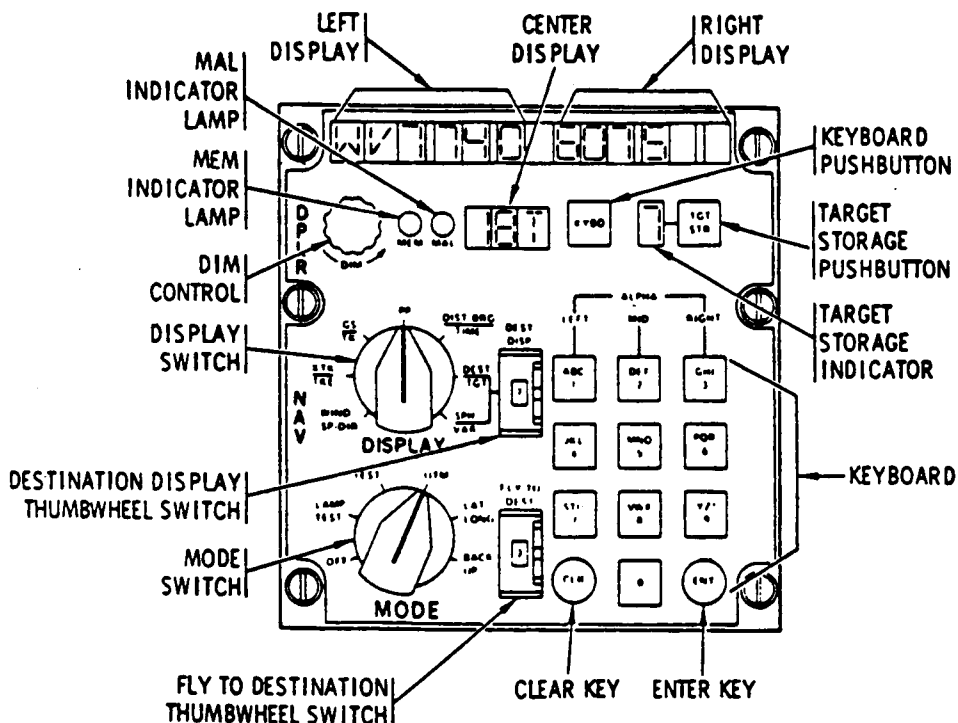


Figure 1

LDNS COMPUTER DISPLAY UNIT

The LDNS has ten programmable destinations and receives attitude information from the Heading and Attitude Reference Set (HARS). The LDNS provides navigation data to the HARS, the Horizontal Situation Indicator (HSI), and the Fire Control Computer (FCC). LDNS outputs to the CDU are:

- Present position or selected destination latitude and longitude (deg, min, tenths of min) or Universal Transverse Mercator (UTM) coordinates.
- Ground Speed (km/hr)
- Track angle (deg)
- Distance cross track (km)
- Bearing to destination (deg)
- Time to destination (min and tenths of min)
- Spheroid code of destination
- Magnetic variation of destination
- Track angle error (deg)
- Distance to destination (km and tenths of km)

The LDNS has a backup mode which relies on air data for navigation with the last remembered windspeed. Power is supplied by the No. 1 essential dc bus.

4 ARMAMENT SYSTEM

The AH-64A system is designed for accurate delivery of Hellfire laser guided missiles, 30 mm rounds, and 2.75 Folding Fin Aerial Rockets (FFAR). Primary Armament system components are:

- a. 30 mm gun
- b. Hellfire system
- c. Aerial Rocket System
- d. External Stores Subsystem
- e. Fire Control Panels

4.1 30 mm Gun

The 30 mm gun, also known as the Area Weapon System (AWS), is a single barrel, externally powered, chain drive machine gun. Weapon design characteristics are presented in Table I.

Table I

30 mm GUN DESIGN CHARACTERISTICS

PARAMETER	CHARACTERISTIC
Type	30 mm Automatic
Drive	External electric
Range	3000 m (8 deg elevation)
Rate of fire	625 +/- 25 rounds per minute
Muzzle velocity	2700 ft/sec
Trunnion reaction	3000 lb max peak
Weight (gun only)	110 lb
Number of Barrels	1
Barrel length	42 in
Electric motor	3 hp, 11,500 rpm at 110/200 Vac
Time to Max rate of fire	0.2 sec
Time to stop	0.1 sec
Clearing Method	Open Bolt
Elevation Range	+11 deg to -60 deg
Azimuth range	+/- 110 deg
Angular slew rate	80 deg/sec
Elevation slew rate	60 deg/sec
Ammunition capacity	600 or 1200 rounds depending on magazine installed

The slew control is hydraulic. In event of hydraulic failure the gun is designed to automatically stow up to prevent dig in on landing.

4.2 Hellfire Missile System

The Hellfire missile (AGM-114A) system, also known as the point target weapon system, is the primary helicopter armament for destruction of tanks and other armored targets. It is designed to provide the capability to fire missiles from the ground or airborne at speeds from hover to maximum level flight speed. The Hellfire missile uses a tri-service type laser seeker. Missile characteristics are classified. The missile is capable of being fired in two modes: Lock On Before Launch (LOBL), and Lock On After Launch (LOAL) in a high, low or direct trajectory. The laser designator can be on board the aircraft or can be from a remote designator. The designating laser must be coded with the same code programmed into the missile by the CPG. The CPG has the capability of selecting two channels of codes and then selecting one code as the primary and one as the secondary. The missiles can be fired in the normal mode, in which one missile and one laser designator are used utilizing the primary code or; the missiles can be fired in the ripple mode where two missiles with different codes are fired at two different targets. The Apache is designed to be able to carry up to sixteen missiles, four on each station. The missiles are launched from Hellfire launchers. The launchers come in pairs and can be stacked to carry up to four missiles on each station.

4.3 Copilot/Gunner Missile Control Panel

The CPG missile control panel is located on the left hand console and is depicted in figure 2.

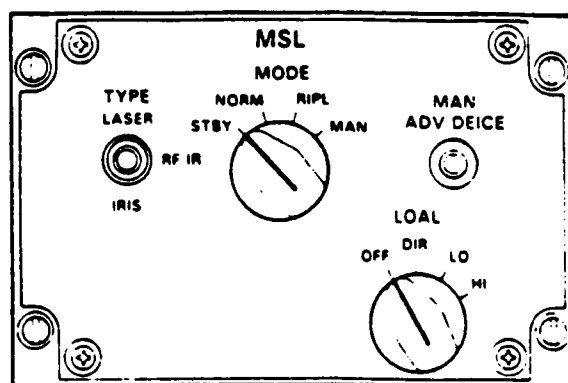


Figure 2

CPG MISSILE CONTROL PANEL

The panel is used to select the type of launch: Lock On Before Launch (LOBL), Lock On After Launch (LOAL) (high, low, or direct) and the mode of launch: normal, ripple, or manual. Manual allows manual advance of missile selection instead of using autoreplenishment.

4.4 Aerial Rocket Control System

The Aerial Rocket Control System (ARCS) is designed to deliver 2.75 in Folding Fin Aerial Rocket (FFAR) as a light antipersonnel assault weapon. The ARCS consists of a rocket control panel, located on the pilot's left console and depicted in figure 3, and four station directors located in each of the four wing station pylons.

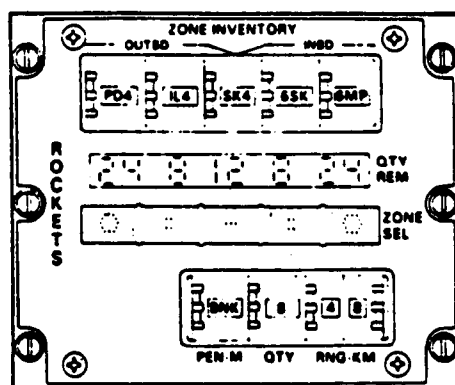


Figure 3

ROCKET CONTROL PANEL

The ARCS is capable of carrying up to five different types of rocket warheads simultaneously. These different types of warheads can be loaded into five selectable inventory zones. The pilot is capable of selecting the type of rocket to be fired, the number to be fired per volley and the type of penetration fuzing. Manual selection of target range is also possible, but not required if a sensor is designating the target. The AH-64 is designed to carry up to four M261 rocket launchers which carry up to 19 rockets each.

4.5 External Stores Subsystem

The External Stores Subsystem consists of an external stores controller and up to four pylon assemblies. The external stores controller commands the pylons to the required elevation angles for various fire control modes. The modes are: ground stow, flight stow, and FCC control. The ground stow mode is designed so that the stores are held parallel to the ground and can be entered either automatically with weight on the wheels, or manually. The flight stow mode is designed for minimum drag in flight. In flight, the pylons are designed to remain in the flight stow mode until missiles or rockets are actioned, which places the pylons under the control of the FCC. The pylons are designed to operate through an elevation range of +4.9 to -1.5 deg. Power is supplied from the No. 1 essential ac bus and the No. 2 essential dc bus.

4.6 Copilot/Gunner Fire Control Panel

The CPG fire control panel is located in the left hand instrument panel and is depicted in enclosure 1, figure 4. The panel provides control for all sighting and acquisition functions as well as arming aircraft weapons systems. The panel also contains the controls to set Hellfire laser codes. The fire control panel is powered by the No. 1 essential ac bus and the No. 3 essential dc bus.

5 COUNTERMEASURES

5.1 Radar Signal Detector

The AN/APR-39V-1 Radar Signal Detector (RSD) depicted in figure 4 is designed to provide visual and audio warning of radar operation above a predetermined lower threshold.

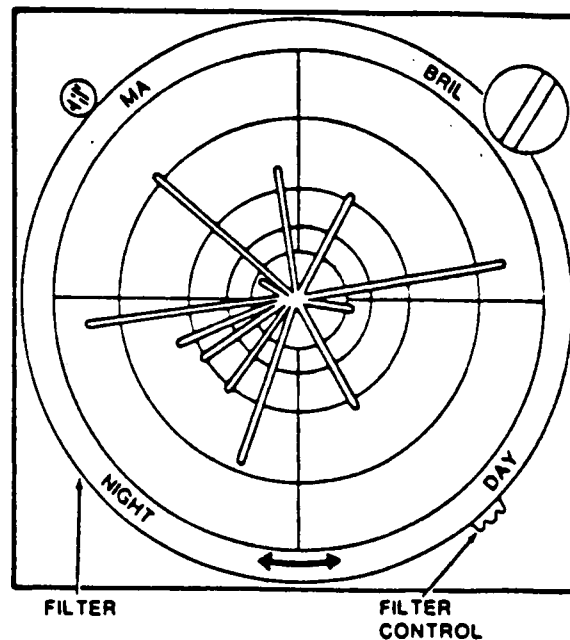


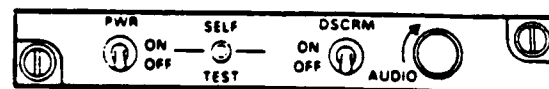
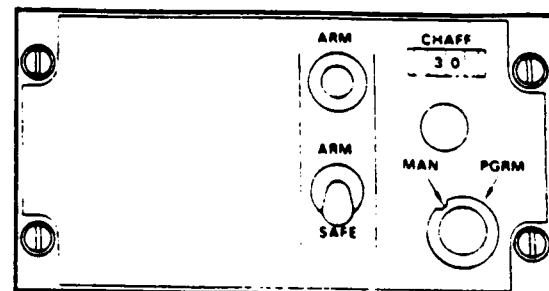
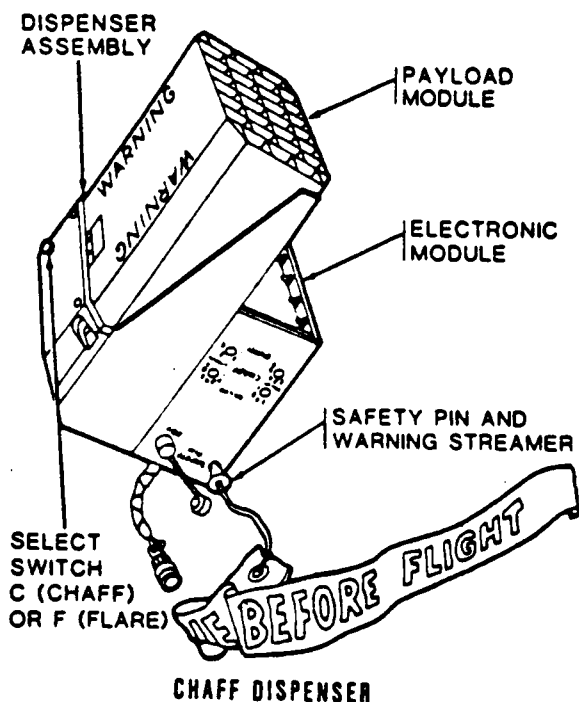
Figure 4

RADAR SIGNAL DETECTOR DISPLAY

The RSD is designed to provide the azimuth and relative power of all radars and to provide louder audio cues and steady visual cues of a Surface to Air Missiles (SAM). The RSD has a discriminate option which only presents radars of a predetermined threat criteria. The AN/APR-39 has two antennas mounted forward and two mounted aft. The RSD receives power from the No. 2 essential dc bus.

5.2 Dispenser Kit

The XM-130 countermeasures set consists of a single dispenser mounted in the tail of the aircraft, an electronics module, and a control panel located on the pilot's instrument panel. XM-130 components are depicted in figure 5.



CONTROL PANELS

Figure 5

XM-130 CHAFF DISPENSER COMPONENTS

The system is designed to provide countermeasures against radar guided missiles by dispensing M-1 chaff. The system fires up to 30 chaff rounds in manual single shots or in predetermined salvos which are set before flight. The basic XM-130 has the capability to carry flares, but that function is not available in the AH-64A installation. The dispenser is powered from the No. 2 essential dc bus.

5.3 Infrared Countermeasures Set

The AN/ALQ-144 countermeasures set is designed to provide countermeasures against IR missiles and is mounted immediately aft of the main rotor. The system uses IR modulation techniques to deceive IR missiles. System characteristics are classified. Power is supplied by the No. 2 essential dc bus.

5.4 Radar Jammer Set

The AN/ALQ-136 radar jammer set is designed to reduce the capabilities of radar guided weapons. System characteristics are classified. The radar jammer has a

transmitter and a receiver antenna and shares a common control panel with the IR countermeasures set. Power is received from the No. 1 essential dc bus.

6 SENSORS

6.1 Target Acquisition Designation Sight

The AN/ASQ-170 Target Acquisition Designation Sight (TADS) is designed to provide the CPG with target acquisition by use of Direct View Optics (DVO), a Day Television (DTV), or a Forward Looking Infrared (FLIR) sensor. These sensors are designed to be operated signally or in combination. A functional diagram of the TADS system is provided in enclosure 1, figure 5. The TADS is designed with +30 deg to -60 deg elevation limits and +/- 120 deg azimuth limits. The TADS maximum slew rate in the FLIR Wide Field Of View (WFOV) is designed to be 80 deg/sec. Target tracking can either be accomplished by manual tracking; or automatically with an Image Auto Tracker or a Laser Spot Tracker (LST). Target designation can be performed by a Laser Rangefinder/Designator (LRF/D). The TADS receives power from the No. 1 essential ac bus and the No. 1 essential dc bus.

6.1.1 TADS Forward Looking Infrared. The TADS FLIR is a thermal imaging sensor operating in IR region from 8 to 14 microns. A functional diagram illustrating actual FLIR operation is depicted in enclosure 1, figure 6. The TADS FLIR is mounted in the TADS mounting system; therefore, it shares the TADS gymbol limits. The TADS FLIR has four possible Field Of Views (FOV). They are:

- a. Wide - 50 deg diagonal
- b. Medium - 10 deg diagonal
- c. Narrow - 3.1 deg diagonal
- d. Zoom - 1.6 deg diagonal

The Zoom FOV is actually a 50 percent electronic underscan of the Narrow FOV, which causes a degradation in resolution. The CPG has primary control of the TADS FLIR from the Optical Relay Tube (ORT) Controls, but both crewmembers can make gain, level, and polarity adjustments to their own displays. TADS FLIR imagery can be presented on the IHADSS, the ORT Heads Out Display (HOD) and Heads Down Display (HDD), and the pilot's Video Display Unit (VDU). FLIR, aircraft, and weapons symbology can be superimposed over FLIR imagery by the symbol generator.

6.1.2 TADS Day Television. The TADS Day Television (DTV) is designed to be a daylight sensor operating in near IR region from 0.7 to 0.95 microns. The TADS DTV shares the same optical path as the Direct View Optics (DVO) into a VIDICON camera. The three possible FOV's are:

- a. Wide - 4.0 deg diagonal
- b. Narrow - 0.9 deg diagonal
- c. Zoom - 0.45 deg diagonal

The Zoom FOV is actually an electronic underscan of Narrow Fov, which causes a degradation in resolution. The TADS DTV incorporates an Automatic Light Control (ALC), which is a variable density filter that is designed to respond to varying light conditions keeping DTV output at a predetermined level. TADS DTV imagery can be presented on the IHADSS, the ORT HOD and HDD, and the pilot's VDU. DTV, aircraft, and weapons symbology can be superimposed over DTV imagery by the symbol generator.

6.1.3 TADS Direct View Optics. The TADS DVO is an optical telescope which is designed to provide the CPG with a "real world" color presentation. DVO presentation can be viewed by looking through the ORT HDD. When DVO is selected, a trip mirror will rotate out of the DVO path enabling DVO presentation. When FLIR or DTV is selected, the mirror interrupts the DVO path and FLIR or DTV imagery is presented on the HDD. The DVO shares the same optical path as the DTV. The DVO path into the ORT HOD is presented in enclosure 1, figure 7. The two possible DVO FOV's are:

- a. Wide - 18.0 deg (diagonal)
- b. Narrow - 4.0 deg (diagonal)

The DVO is designed to have all optical paths safe to laser energy.

6.1.4 Manual tracking. TADS LOS can be tracked on a target through manual control from the CPG. After the TADS LOS is initially positioned, the CPG can select the manual tracker and slew the TADS LOS with the MAN TKR switch which is depicted in enclosure 1, figure 8. The LOS slew rate is designed to be proportional to the force on the MAN TKR switch.

6.1.5 Image Auto Tracker. The Image Auto Tracker (IAT) is an area balanced contrast tracker; designed to track the centroid of the contrast area of an object. The IAT can use either FLIR or DTV video. The IAT is selected by the CPG using ORT controls depicted in enclosure 1, figure 8.

6.1.6 Laser Spot Tracker. The Laser Spot Tracker (LST) is designed to detect, decode, and track reflected laser energy. Laser energy is reflected off of a parabolic mirror and is focused on the detector. The LST compares the code of incoming signals to the code set in by the CPG. If the codes are the same, the LST is designed to lock on to the source. The LST can be used to search in two modes. In the manual mode, search is performed by the CPG using the MAN TKR switch on the ORT until the laser is detected, at which time the LST goes into track mode. In the automatic search mode, the LST performs a four-box search pattern centered about the TADS LOS. The LST does not share any optical path with another sensor.

6.1.7 Laser RangeFinder/Designator. The Laser RangeFinder/Designator (LRF/D) is designed to provide coded pulsed laser energy for target designation and range determination. The Laser Transceiver Unit (LTU) generates the laser energy of a specific code. This energy is reflected through a laser prism and sent out through a the Narrow FOV lens. Reflected energy follows the same path on return and is used to determine target range. To do pure ranging the LRF/D fires three pulses in one second. Continuous laser firing is used when designating a target. The LRF/D share the same optical path as the DVO and the DTV in Narrow FOV.

6.2 Pilot Night Vision Sensor

The AN/AAQ-11 Pilot Night Vision Sensor (PNVS) is a FLIR which is used by the pilot for externally aided vision at night. A block diagram of the PNVS is presented in enclosure 1, figure 9. The stabilized FLIR is mounted above the TADS and is designed with elevation limits of +20 deg and -45 deg and azimuth limits of +/- 90 deg. The PNVS is designed with a 30 deg vertical and 40 deg horizontal fixed FOV and a maximum slew rate of 120 deg/sec. The PNVS can be monitored by the CPG and controlled by him in emergency operation. The PNVS receives power from the No. 1 essential ac bus and the No. 3 essential dc bus.

7 INTEGRATED CONTROLS AND DISPLAYS

7.1 Optical Relay Tube Controls and Displays

The Optical Relay Tube (ORT) is located between the left and right CPG instrument panels and is depicted in enclosure 1, figure 8. The ORT is the primary controller for weapons and laser firing, tracker selection, and TADS image control. The ORT also provides the CPG with Heads Down Display (HDD) capability and a Head Out Display HOD

capability. The primary function of the HDD is to allow Direct View Optics (DVO). When not used for DVO, the HDD can supply the same information as the HOD.

7.2 Integrated Helmet Display and Sight System

The Integrated Helmet Display and Sight System (IHADSS) establishes Line of Sight (LOS) reference for the aircraft armament and sensors, and provides capabilities to project TADS and PNVIS images and symbology on to a combining lens in front of the right eye of each crewmember. The IHADSS consists of:

- a. The crewmember's helmets
- b. Helmet Display Units (HDU)
- c. Sight Survey Units (SSU)
- d. Display Adjust Panels (DAP)
- e. Boresight Reticle Units (BRU)
- f. Sight Electronics Unit (SEU)
- g. Display Electronics Unit (DEU)

The general arrangement of IHADSS components is presented in enclosure 1, figure 10.

7.2.1 Crewmens helmets. The helmets consist of a shell, an infrared sensor assembly, an energy liner, earphones, and a microphone. The sensor, liner, and earphone assemblies are fitted inside. The infrared sensor assembly has four IR detectors which allow the SEU to determine the crewmember's LOS.

7.2.2 Helmet Display Unit. The HDU (enclosure 1, figure 10) is designed to allow TADS or PNVIS video and symbology to be projected onto a combiner lens in front of the crewmembers right eye, allowing simultaneous viewing of the outside world.

7.2.3 Sight Survey Unit. The SSU's, located in each crewstation (behind, above, left and right of each seat as depicted in enclosure 1, figure 10), generate pairs of IR beams that rotate at constant speed. The SSU's direct IR beams at the IR detectors on the helmet and provide reference pulses for the SEU.

7.2.4 Display Adjust Panels. The DAP's are located behind each crewmember's seat as depicted in enclosure 1, figure 10. The DAP's amplify the video/symbol signals from the DEU and output them on the crewmembers HDU. The panels also provide for adjustment of the video image for each respective HDU.

7.2.5 Boresight Reticle Unit. The BRU is located above the center of each crewmembers instrument panel as depicted in enclosure 1, figure 10. The BRU is designed to provide a collimated sighting target aligned with the aircraft's armament datum line, for alignment of the IHADSS LOS.

7.2.6 Sight Electronics Unit. The SEU, located in the forward avionics bay, uses Integrated Helmet Unit (IHU) position pulse and SSU reference pulse to determine IHADSS LOS. The LOS information is provided to the FCC for pointing weapons and sensors.

7.2.7 Display Electronics Unit. The DEU is located next to the SSU and processes the video/symbol inputs from the symbol generator and generates deflection signals.

7.3 Data Entry Keyboard

The Data Entry Keyboard (DEK) is located on the CPG left console as is depicted in enclosure 1, figure 11. The DEK provides the CPG with the capability to enter alphanumeric inputs for manual target range entry, FD/LS interface, laser codes, target coordinates, and interface with the FCC.

7.4 Alpha Numeric Display

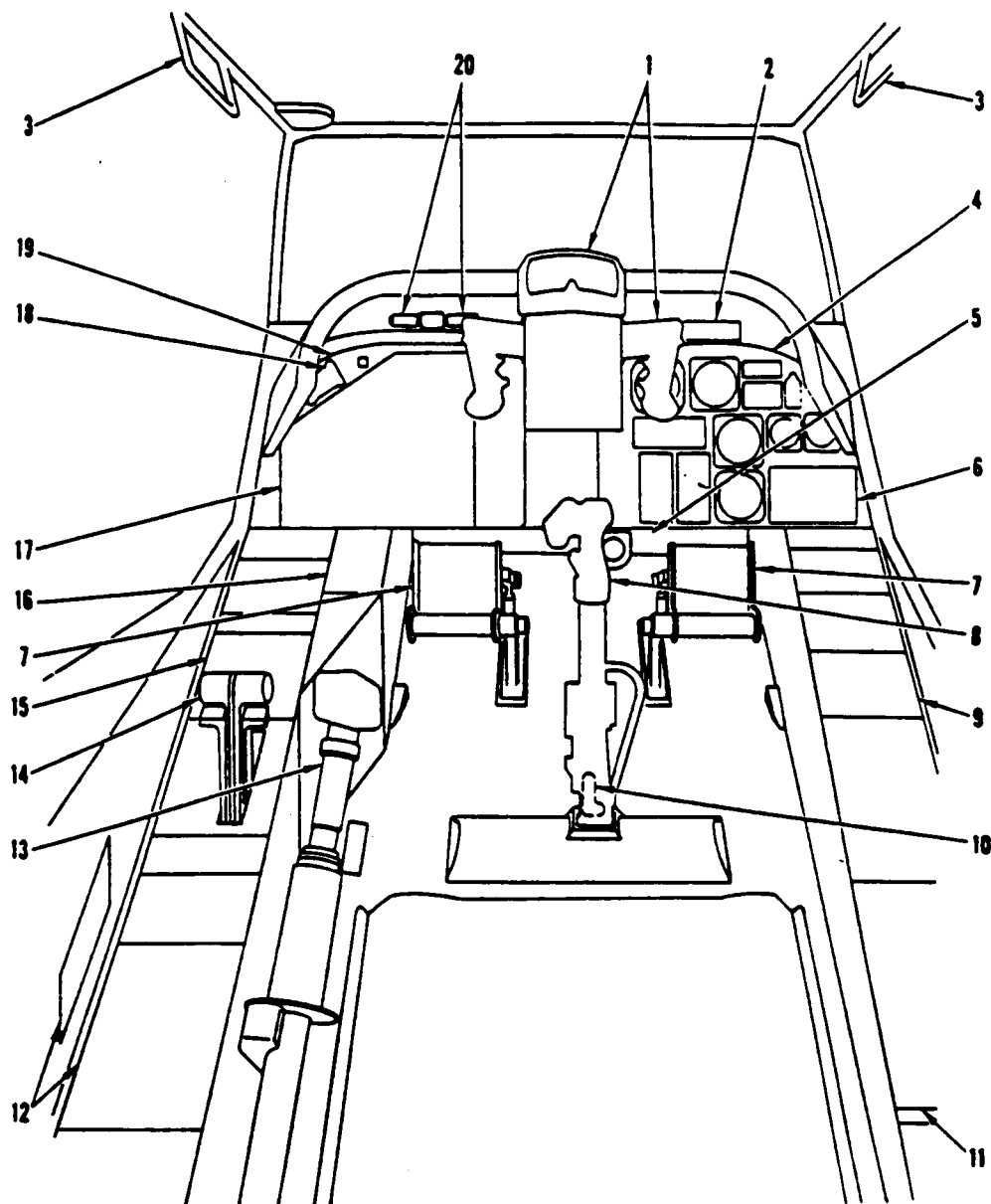
The Alpha Numeric Display (AND) provides information to the CPG for use in operating mission equipment. The AND is a Light Emitting Diode (LED) display located in the lower portion of the ORT HDD.

7.5 Video Display Unit

The Video Display Unit (VDU) is located on the pilots instrument panel. The VDU is designed to provide the pilot with the capability to view either pilot or CPG video independent of his IHADSS. The VDU also serves as a backup for night terrain flight in the event of IHADSS failure. The VDU is powered from the No. 2 essential dc bus.

7.6 Display Symbology

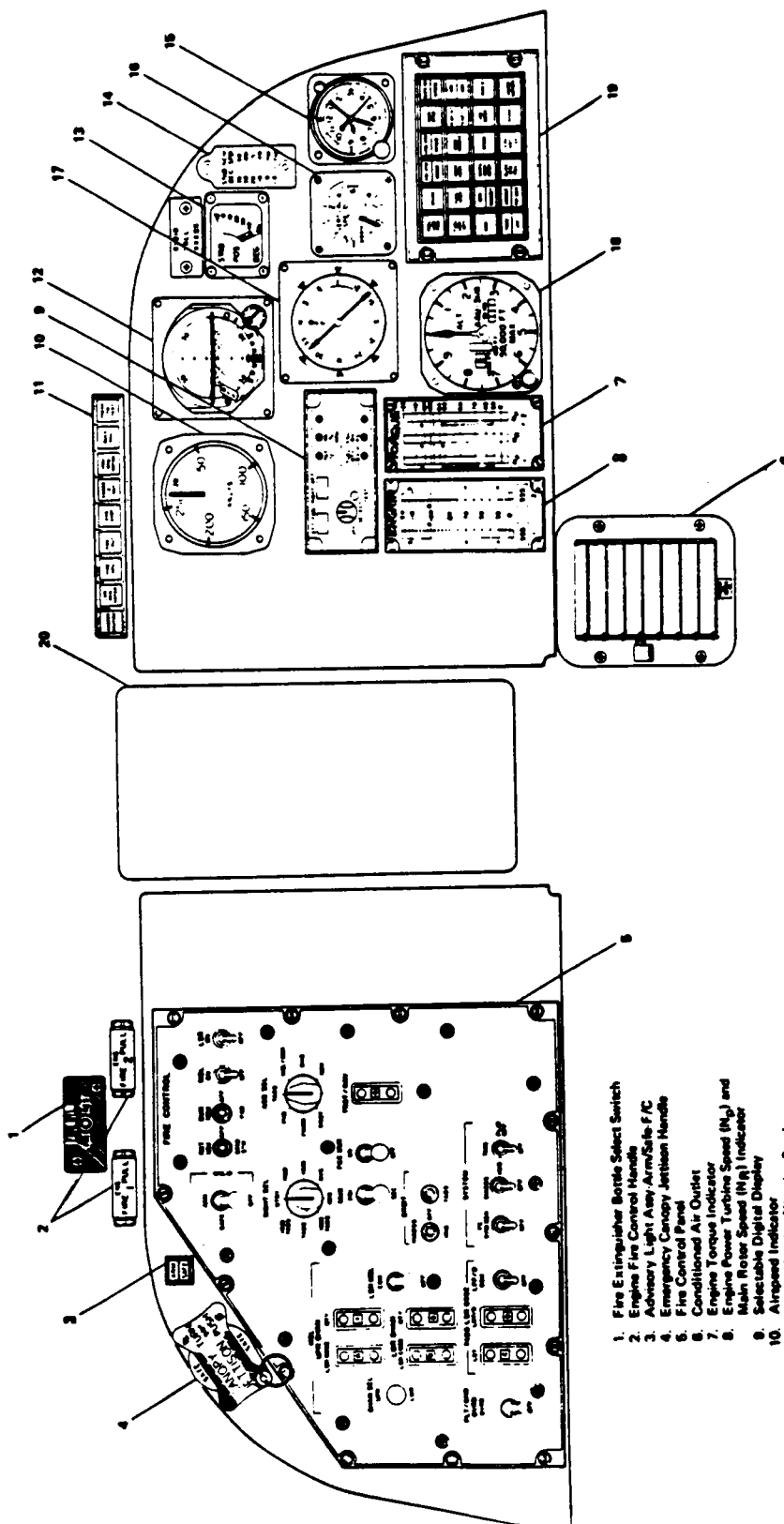
Symbology for the IHADSS and the ORT are generated by the symbol generator. The symbol generator also drives the AND in the HOD of the ORT. There are two basic types of symbology, flight and weapons. The flight symbology is broken up into four modes: cruise, transition, hover, and bob-up. Common flight symbology is depicted in enclosure 1, figure 12. Common weapons sight symbology is depicted in enclosure 1, figure 13.



- | | |
|---|------------------------------|
| 1. OPTICAL RELAY TUBE AND HANDGRIPS | 12. CIRCUIT BREAKER PANELS |
| 2. MASTER CAUTION AND WARNING PANEL | 13. COLLECTIVE STICK |
| 3. CANOPY FRAME HANDHOLDS | 14. POWER LEVERS |
| 4. RIGHT INSTRUMENT PANEL | 15. LEFT CONSOLE |
| 5. CONDITIONED AIR OUTLET | 16. DATA ENTRY KEYBOARD |
| 6. CAUTION / WARNING PANEL | 17. FIRE CONTROL PANEL |
| 7. DIRECTIONAL CONTROL AND BRAKE PEDALS | 18. CANOPY JETTISON HANDLE |
| 8. CYCLIC STICK | 19. LEFT INSTRUMENT PANEL |
| 9. RIGHT CONSOLE | 20. ENGINE FIRE PULL HANDLES |
| 10. PEDAL ADJUST LEVER | |
| 11. MAP STORAGE COMPARTMENT | |

Figure 1

COPILOT/GUNNER COCKPIT GENERAL ARRANGEMENT



1. Fire Extinguisher Bottle Select Switch
2. Engine Fire Control Handle
3. Advisory Light Arm/Arm/Safe F/C
4. Emergency Ejector Jet/Jettison Handle
5. Fire Control Panel
6. Conditioned Air Outlet
7. Engine Torque Indicator
8. Engine Power/Torque Speed (N₂) and Main Motor Speed (N₁) Indicator
9. Selectable Digital Display
10. Airspeed Indicator
11. Master Caution/Warning Panel
12. Altitude Indicator
13. Stabilizer Position Indicator
14. Stabilizer/Airspeed Placard
15. Clock
16. Rapid Response Vertical Speed Indicator (VS)
17. Radio Magnetic Indicator (RMI)
18. Pressure Altimeter
19. Caution Panel
20. Optical Relay Tube

Figure 2
COPILLOT/GUNNER INSTRUMENT PANEL

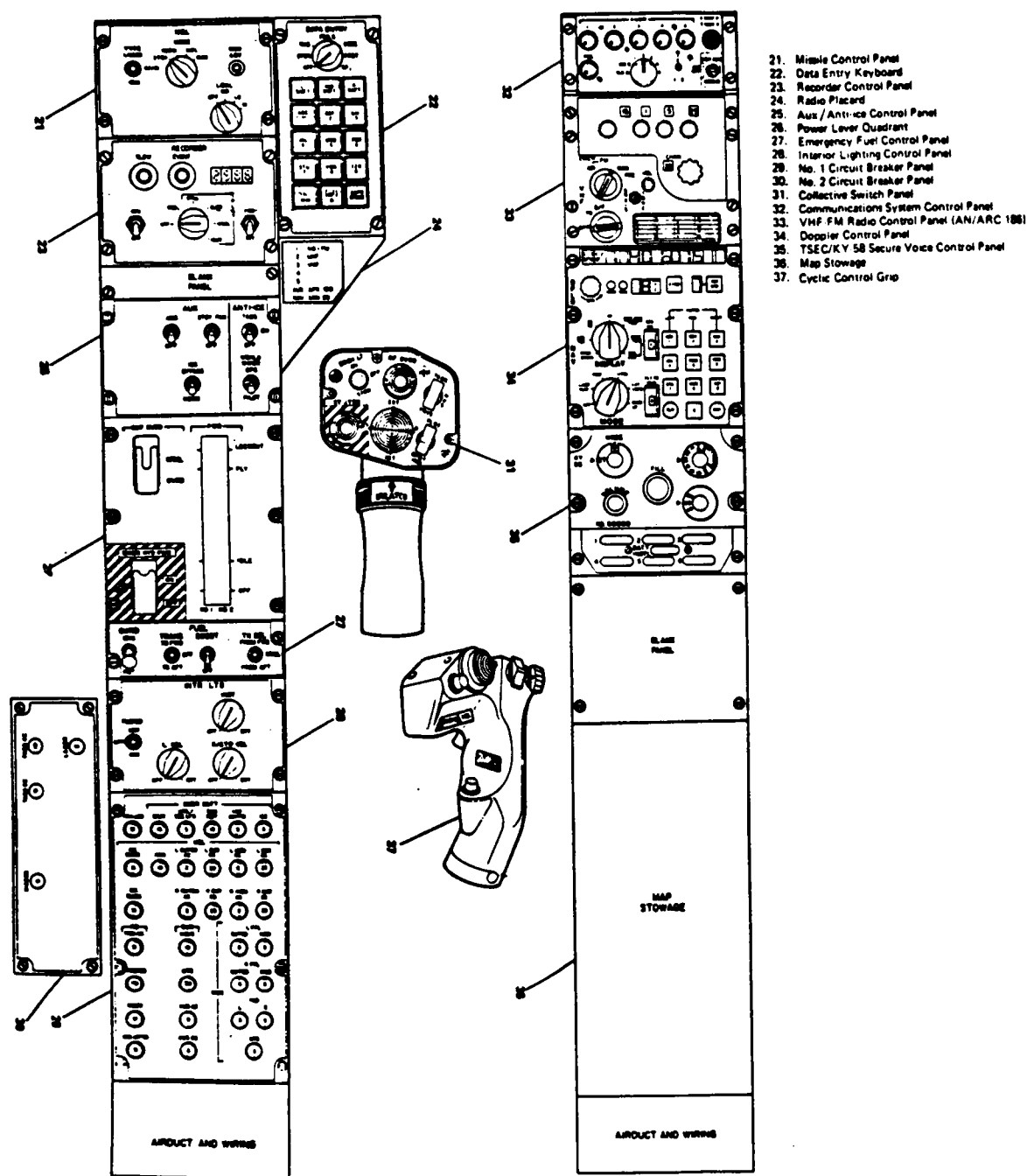


Figure 3
 COPILOT/GUNNER CONSOLES

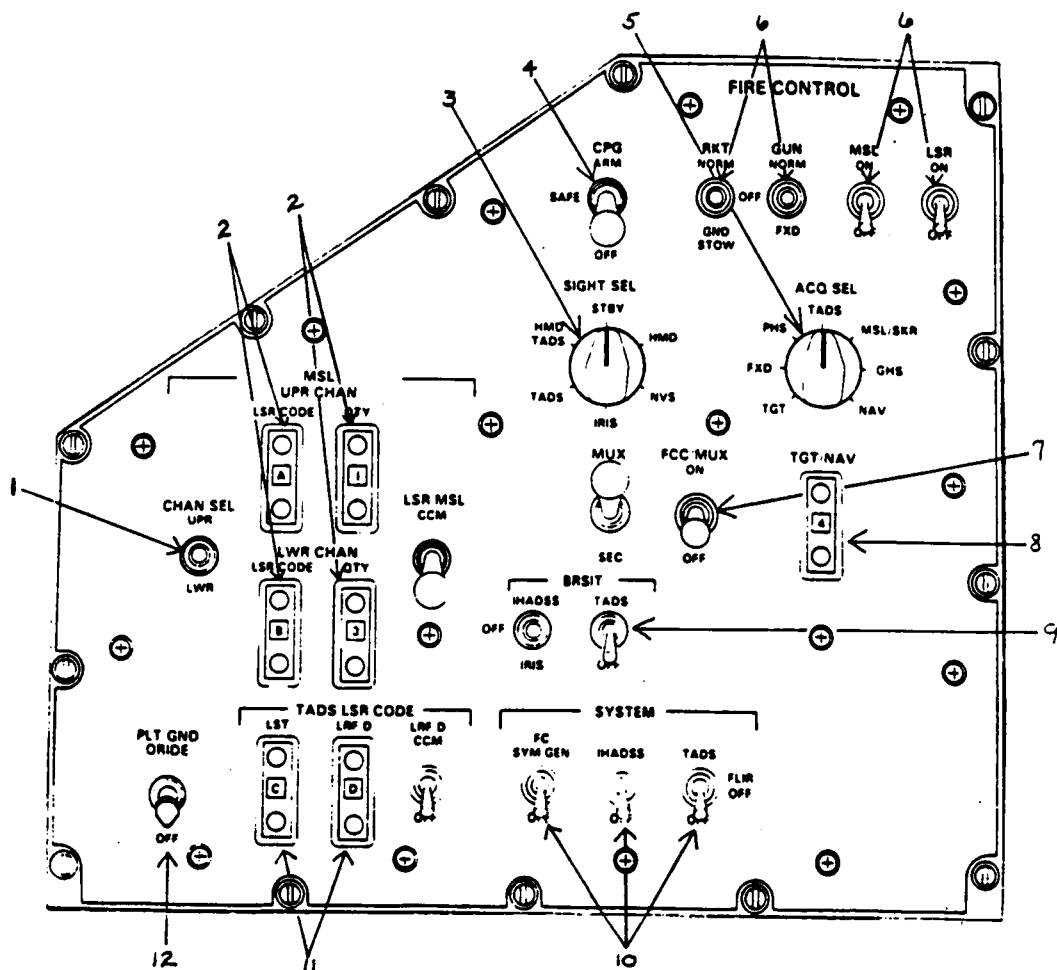


Figure 4

COPILLOT/GUNNER FIRE CONTROL PANEL

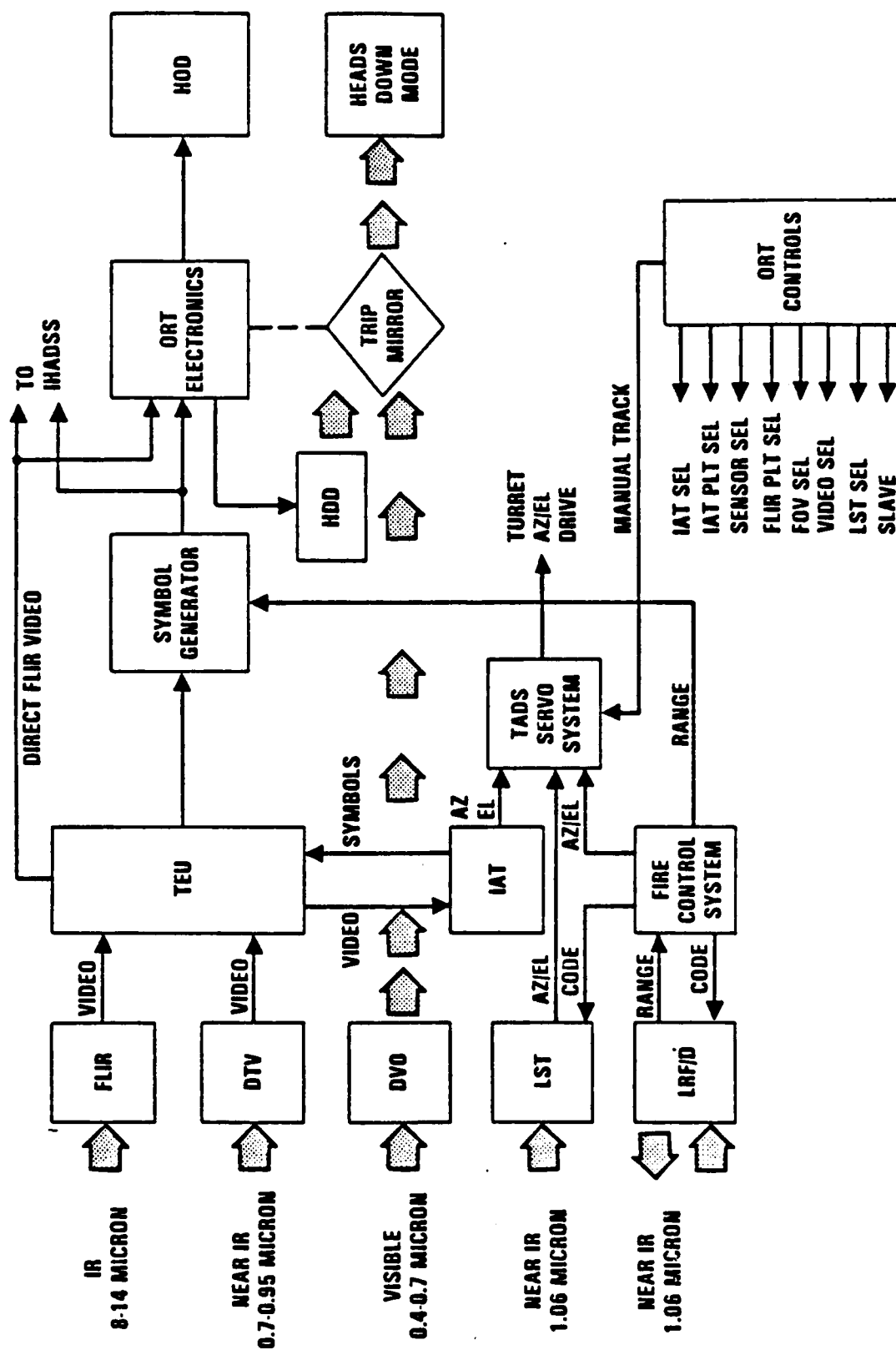


Figure 5

TARGET ACQUISITION DESIGNATION SIGHT (TADS) FUNCTIONAL DIAGRAM

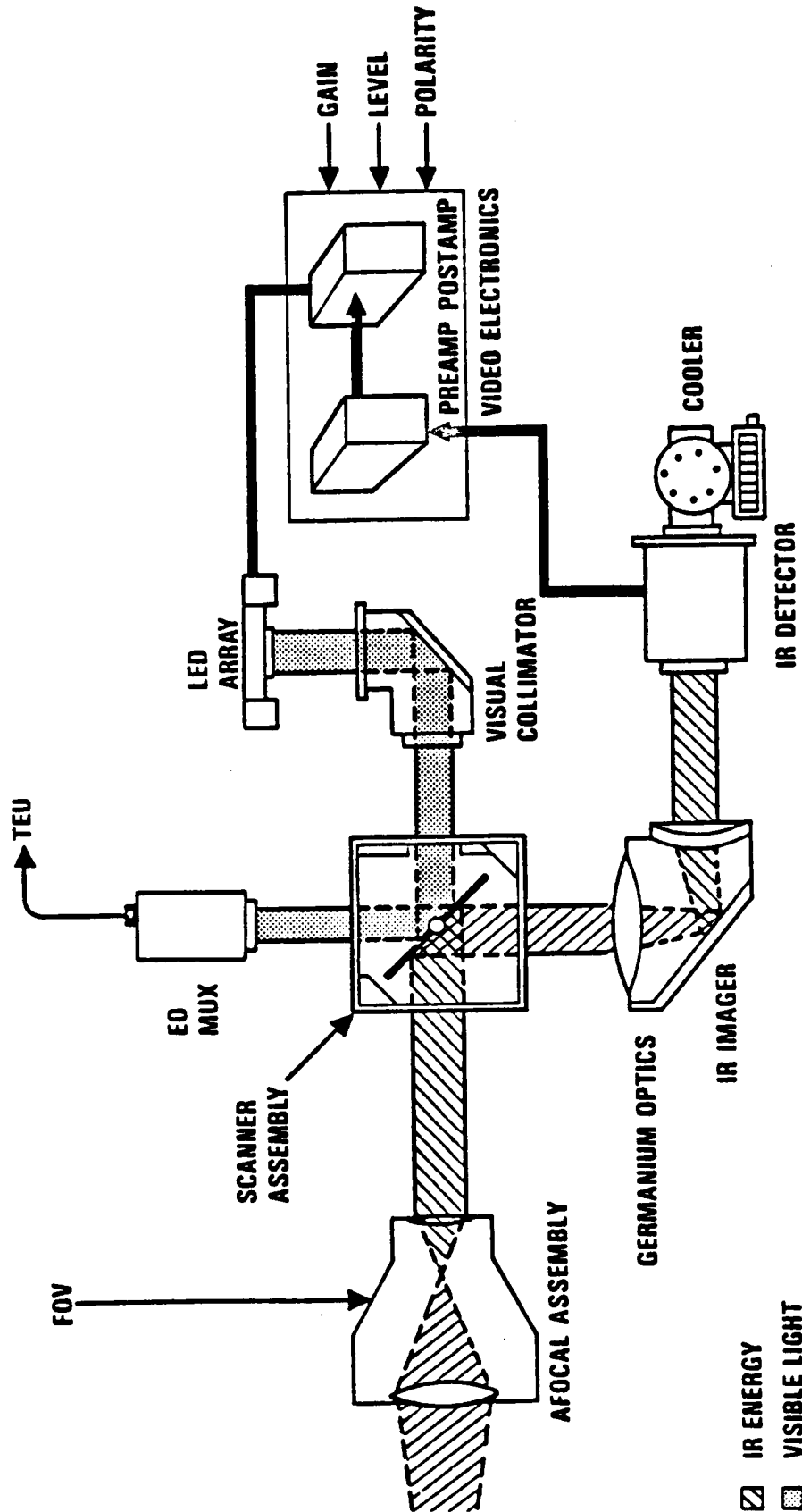


Figure 6
TARGET ACQUISITION DESIGNATION SIGHT FLIR OPERATION

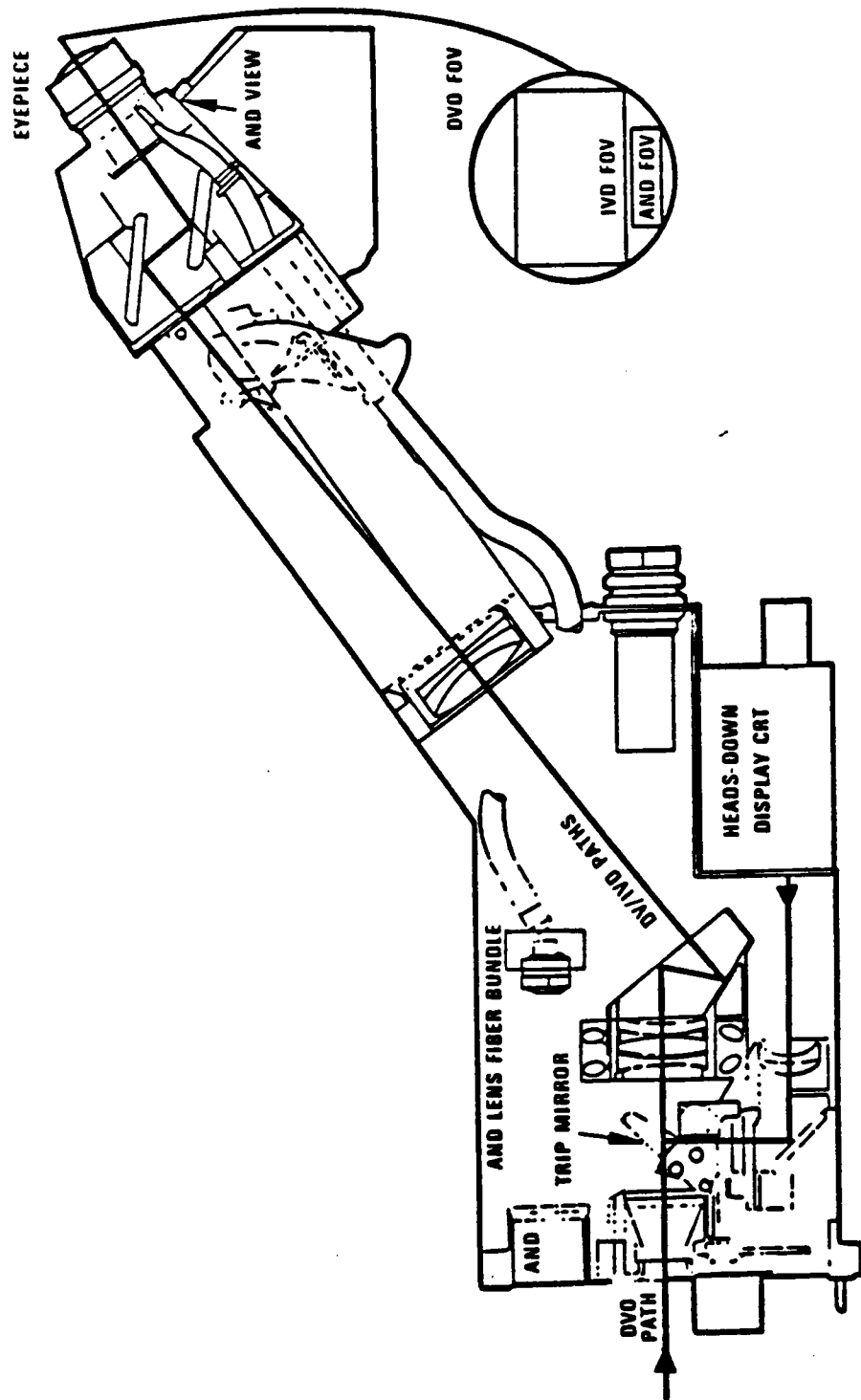


Figure 7
DIRECT VIEW OPTICS

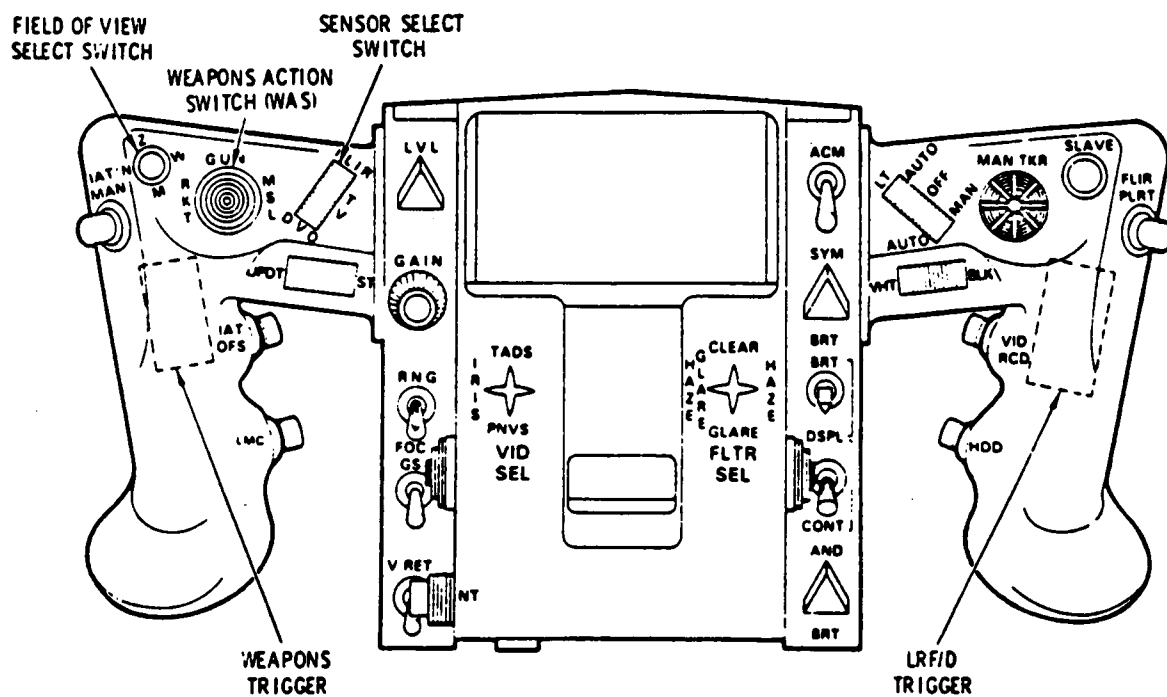


Figure 8

OPTICAL RELAY TUBE CONTROLS AND DISPLAYS

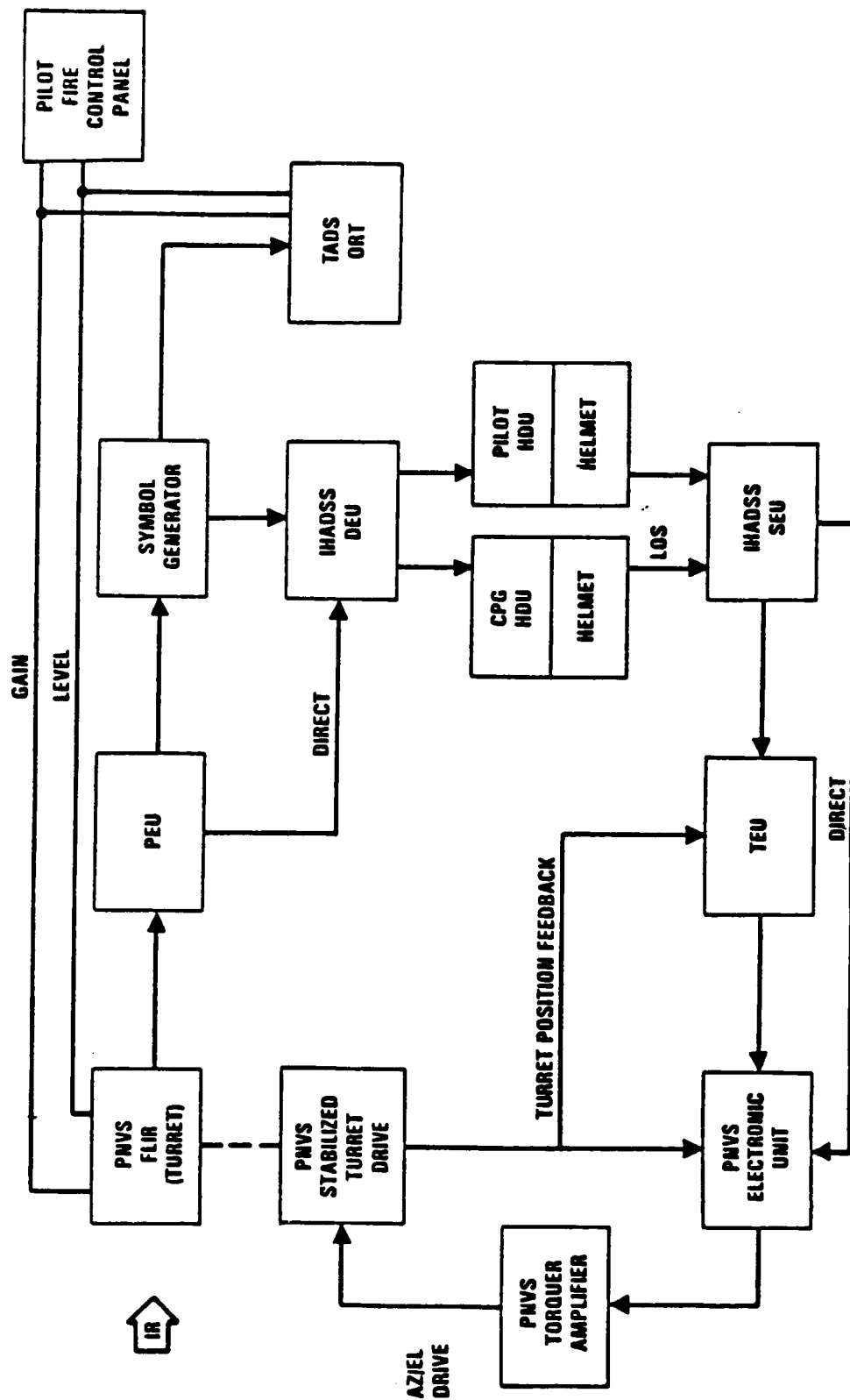


Figure 9
PILOT NIGHT VISION SENSOR

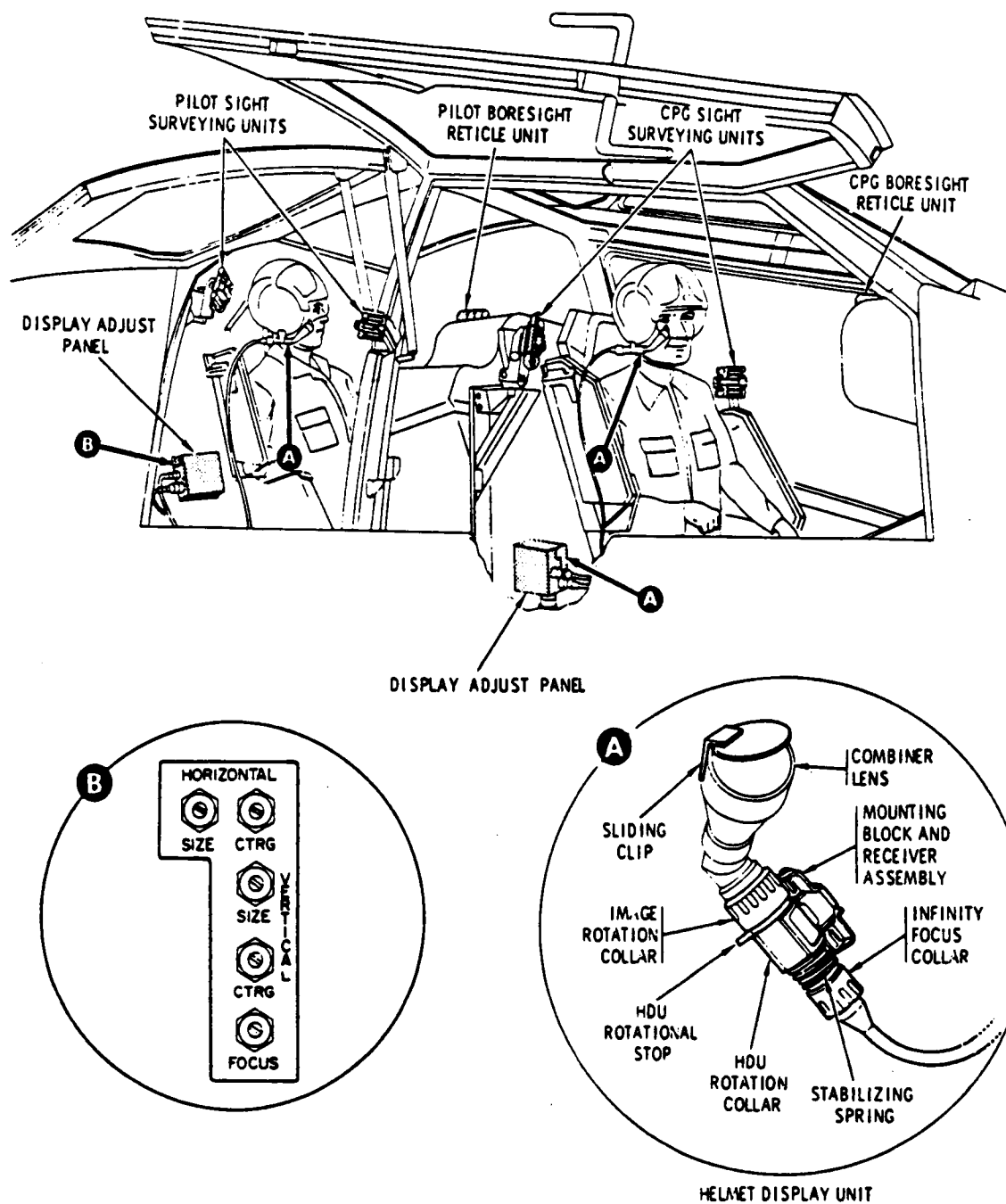


Figure 10

INTEGRATED HELMET AND DISPLAY SIGHT SYSTEM

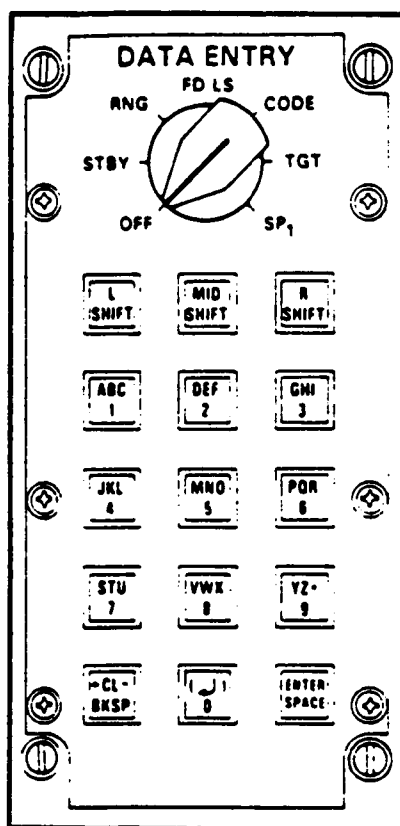


Figure 11

DATA ENTRY KEYBOARD

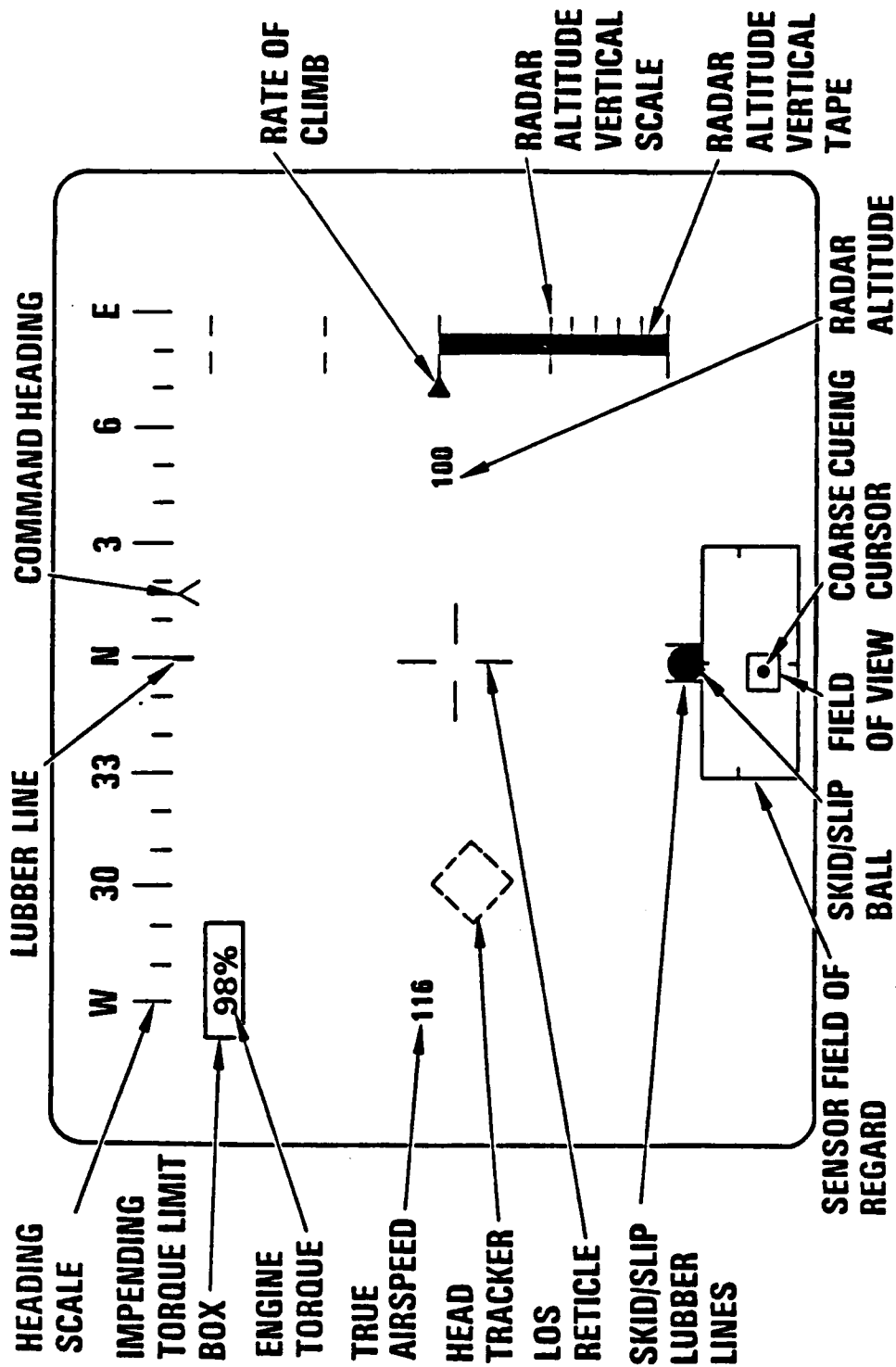


Figure 12

FLIGHT SYMBOLOGY

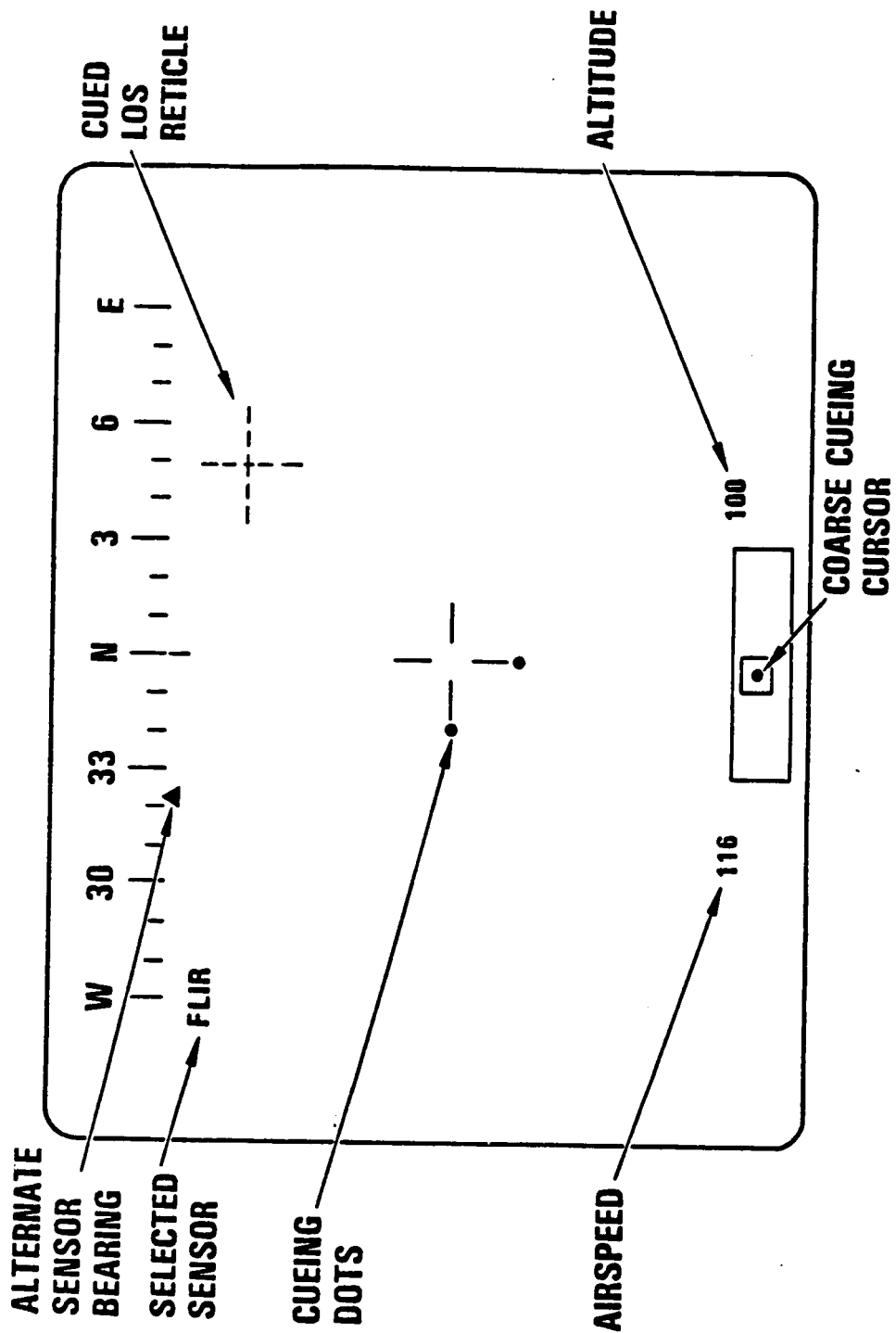


Figure 13

WEAPON SYMBOLOGY

Table I
GROUND TESTS AND TEST CONDITIONS

TEST	COMPONENT	REMARKS
Functional Reach	Controls listed in appendix C, enclosure 1, figures 2 & 3	Classified in zones 1, 2, & 3 as defined by reference 4. Full equipment worn.
External Field of View	Front Cockpit	From Design Eye Position
Internal Field of View	Components in appendix C, enclosure 1, figures 2 & 3	-
Egress Emergency & Normal	Front Cockpit	Engines off, rotors still, in full equipment.
Preflight	Doppler, TADS, PNVs, IHADSS	-
BIT	Doppler, TADS, PNVs	IHADSS omitted due to equipment availability.
Controls	ORT, Fire Control panel, missile control panel, Doppler	-
Displays	ORT, IHADSS	-
Slew Limits	TADS	-
Slew rates	TADS FLIR, DVO, & Day DTV	All FOV's.
Field of View	TADS FLIR, DVO & Day TV + PNVs	All FOV's. Azimuth only.

Table II
FLIGHT TESTS AND TEST CONDITIONS

TEST	FLT #	A/S (KIAS)	ALT (AGL)	REMARKS
<u>DOPPLER NAVIGATION</u>				
Accuracy	1	0-150	0-5K	Included hover, rearward, & sideward flight.
Drift in hover	1	0	20	-
Attitude Limits	1	80	500	Indeterminate because memory light did not come on.
Altitude Limits	1	80	500	Indeterminate because memory light did not come on.
<u>TARGET ACQUISITION AND DESIGNATION SYSTEM (TADS)</u>				
<u>FORWARD LOOKING INFRARED</u>				
Max detection/ Max ID	1,2	40-60	200- 300	Doppler provided range. data.
Stabilization	1	80 0 (yaw)	500	+/- 60 deg bank +/- 30 deg pitch +/- 120 yaw
Spacial resolution	1,2	0-100	20- 300	Qualitative on targets of opportunity
Temperature resolution	1,2	0-100	20- 300	Qualitative on targets of opportunity
Image Auto Tracker	1,2	0-100	20- 300	Targets of opportunity

Table II (Continued)

FLIGHT TESTS AND TEST CONDITIONS

TEST	FLT #	A/S (KIAS)	ALT (AGL)	REMARKS
<u>DAY TELEVISION</u>				
Max detection/ Max ID	1,2	40-60	200- 300	Doppler Provided range data.
Stabilization	1	80 0 (yaw)	500	+/- 60 deg bank +/- 30 deg pitch +/- 120 yaw
Spacial resolution	1,2	0-100	20- 300	Qualitative on targets of opportunity
Image Auto Tracker	1,2	0-100	20- 300	Targets of opportunity
<u>DIRECT VIEW OPTICS (DVO)</u>				
Max detection/ Max ID	1,2	40-60	200- 300	Doppler Provided range data.
Stabilization	1	80 0 (yaw)	500	+/- 60 deg bank +/- 30 deg pitch +/- 120 yaw
Spacial resolution	1,2	0-100	20- 300	Qualitative on targets of opportunity
<u>PILOT NIGHT VISION SENSOR</u>				
Slew Limits	3	0	20	Used aircraft heading changes to determine limits.
Slew Rates	3	0	20	Qualitative
Stabilization	1	80 0 (yaw)	500	+/- 60 deg bank +/- 30 deg pitch +/- 120 yaw

Table II (Continued)

FLIGHT TESTS AND TEST CONDITIONS

TEST	FLT #	A/S (KIAS)	ALT (AGL)	REMARKS
<u>RADAR SIGNAL DETECTOR</u>				
Direction of Arrival	1	0	50	Targets of Opportunity
Threat ID	1	0	50	Targets of Opportunity
<u>INTEGRATED HELMET AND DISPLAY SIGHT SYSTEM (IHADSS)</u>				
Qualitative Evaluation	3	0-50	0-40	Disorienting effects, image quality, boresight, integration.
<u>WEAPON SYSTEM INTEGRATION</u>				
Weapon system integration	1,2	0-40	20- 200	Acquired target with all three TADS sensors and performed simulated attacks with Hellfire, rockets, and 30 mm gun

Table III
METEOROLOGICAL CONDITIONS FLIGHT 1

ITEM	CONDITION
Date	12 November 1986
Duration	2.2 hours
Lighting	1.2 daylight, .5 dusk, .5 night
Location	Cairns operating area
Start temperature	73 deg F
End Temperature	68 deg F
Start relative humidity	75%
End relative humidity	79%
Visibility	7 nmi
Cloud Layers	1600 ft scattered 6000 ft scattered Estimated 10,000 ft broken
Precipitation	None
Turbulence	Light

Table IV
METEOROLOGICAL CONDITIONS FLIGHT 2

ITEM	CONDITION
Date	13 November 1986
Duration	1.8 hours
Lighting	Daylight
Location	Cairns operating area
Start temperature	55 deg F
End Temperature	55 deg F
Start relative humidity	42%
End relative humidity	42%
Visibility	7 nmi
Cloud Layers	3000 ft broken 10,000 ft broken
Precipitation	None
Turbulence	Moderate

Table V

METEOROLOGICAL CONDITIONS FLIGHT 3

ITEM	CONDITION
Date	13 November 1986
Duration	0.4 hours
Lighting	Daylight
Location	Cairns airfield
Start temperature	52 deg F
End Temperature	52 deg F
Start relative humidity	45%
End relative humidity	45%
Visibility	7 nmi
Cloud Layers	3000 ft broken 10,000 ft broken
Precipitation	None
Turbulence	Moderate

Table VI

GROUND TESTS EXCEPTIONS/ADDITIONS TO VAX

TEST	COMPONENT	VAX PARAGRAPH	EXCEPTIONS ADDITIONS
Functional Reach	Controls listed in appendix C, enclosure 1, Figures 2 & 3	N/A	-
External Field of View	Front Cockpit	N/A	-
Internal Field of View	Component in appendix C, enclosure 1, figures 2 & 3	N/A	-
Egress Emergency & Normal	Front Cockpit	N/A	-
Preflight	Doppler, TADS, PNVs, IHADSS,	194,95	none
BIT	Doppler, TADS, PNVs	195,96,73	Fault insertion techniques not utilized Mission Systems Test Lab not used.
Controls	ORT, Fire Control panel, missile control panel, Doppler	196,97	One evaluator used
Displays	ORT, IHADSS, Doppler	197,98	none.

Table VI (Continued)

GROUND TESTS EXCEPTIONS/ADDITIONS TO VAX

TEST	COMPONENT	VAX PARAGRAPH	EXCEPTIONS ADDITIONS
Slew Limits	TADS	103	Elevation limit measured by measuring movement of TADS hardware Azimuth limit in accordance with VAX.
Slew rates	TADS FLIR, DVO, & Day DTV	102	none.
Field of View	TADS FLIR, DVO & Day TV + PNVS	104	none.

Table VII

FLIGHT TESTS EXCEPTIONS/ADDITIONS TO VAX

TEST	VAX PARAGRAPH	EXCEPTIONS/ADDITIONS
<u>DOPPLER NAVIGATION</u>		
Accuracy	200	90% confidence level not achieved
Drift in hover	N/A	-
Attitude Limits	203	500 ft AGL only altitude tested.
Altitude Limits	204	5000 ft highest altitude tested.

TARGET ACQUISITION AND DESIGNATION SYSTEM (TADS)FORWARD LOOKING INFRARED

Max detection/ Max ID	113,114	Targets of opportunity. used. Truth data from Doppler. 90% confidence level not achieved.
Stabilization	116	none.
Spacial resolution	110	VAX not used. Totally qualitative.
Temperature resolution	111	VAX not used. Totally qualitative
Image Auto Tracker	N/A	-

Table VII (Continued)

FLIGHT TESTS EXCEPTIONS/ADDITIONS TO VAX

TEST	VAX PARAGRAPH	EXCEPTIONS/ADDITIONS
<u>DAY TELEVISION</u>		
Max detection/ Max ID	113,114	Targets of opportunity used. Truth data from Doppler. 90% confidence level not achieved.
Stabilization	116	none.
Spacial resolution	110	VAX not used. Totally qualitative.
Image Auto Tracker	N/A	-
<u>DIRECT VIEW OPTICS (DVO)</u>		
Max detection/ Max ID	113,114	Targets of opportunity used. Truth data from Doppler. 90% confidence level not achieved.
Stabilization	116	none.
Spacial resolution	110	VAX not used. Totally qualitative.
<u>PILOT NIGHT VISION SENSOR</u>		
Slew Limits	103	Measured in flight by noting max heading change until limit.
Slew Rates	102	VAX not used. Qualitative using IHADSS
Stabilization	116	none.

Table VII (Continued)

FLIGHT TESTS EXCEPTIONS/ADDITIONS TO VAX

TEST	VAX PARAGRAPH	EXCEPTIONS/ADDITIONS
<u>RADAR SIGNAL DETECTOR</u>		
Direction of Arrival	82	Correlation with Cairns traffic radar used.
Threat ID	85	Correlation with Cairns traffic radar used.
<u>INTEGRATED HELMET AND DISPLAY SIGHT SYSTEM (IHADSS)</u>		
Qualitative Evaluation	N/A	-
<u>WEAPON SYSTEM INTEGRATION</u>		
Weapon system integration	N/A	-

Table VIII
FLIR BASELINE SETTINGS

MODE	SETTING
Field of View	MEDIUM
Level	A/R
Gain	A/R
Automatic Contrast (ACM)	OFF
Night Filter	OFF
Polarity	WHITE

Table IX
DAY TV BASELINE SETTINGS

MODE	SETTING
Field of View	WIDE
Level	A/R
Gain	A/R
Automatic Contrast (ACM)	OFF
Night Filter	OFF

Table X

DIRECT VIEW OPTICS BASELINE SETTINGS

MODE	SETTING
Field of View	WIDE
Filter	CLEAR

Table XI
EVALUATOR'S ANTHROPOMETRIC DATA

MEASUREMENT	VALUE	PERCENTILE (1)
Weight	175 lb	40
Standing Height	70.4 in	45
Sitting Height	35.3 in	25
Sitting Eye Height	29.5 in	10
Functional Reach	29.0 in	10
Buttock-Knee Length	24.0 in	50
Buttock-Leg Length	41.8 in	45

note: (1) Percentages based on reference 4.

Table XII
VIBRATION RATING SCALE

Rating	Term used for degree	Description
0	No Vibration	-
1 2 3	Slight	Not apparent to experienced aircrew full occupied by their tasks, but noticeable if their attention is directed to it or if otherwise not occupied.
4 5 6	Moderate	Experienced aircrew are aware of the vibration, but it does not affect their work, at least over a short period.
7 8 9	Severe	Vibration is immediately apparent to experienced aircrew, even when fully occupied. Performance of primary task is affected or tasks can only be done with difficulty.
10	Intolerable	Sole occupation of aircrew is to reduce vibration level.

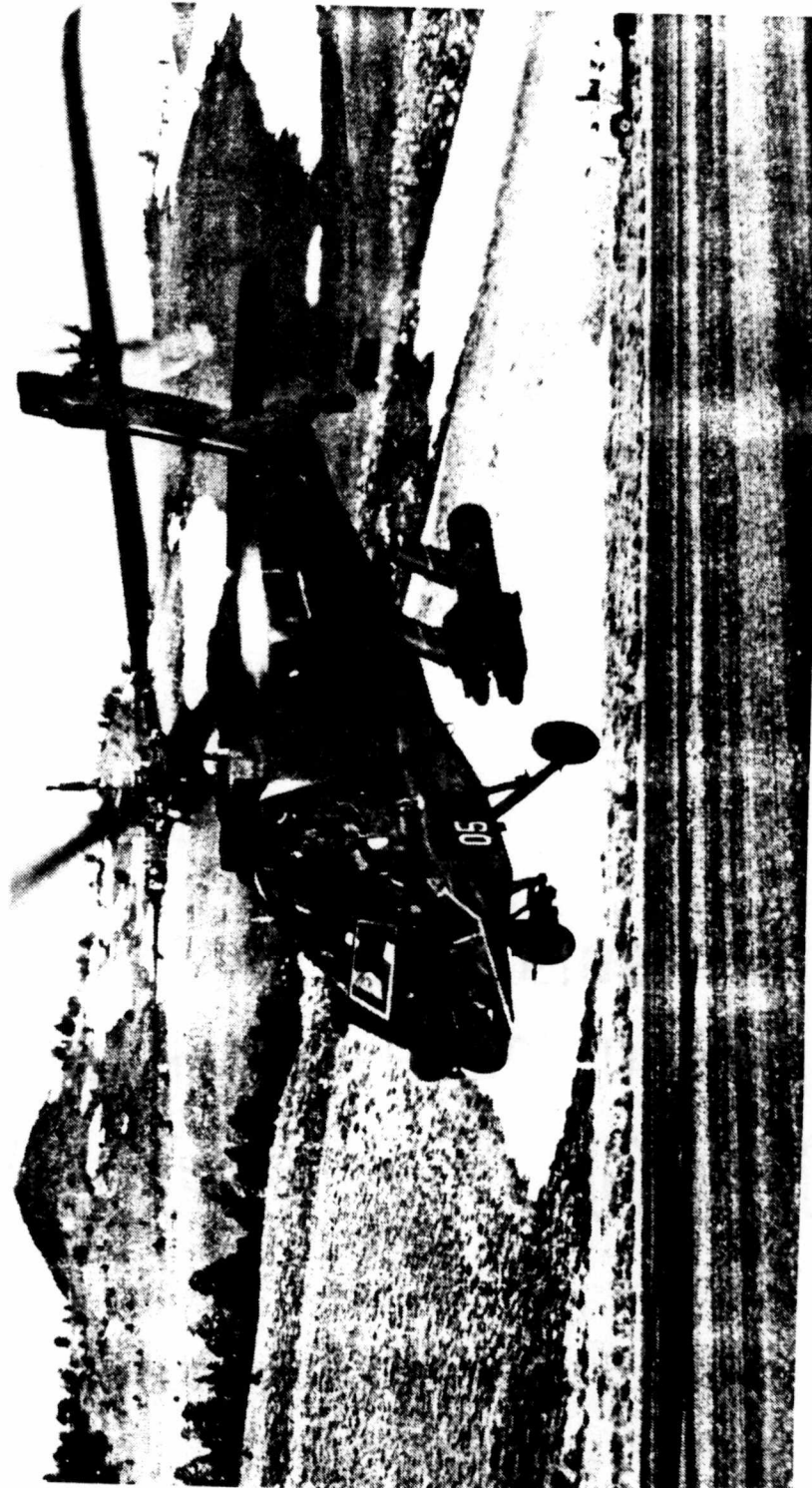


Figure 1
AH-64A HELICOPTER

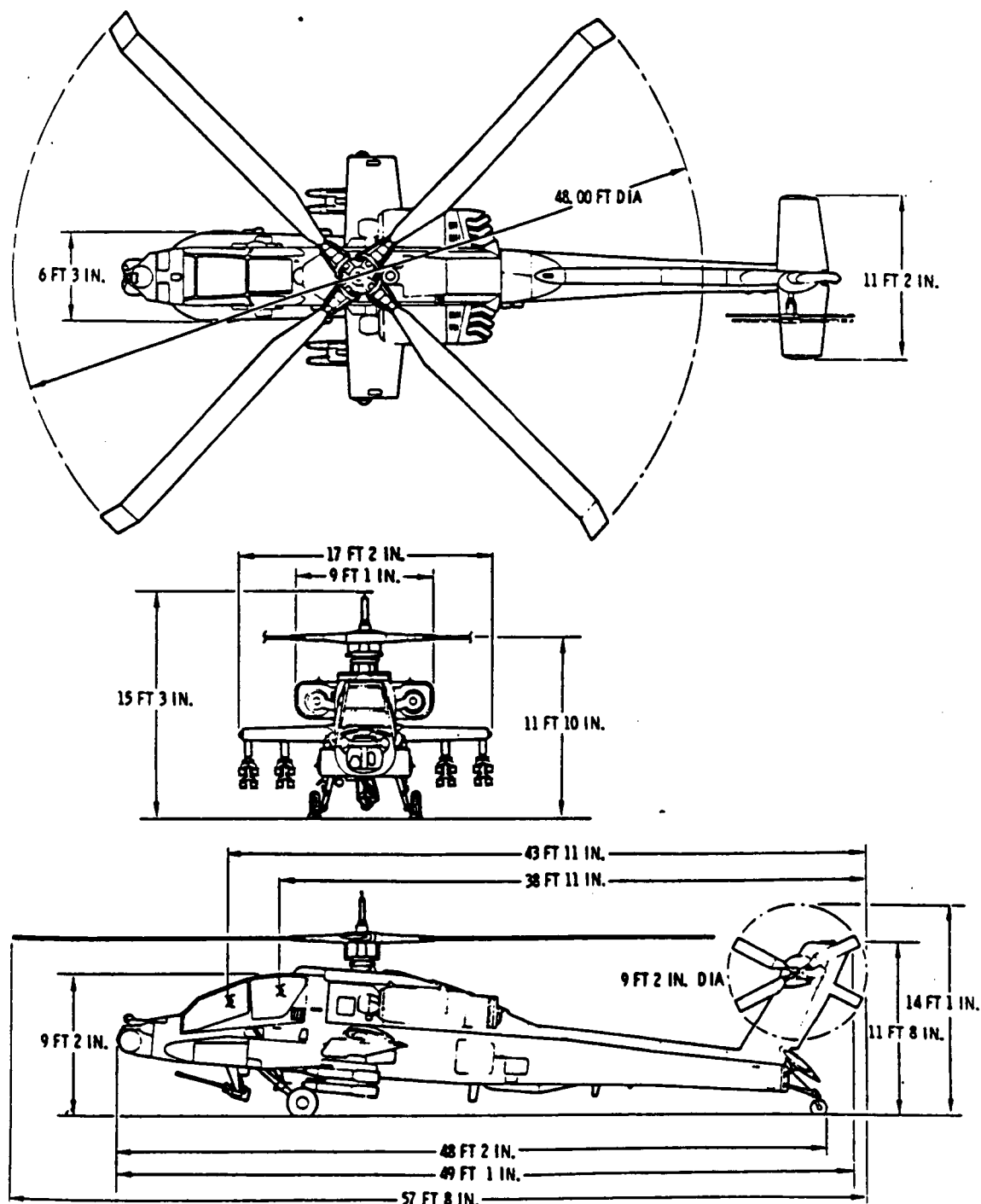


Figure 2

AH-64A PRINCIPAL DIMENSIONS

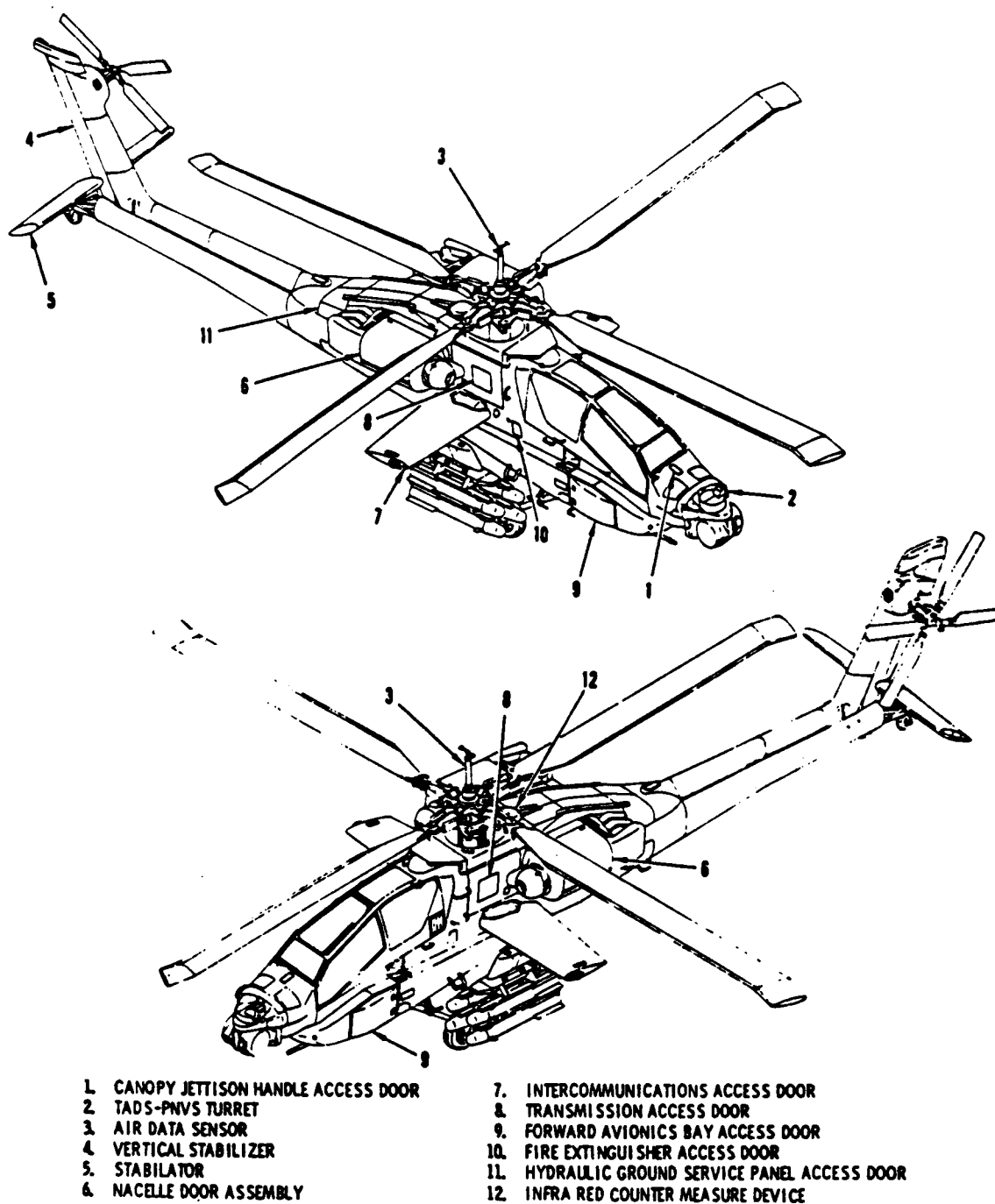


Figure 3

AH-64A EXTERNAL ARRANGEMENT

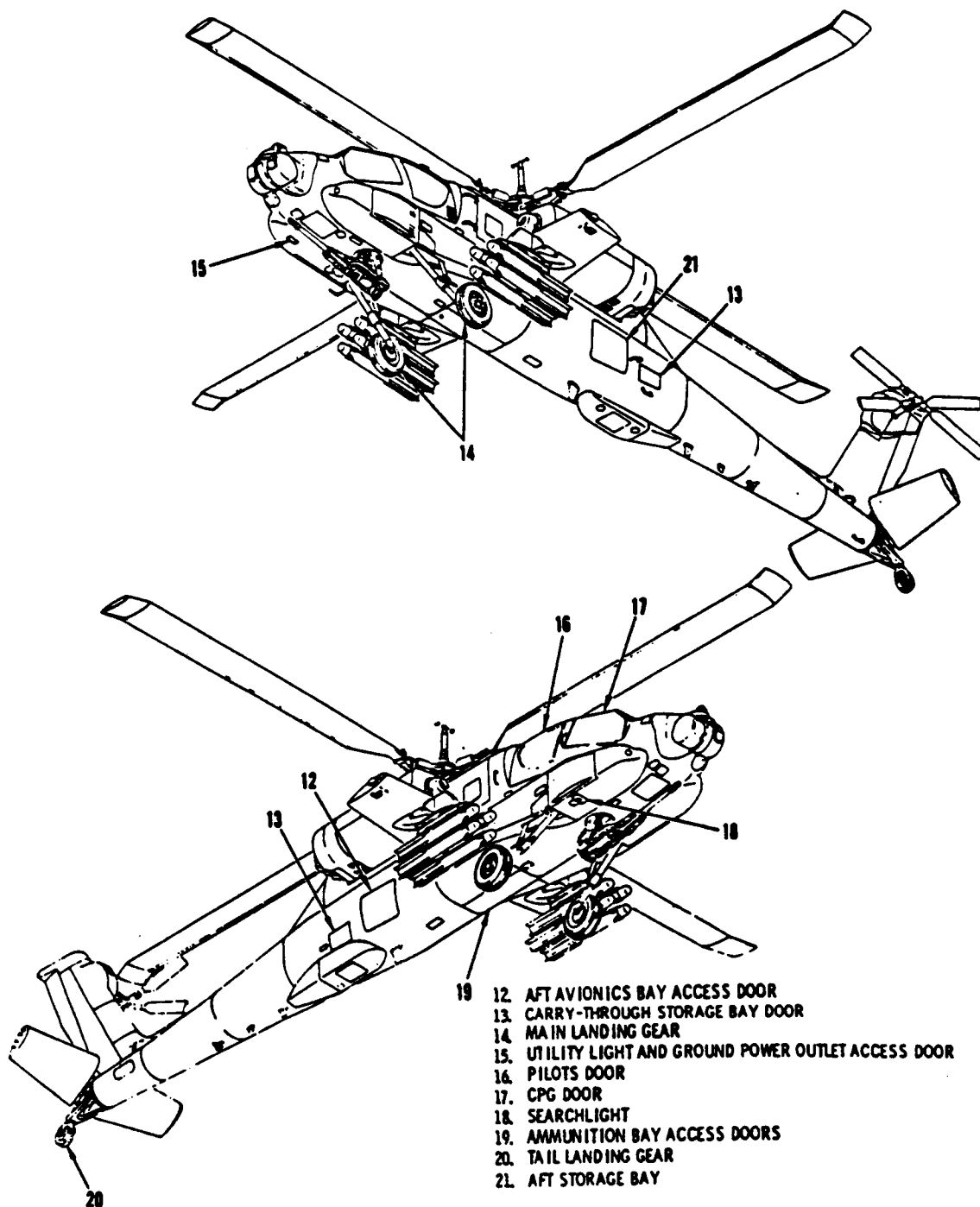


Figure 3 (Continued)

AH-64A EXTERNAL ARRANGEMENT

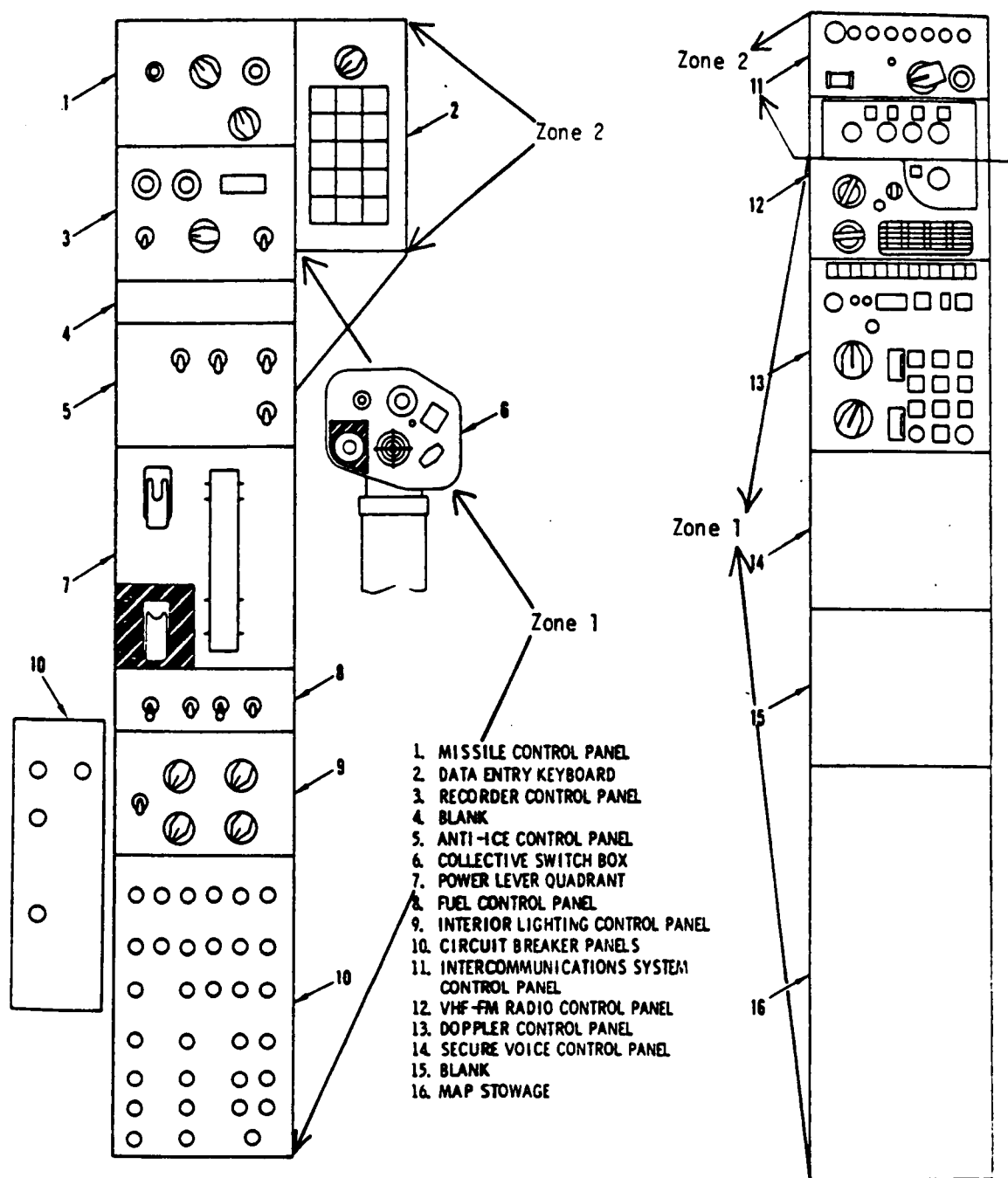
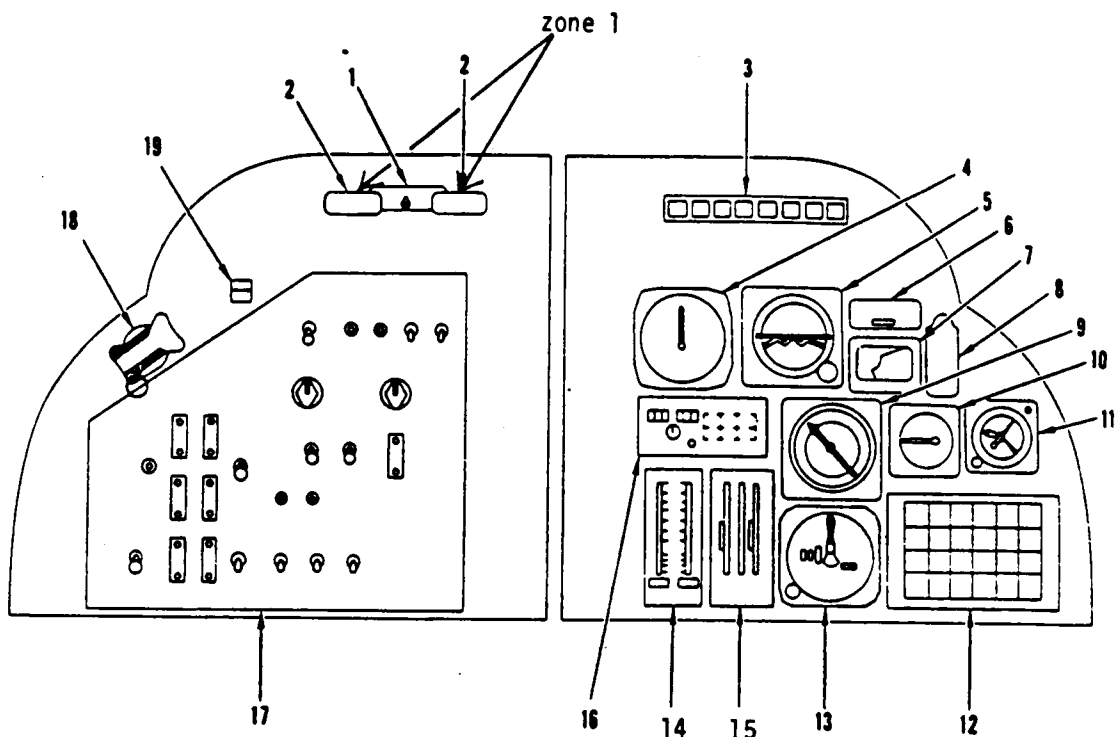


Figure 4

COPILOT/GUNNER CONSOLES FUNCTIONAL REACH



1. FIRE EXTINGUISHER BOTTLE SELECT SWITCH
2. ENGINE FIRE PULL HANDLES
3. MASTER CAUTION, WARNING PANEL
4. AIRSPEED INDICATOR
5. REMOTE ATTITUDE INDICATOR
6. RADIO CALL PLACARD
7. STABILATOR POSITION INDICATOR
8. STABILATOR/AIRSPEED PLACARD
9. RADIO MAGNETIC INDICATOR (RMI)
10. INSTANTANEOUS VERTICAL SPEED INDICATOR (IVSI)
11. CLOCK
12. CAUTION/WARNING PANEL
13. BAROMETRIC ALTIMETER
14. ENGINE (N_p), ROTOR (N_r) INDICATOR
15. ENGINE TORQUE INDICATOR
16. SELECTABLE DIGITAL DISPLAY PANEL
17. FIRE CONTROL PANEL
18. CANOPY JETTISON HANDLE
19. ARM SAFE INDICATOR

Note: all other controls on instrument panel were Zone 2 except optical relay tube, which was Zone 1

Figure 5

COPILOT/GUNNER INSTRUMENT PANEL

RECTILINEAR GRAPH

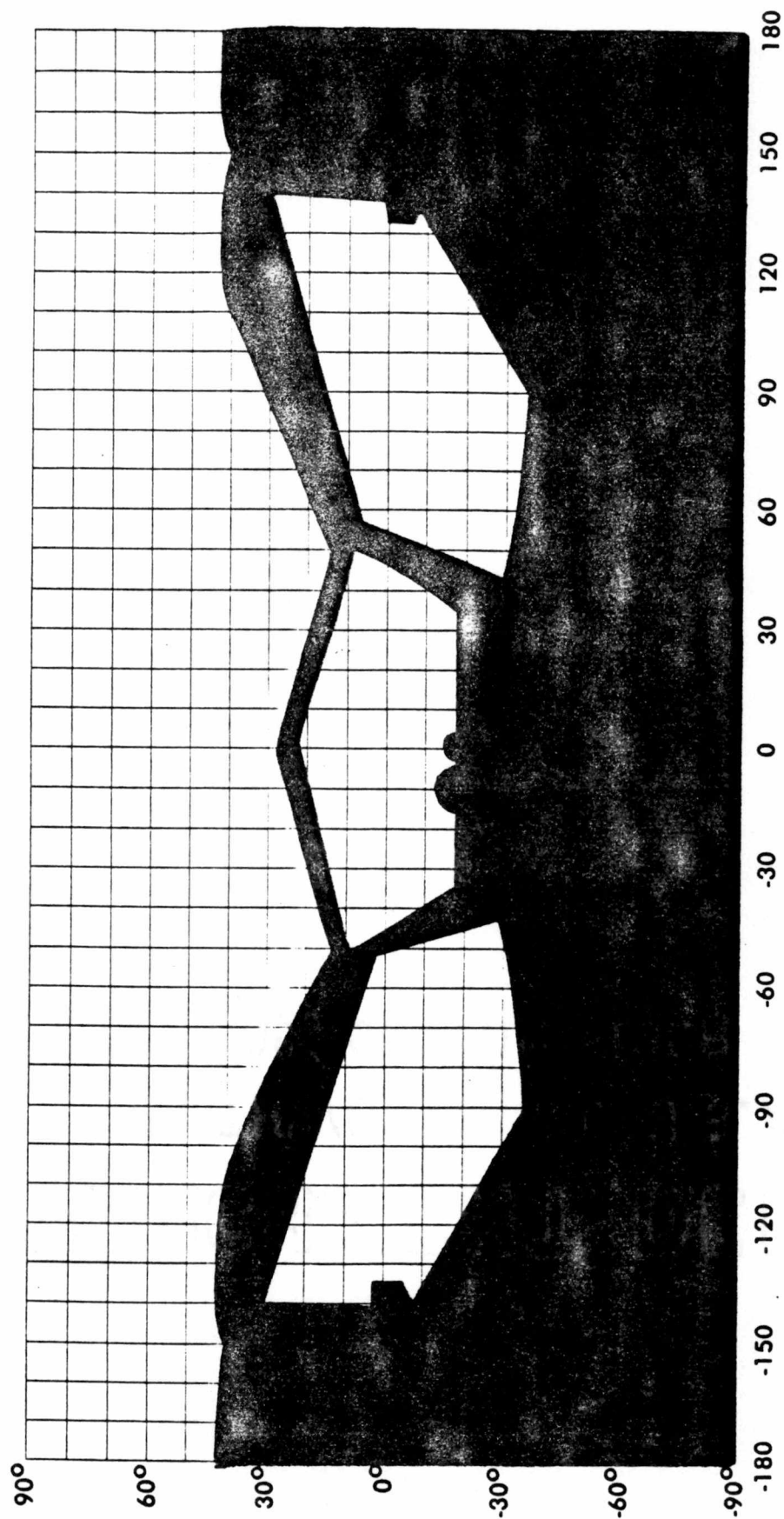
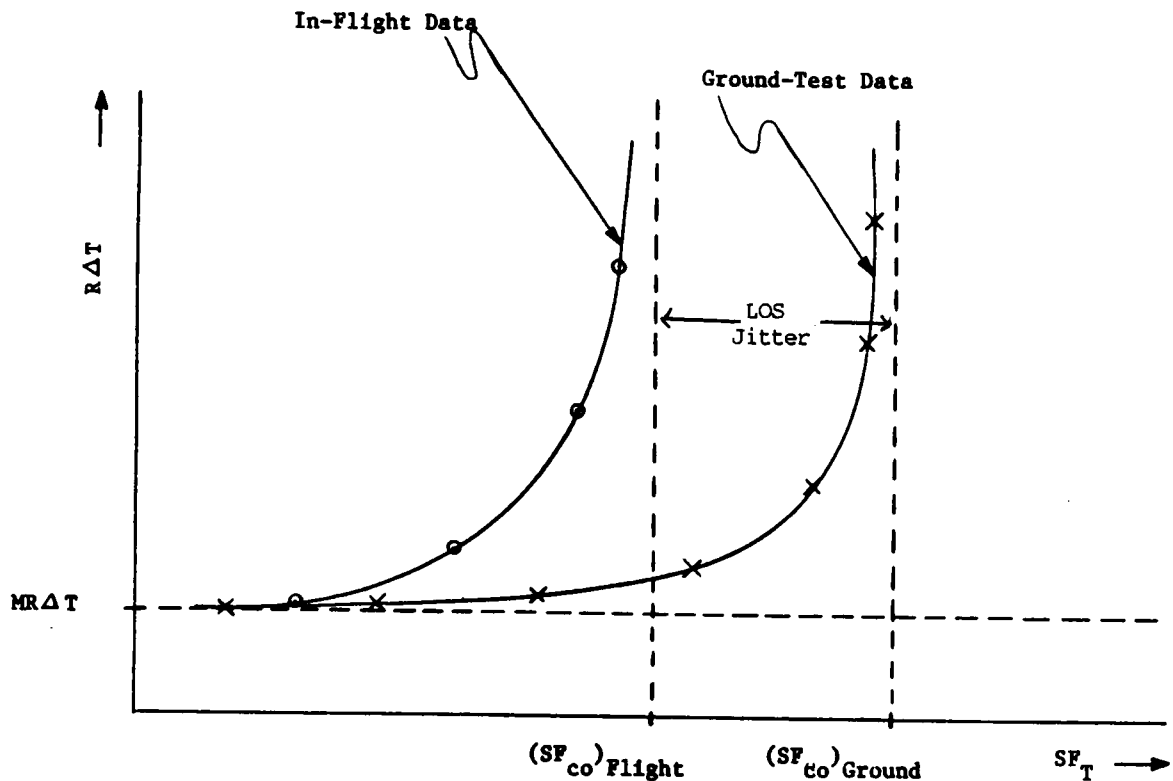


Figure 6

AH-64A EXTERNAL FIELD OF VIEW



$(SF_{co})_{Flight}$ = Cut off spacial frequency of sensor with LOS jitter

$(SF_{co})_{Ground}$ = Cut off spacial frequency of sensor without LOS jitter

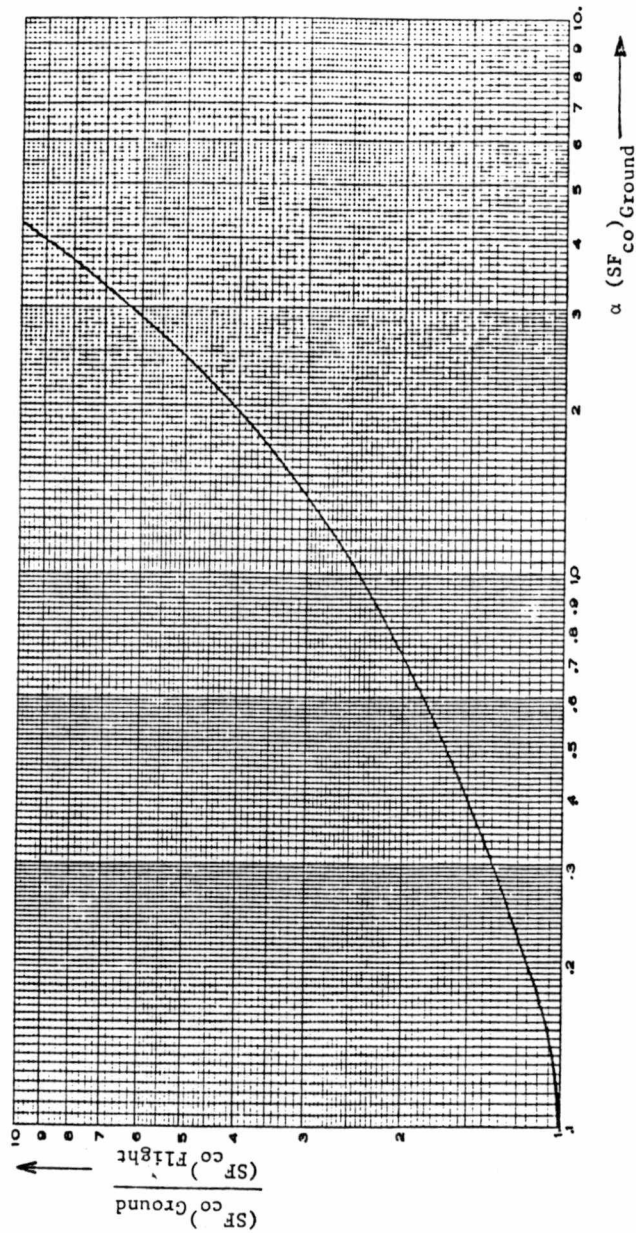
$R\Delta T$ = Resolvable Temperature Differential

SF_T = Spacial Frequency of Bar Target

$MR\Delta T$ = Minimum Resolvable Temperature Differential

Figure 7

INFLIGHT AND GROUND ANGULAR AND THERMAL RESOLUTION



$(SF_{co})_{Flight}$ = Cut-off spatial frequency of sensor with LOS jitter (Cycles/Radian)
 $(SF_{co})_{Ground}$ = Cut-off spatial frequency of sensor without LOS jitter (Cycles/Radian)
 α = RMS value of sensor LOS jitter (Radians)

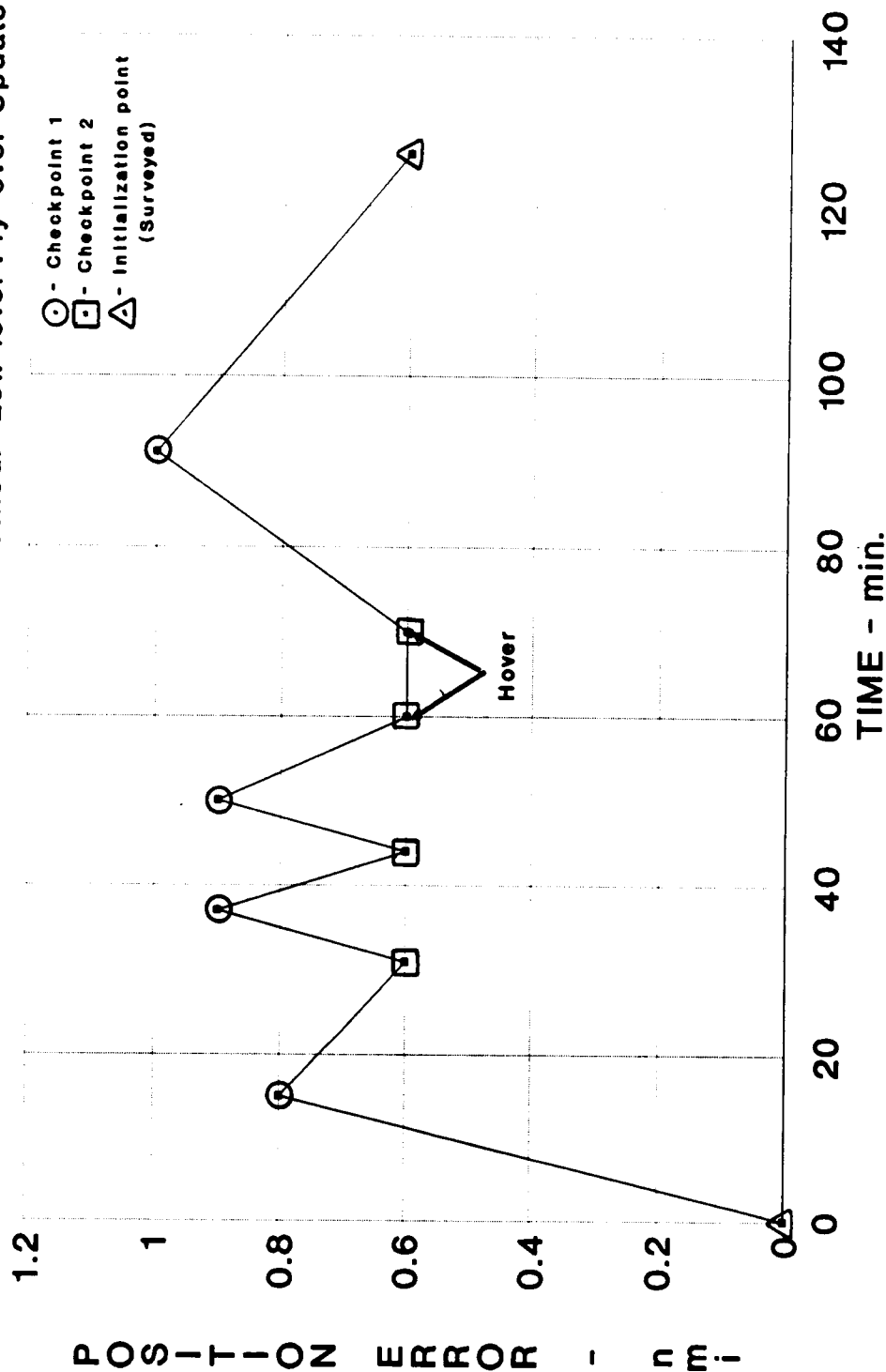
Figure 8
EFFECT OF LINE OF SIGHT JITTER ON ANGULAR RESOLUTION

MODEL AH-64A AIRPLANE

System: AN/ASN-128
Software: CP 125
Date of Test: 12 November 1986

SN 8424216

Align Location: CAIRNS
Align Mag Var: 0.0
Method: Low level Fly-over Update



Evaluator: S. Kracinovich

Figure 9
RADIAL POSITION ERROR

MODEL AH-64A AIRPLANE

SN 8424216

System: AN/ASN-128

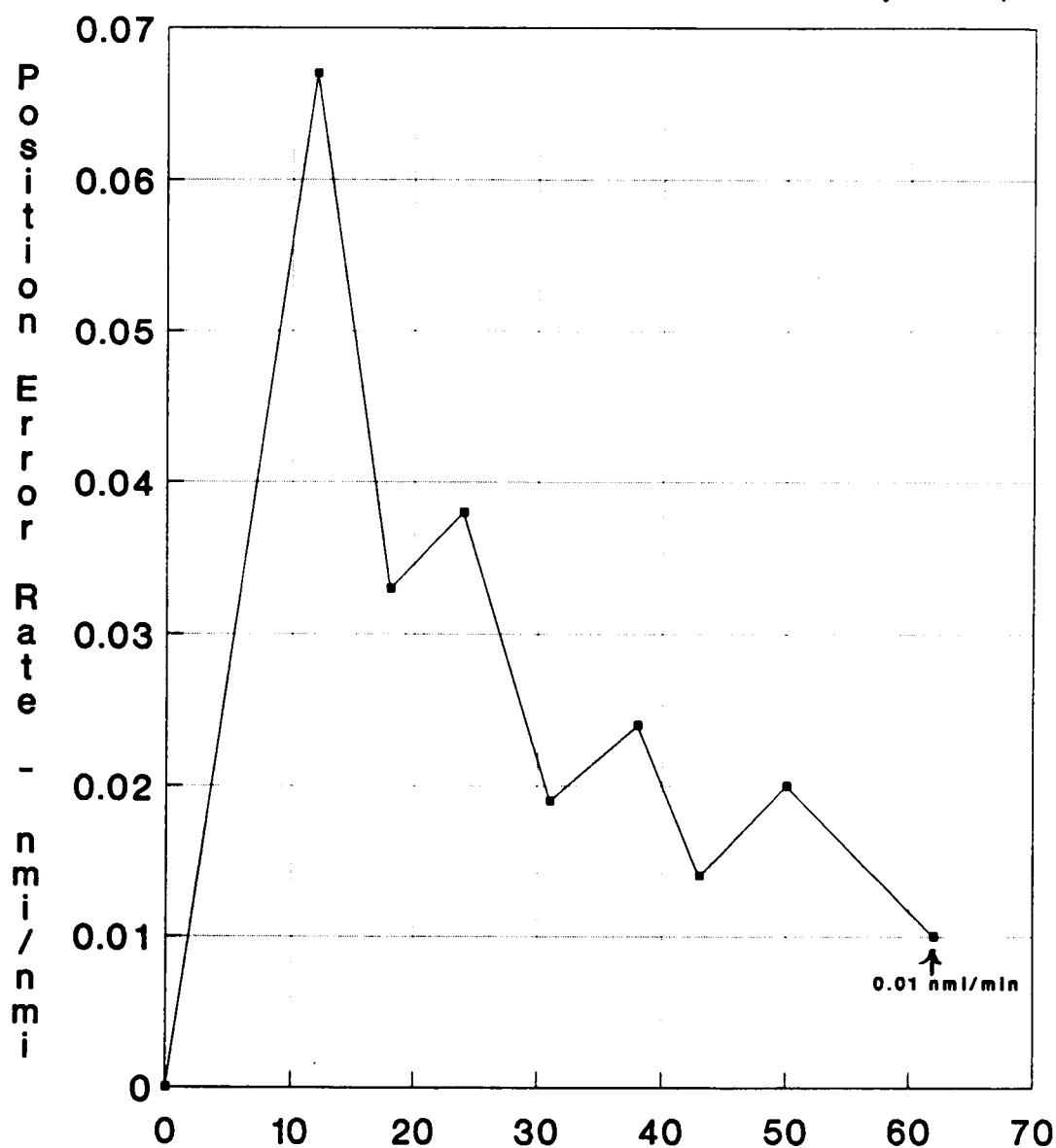
Software: CP 125

Date of Test: 12 Nov. 1986

Align Location: CAIRNS

Align Mag Var: 0.0

Method: Low Level Fly-over Update



Evaluator: S. Kracinovich

Distance - nmi

Figure 10

RADIAL CUMULATIVE ERROR RATE VS DISTANCE

VITA

Stephen A. Kracinovich was born on July, 13 1961 in Jersey City, New Jersey. In 1979 he graduated from Bricktownship High School and entered Virginia Tech. Upon graduation in 1983, he received a Bachelor of Science degree in Aerospace Engineering and went to work for the Naval Air Test Center.

Mr. Kracinovich was a structural analysts for the Computer Sciences Directorate until 1984 when he transferred to the Rotary Wing Aircraft Test Directorate as a flight test engineer.

In 1986 he was selected as one of four engineers to enter Class 90 of the United States Naval Test Pilot School. Upon graduation from Test Pilot School the author returned to the Rotary Wing Aircraft Test Directorate and began pursuing a Masters of Science Degree in Aviation Systems from the University of Tennessee. This thesis will complete the requirements of that degree.

Mr. Kracinovich is presently the Lead Flight Test Engineer for the V-22 Osprey, the joint service tilt-rotor.