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APPLICATION OF AIDS TO THE A-7E AND A PROJECTED FUTURE TACTICAL--ETC(U)

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APPLICATION OF AIDS TO THE A-7E AND A PROJECTED FUTURE TACTICAL AIRCRAFT

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A study program to evaluate the application of the AIDS concept to the A-7E as well as a future tactical aircraft has been completed. The study evaluated the physical characteristics of the AIDS as applied to the A-7E and selected the Type "A" V/STOL as the future tactical aircraft to evaluate physical compatibility, interface requirements, display format analysis, cockpit ambient lighting, and unique display system requirements associated with the V/STOL application. The study results reported in this document

verify the feasibility of utilizing the integrated display concept in the A-7E aircraft as well as the type "A" V/STOL. Certain physical incompatibilities were noted for the V/STOL application with regard to component sizes, and several unique display requirements are identified relative to V-mode operations.

SUMMARY

The feasibility of incorporating the "Advanced Integrated Display System" (AIDS) into the A-7E, as well as the Type "A" V/STOL, has been established by the results of this study. The operational AIDS configuration, Engineering Development Model (EDM), was used as a reference to conduct the physical characteristics evaluation for the A-7E. The evaluation revealed adequate space attainable in the avionics bays for the AIDS processors, and with major modifications to the current instrument panel and consoles, a practical installation of the cockpit displays and controls can be achieved.

For the future tactical aircraft evaluation, the Type "A" V/STOL was selected as the candidate for AIDS incorporation. Mission requirements were established using a typical ASW mission scenario to evaluate crew task loading, workload and display requirements using an AIDS equipped three man crew. Vertical mode considerations were evaluated with particular attention to application of the AIDS concepts to Type A V/STOL requirements. Significant incompatibilities became evident between the AIDS HUD and V/STOL external vision requirements and cockpit geometry. The large physical size of the AIDS displays and control panels pose installation problems in the V/STOL cockpit. Unique V/STOL interface requirements were identified and human engineering analyses were conducted which included display format considerations, as well as cockpit ambient lighting and degraded mode instrumentation assessments.

The results of the study indicated that, with special attention given to the design and the physical size of the displays, AIDS is well suited to a Type "A" V/STOL application.

PREFACE

This final report has been prepared in compliance with the data requirements of NADC contract N62269-77-C-0186. The report documents the results of a study of the application of AIDS to the A-7E and a projected future tactical aircraft. This work was supported by the Naval Air Systems Command under the sponsorship of Mr. G. Tsaparas. The program was under the technical direction of Mr. W. G. Mulley and K. D. Quiring of the Naval Air Development Center, Warminster, Pennsylvania.

Significant contributors to this report include Mr. J. R. Hanking, Human Factors Engineering and the principal investigator for the Vought Corporation, Mr. P. E. Greer, Electronic Technology. The Advanced Technology Avionics Project Engineer was Mr. G. T. Litton.

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1.0 INTRODUCTION

The Vought Corporation submits this final report on a six month study that established the conceptual feasibility for the application of the AIDS into the current A-7E as well as the future application of AIDS into the Type "A" V/STOL aircraft.

The initial phase of the study effort included an evaluation of the impact of an AIDS installation into the A-7E light attack aircraft. The principal avionics areas addressed were the required weight, volume, power and cooling as compared to the existing installation. A system interface concept was developed to determine the overall weapon system impact of integrating the AIDS with the A-7E systems. The A-7E has a high density conventional single place cockpit and a highly integrated navigation/weapons delivery system (NWDS) with a head-up display (HUD), making it a good representative for evaluating the feasibility of an AIDS installation. The feasibility of such an installation was established by the study and recommended methods for resolution of incompatibilities encountered are included in this report.

For the second phase of this program, "the evaluation of AIDS in a selected future tactical aircraft", the Type "A" V/STOL aircraft was selected as the most likely candidate for the next production application of the AIDS. Therefore, the remainder of the study effort was devoted to application of AIDS to the Type "A" V/STOL. The system interface characteristics evaluation consisted of a mission requirements analysis, followed by special V/STOL considerations unique to the AIDS application. Physical characteristics of the AIDS installation in a V/STOL aircraft were evaluated and a conceptual description of an AIDS installation defined. A review of the original AIDS signal interface requirements document was conducted with a specific V/STOL application in mind, and finally the unique requirements, associated with an AIDS application to V/STOL which may impact the current AIDS development concepts, were identified and are reported herein.

In addition to the avionics, the human factors considerations share an important role in the adaptation of the AIDS concept to a V/STOL type aircraft, and accordingly, a closely coordinated human engineering effort has been conducted as a part of this study effort.

The initial psychophysical requirements analysis was to define a display format for the pilot's display that could decrease pilot confusion and ease the task of aircraft operation during transition from conventional flight to vertical landing. An extensive literature search was conducted to define information requirements and acceptable symbology for use during transition from conventional flight to vertical landing. The results of this analysis is a proposed display format that meets the information requirements. Rationale for the selection of the specific symbols is also included.

The next task addressing AIDS psychophysical requirements analysis was to assess the effects of cockpit ambient lighting upon AIDS for four different environmental conditions. Conditions of worst angle of sun's rays at high altitude, black night operations, and high ambient and black night conditions while operating on emergency power were evaluated for impact on the AIDS displays. The cockpit geometry is as currently specified for a two place, side by side, Type A V/STOL configuration. This portion of the study was conducted independent of the known proposed AIDS display capabilities. (Ref. 9) However, the results in the form of display requirements, can be compared to proposed AIDS display capabilities.

The final area of displayed information requirements analysis concerned standby instrumentation. A list of current standby information requirements (Exhibit C - Ref. 14) was evaluated and a number of V/STOL unique information requirements added.

The last task was to review a preliminary AIDS Human Factors Program Plan supplied by NADC. (Included as Appendix A.) This plan was reviewed and recommendations for changes are contained herein.

2.0 SYSTEM INTERFACE CHARACTERISTICS

2.1 APPLICATION OF AIDS TO A-7E

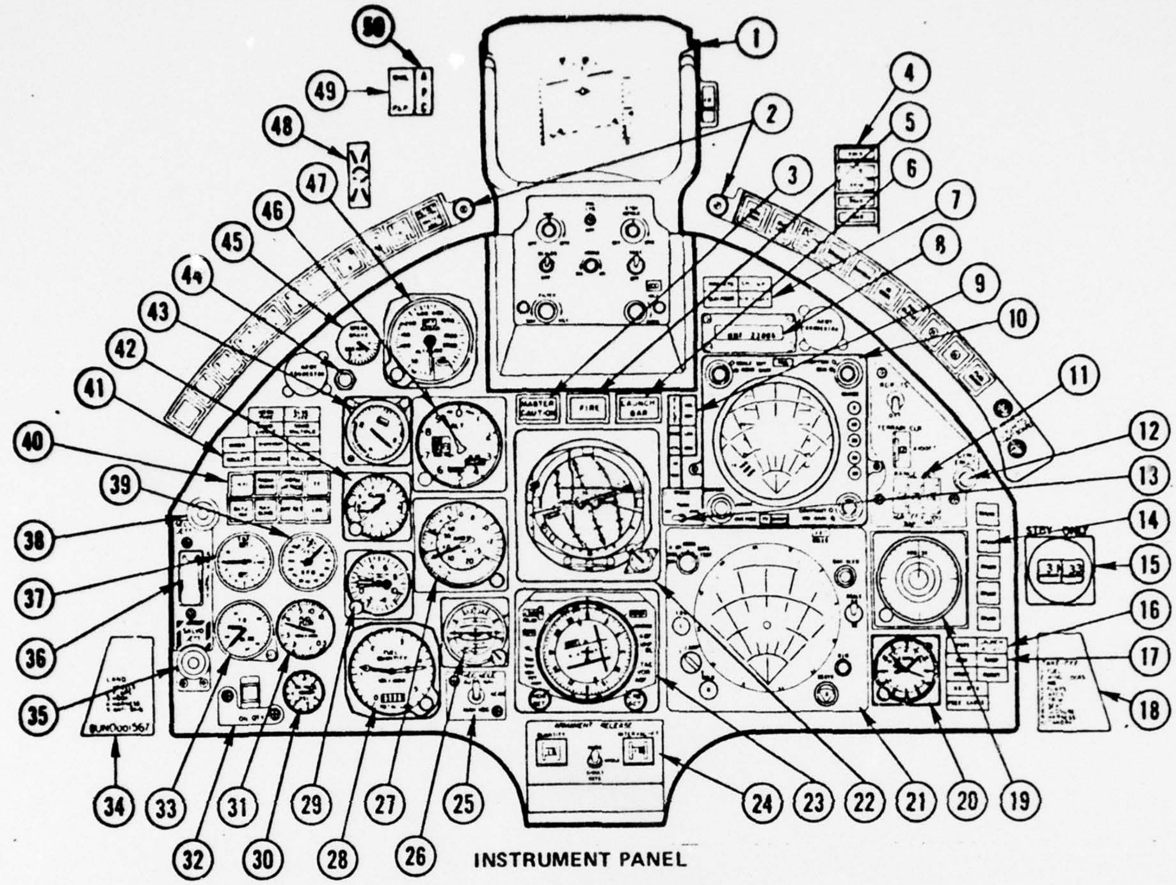
Part 1 of this study evaluated the impact of installing the AIDS into an A-7E light attack aircraft. The principal areas addressed were the required weight, volume, power and cooling as compared to the existing installation. A system interface concept was developed to determine the overall weapons system impact of integrating the AIDS with the A-7E systems. The A-7E has a high density conventional single place cockpit and a highly integrated navigation/weapons delivery system with a head-up display (HUD), making it a good representative for evaluating the feasibility of an AIDS installation.

2.1.1 Existing A-7E Cockpit Instruments

The instruments and indicators currently in the A-7E cockpit are, for the most part, dedicated to individual functions and flight parameters. As new capabilities are added to the aircraft for which new displays are required, the competition for the prime cockpit space becomes more and more severe. This situation is typical of most operational aircraft today. All of the displays and indicators need to be located in positions which are readily visible to the pilot at the time that function is important to him but, obviously, there are limits to optimizing the location of dedicated individual displays.

The current arrangement of displays and controls in the A-7E cockpit are shown in Figures 2-1 thru 2-3. These figures depict the locations of the controls and displays in the instrument panel as well as the left and right consoles.

The flight instruments are functionally grouped on the instrument panel (see Figure 2-1) with the navigation and flight instruments in the center, the engine and fuel system monitoring (fuel quantity, oil pressure, turbine outlet pressure and temperature) instruments on the lower left of the panel and the armament controls and indicators located on the lower center and



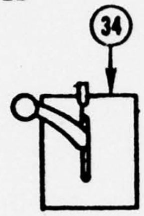
INSTRUMENT PANEL

1. HEAD-UP DISPLAY
2. ARMAMENT SELECT SWITCHES
3. MASTER CAUTION LIGHT
4. RHAW THREAT LIGHTS
5. FIRE WARNING LIGHT
6. LAUNCH BAR LIGHT
7. ARMAMENT ADVISORY LIGHTS
8. UHF REMOTE CHANNEL INDICATOR
9. DATA LINK DISCRETE LIGHTS
10. RADAR SCOPE
11. RADAR RANGE SET CONTROLS
12. GYRO ERECT SWITCH
13. SHRIKE SWITCH
14. RHAW WARNING LIGHTS
15. STANDBY COMPASS
16. LAUNCH ALERT WARNING LIGHT
17. DATA LINK DISCRETE LIGHTS
18. TAKEOFF CHECKLIST
19. ECM THREAT ANALYZER
20. CLOCK
21. PROJECTED MAP DISPLAY
22. ATTITUDE DIRECTOR INDICATOR
23. HORIZONTAL SITUATION INDICATOR
24. ARMAMENT RELEASE PANEL
25. HEADING MODE SWITCH
26. STANDBY ATTITUDE INDICATOR
27. AIRSPEED INDICATOR
28. FUEL QUANTITY INDICATOR
29. ACCELEROMETER
30. OIL PRESSURE INDICATOR
31. FUEL FLOW INDICATOR
32. OIL QUANTITY INDICATOR
33. TURBINE OUTLET PRESSURE INDICATOR
34. LANDING CHECKLIST
35. SALVO JETTISON SWITCH
36. AUXILIARY JETTISON SWITCH
37. TURBINE OUTLET TEMPERATURE INDICATOR
38. SELECT JETTISON SWITCH
39. TACHOMETER
40. MASTER FUNCTION SELECTORS
41. ARMAMENT ADVISORY LIGHTS
42. VERTICAL VELOCITY INDICATOR
43. ANGLE-OF-ATTACK INDICATOR
44. RADAR ALTIMETER LOW ALTITUDE WARNING LIGHT
45. SPEED BRAKE POSITION INDICATOR
46. SERVOED ALTIMETER
47. RADAR ALTIMETER
48. APPROACH INDEXER
49. WHEELS/FLAPS WARNING LIGHTS
50. APPROACH POWER CONTROL WARNING LIGHT

FIGURE 2-1 COCKPIT INSTRUMENT PANEL A-7E

LH CONSOLE ARRANGEMENT

1. AFCS TRIM INDICATORS
2. EMERGENCY POWER PACKAGE HANDLE
3. LEADING EDGE FLAPS POSITION INDICATOR
4. TRAILING EDGE FLAPS POSITION INDICATOR
5. LANDING GEAR POSITION INDICATORS
6. LANDING GEAR CONTROL HANDLE
7. GENERATOR INDICATOR
8. BULLPUP CONTROL
9. CATAPULT GRIP
10. EMERGENCY BRAKE CONTROL
11. THROTTLE CONTROL
12. RUDDER TRIM CONTROL
13. RADAR CONTROL PANEL
14. UHF CONTROL PANEL
15. FUZE FUNCTION CONTROL
16. DATA LINK
17. SPEECH SECURITY
18. UHF/ADF RADIO
19. OXYGEN QUANTITY INDICATOR
20. PILOT SERVICES PANEL
21. SUIT TEMPERATURE CONTROL
22. AUDIO CONTROL
23. IFF CONTROL PANEL
24. FLAPS CONTROL
25. AUTOPILOT CONTROL PANEL
26. APC
27. ANTISKID CONTROL
28. AIR REFUELING SWITCH
29. PITOT ANTI-ICE SWITCH
30. FUEL MANAGEMENT CONTROL PANEL
31. TRIM POSITION INDICATOR
32. AFCS TEST CONTROL
33. PITCH AND ROLL TRIM SWITCHES
34. CANOPY JETTISON HANDLE
35. DECOY SWITCH



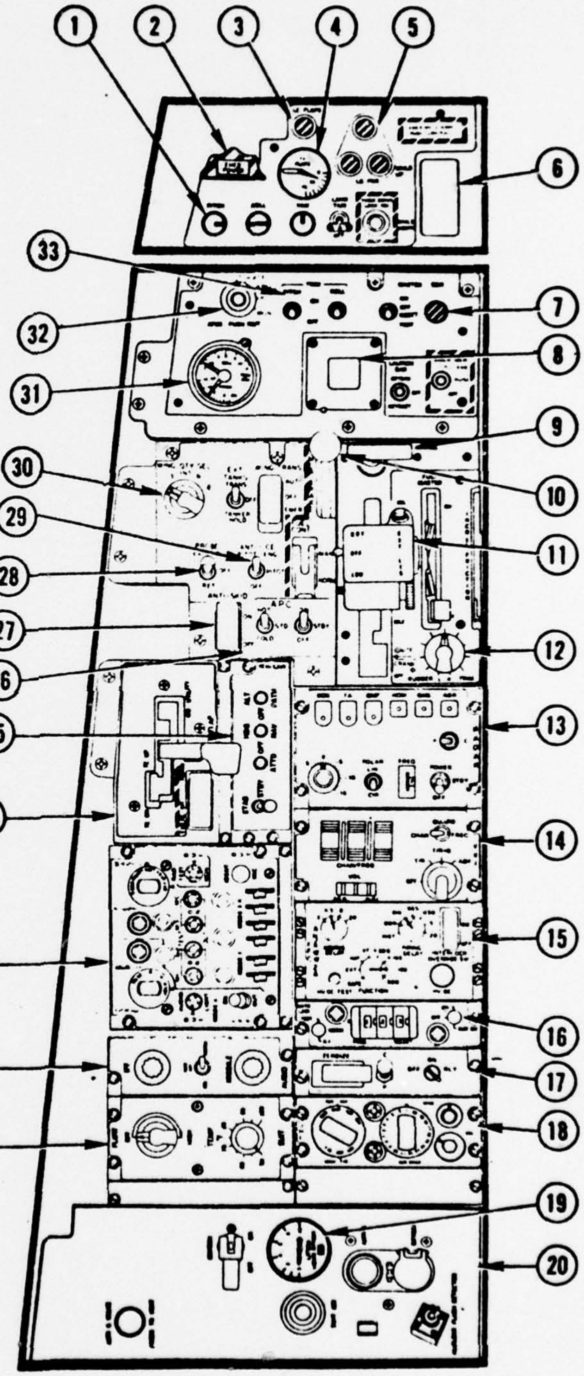
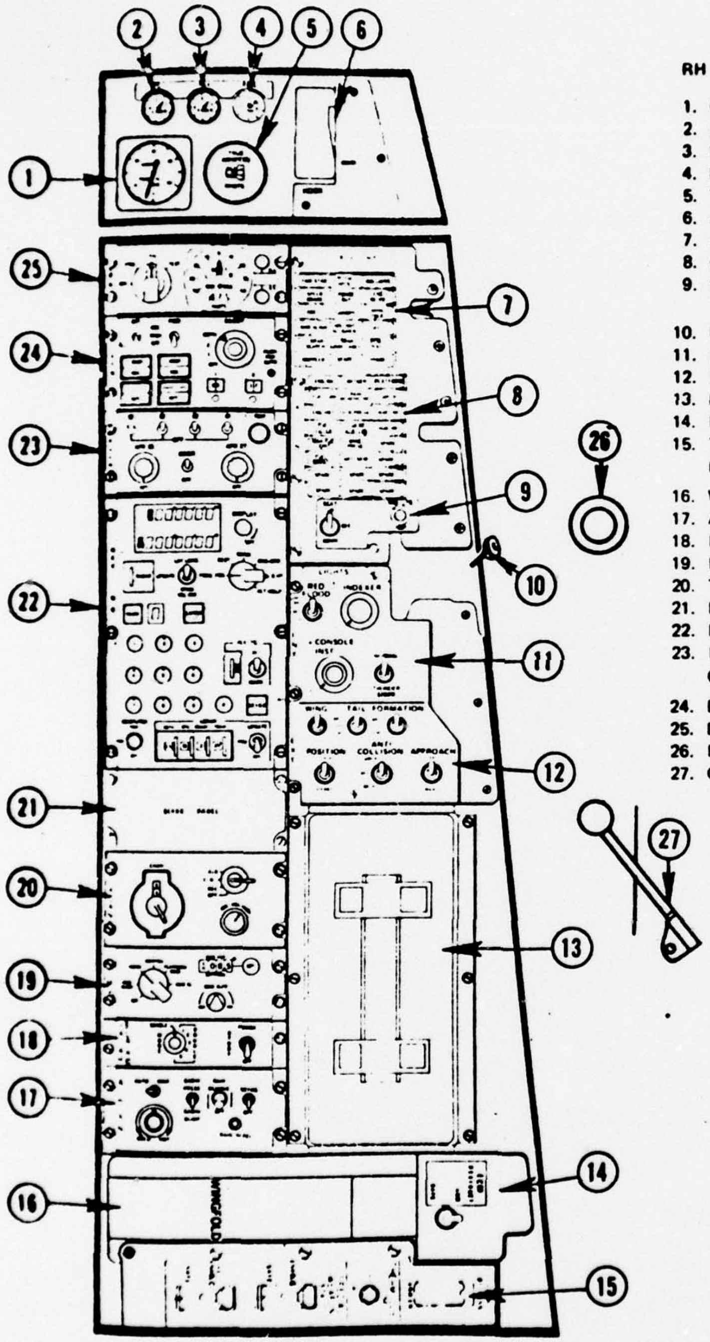


FIGURE 2-2 LEFT CONSOLE



RH CONSOLE ARRANGEMENT

1. CABIN PRESSURE ALT
2. PC-1 PRESSURE INDICATOR
3. PC-2 PRESSURE INDICATOR
4. PC-3 PRESSURE INDICATOR
5. TRUE AIRSPEED INDICATOR
6. ARRESTING HOOK CONTROL
7. ADVISORY LIGHTS
8. CAUTION LIGHTS
9. SEAT AND INDICATOR LIGHT TEST SWITCHES
10. FOOT AIR VENT CONTROL
11. INTERIOR LIGHTS CONTROL PANEL
12. EXTERIOR LIGHTS CONTROL PANEL
13. MAP CASE
14. ECM DESTRUCT
15. THERMAL CLOSURE, SPECIAL WEAPONS, HOOK BYPASS
16. WINGFOLD
17. AIR-CONDITIONING CONTROL PANEL
18. RADAR BEACON CONTROL
19. IMS CONTROL PANEL
20. TACAN CONTROL PANEL
21. BLANK PANEL
22. NAV/WEAPON COMPUTER PANEL
23. RADAR HOMING AND WARNING CONTROL PANEL
24. ECM CONTROL PANEL
25. DOPPLER RADAR CONTROL PANEL
26. EMERGENCY VENT AIR CONTROL
27. CANOPY LOCK HANDLE

FIGURE 2-3 RIGHT CONSOLE

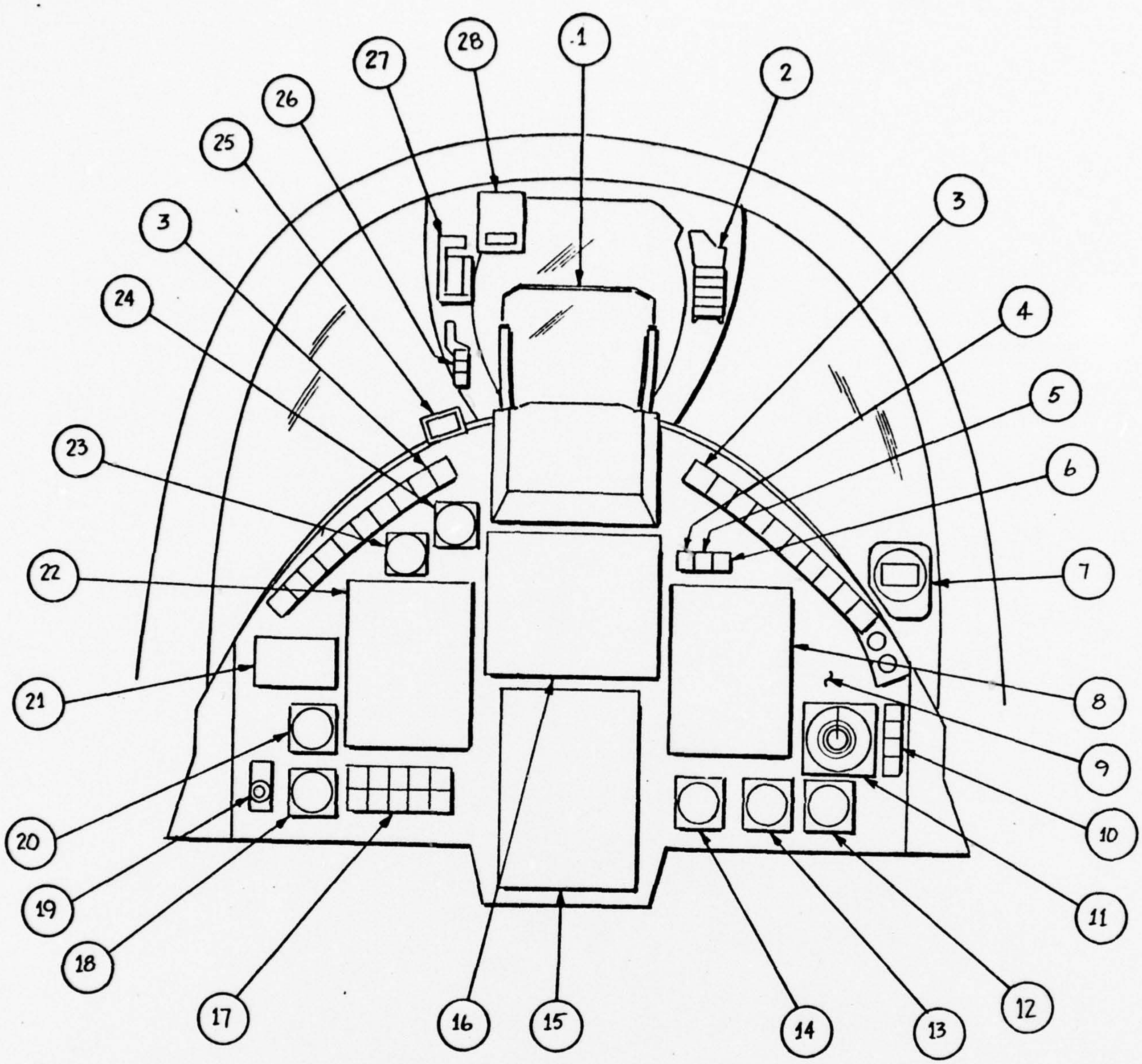
along the upper cowl on both sides. Threat warning and warning functions and advisories are in the center and on the lower right side and on the right windscreen bow. The left console shown in Figure 2-2 contains displays and controls for, automatic flight control system, landing gear, emergency power package, autopilot, engine, fuel flaps, UHF, IFF, radar, fuze control, oxygen, air refueling, suit vent and pilot services. The right console contains interior and exterior lighting controls, caution and advisory annunciators, and controls and indicators for hydraulic pressure, arresting hook, doppler radar, tactical computer, TACAN, ECM, Inertial Measurement Set (IMS), radar beacon, environmental, and wingfold systems.

2.1.2 A-7E AIDS Cockpit Arrangement

A conceptual AIDS configured A-7E cockpit configuration was defined to form a basis for the installation studies. The cockpit layout is depicted in Figures 2-4 through 2-6. The AIDS components used for this study are as follows:

- o Head-Up Display (HUD)
- o Vertical Situation Display (VSD)
- o Horizontal Situation Display (HSD)
- o Left and Right Situation Advisory Displays (LSAD/RSAD)
- o Integrated Display Control Panels (IDCP) (2 each)
- o Master Mode Control Panel
- o Briefing Information Entry Device (BIED)
- o Modular Integrated Display Electronics Racks (MIDER) (Located outside cockpit) (2 each)

The cockpit configuration shown in Figures 2-4 through 2-6 depict space required and not necessarily the most useful or functional location. It is recommended that a separate study be conducted to define an optimum arrangement avoiding major airframe structural changes and the feasibility of integrating the present NWDC input panel into the IDCP. For this study the throttle quadrant, flaps, landing gear and tail hook controls, and the console structure were retained in their present location and/or configuration. This



1. Head-Up Display
2. RHAW Threat Lights
3. Armament Select Switches
4. Master Caution Light
5. Fire Warning Light
6. Launch Alert Warning Light
7. Standby Compass
8. Advisory Display
9. Space for additional discrete Lights/ Standby Instruments as Needed
10. RHAW Warning Lights
11. ECM Threat Analyzer
12. Standby Fuel Quantity Indicator
13. Standby Indicated Airspeed Indicator
14. Standby Altimeter Indicator
15. Horizontal Situation Display
16. Vertical Situation Display
17. System Mode Control Panel
18. Spare
19. Salvo Jettison Switch
20. Clock
21. Engine Status Indicator
22. Advisory Display
23. Standby Angle-of-Attack Indicator
24. Standby Attitude Indicator
25. Low Attitude Warning Light
26. Approach Indexer
27. Wheels/Flaps/Approach Power Control Warning Lights
28. Warning Light

FIGURE 2-4 A-7E/AIDS COCKPIT LAYOUT

LH CONSOLE ARRANGEMENT

1. Emergency Power Package Handle
2. Landing Gear Control Handle
3. Generator Indicator
4. Catapult Grip
5. Emergency Brake Control
6. Throttle Control
7. Rudder Trim Control
8. Space for Integrated Control Panel
9. Fuze Function Control
10. Speech Security
11. Pilot Services Panel
12. Suit Temperature Control
13. Space for Briefing Info Entry Devise
14. Flaps Control
15. Autopilot Control Panel
16. APC
17. Antiskid Control
18. Air Refueling Switch
19. Pitot Anti-Ice Switch
20. Fuel Management Control Panel
21. AFCS Test Control
22. Canopy Jettison Handle
23. Decoy Switch

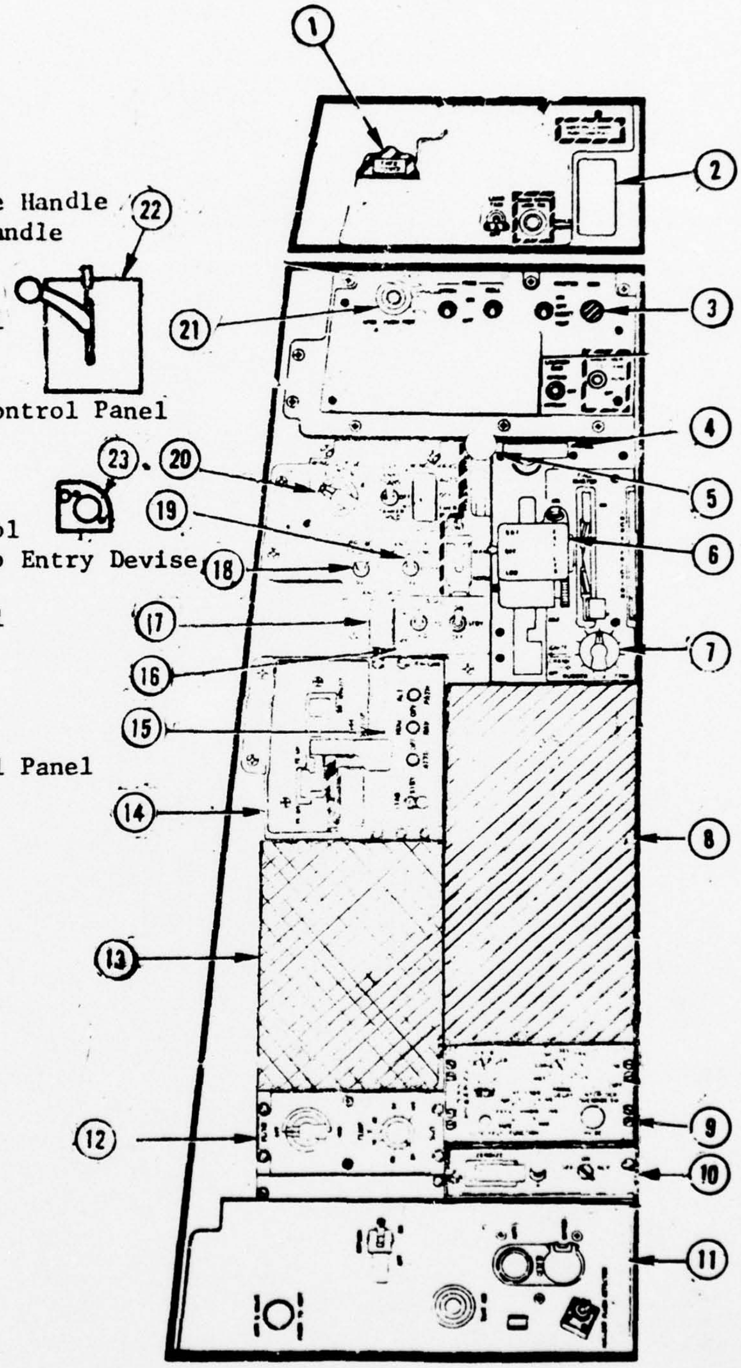
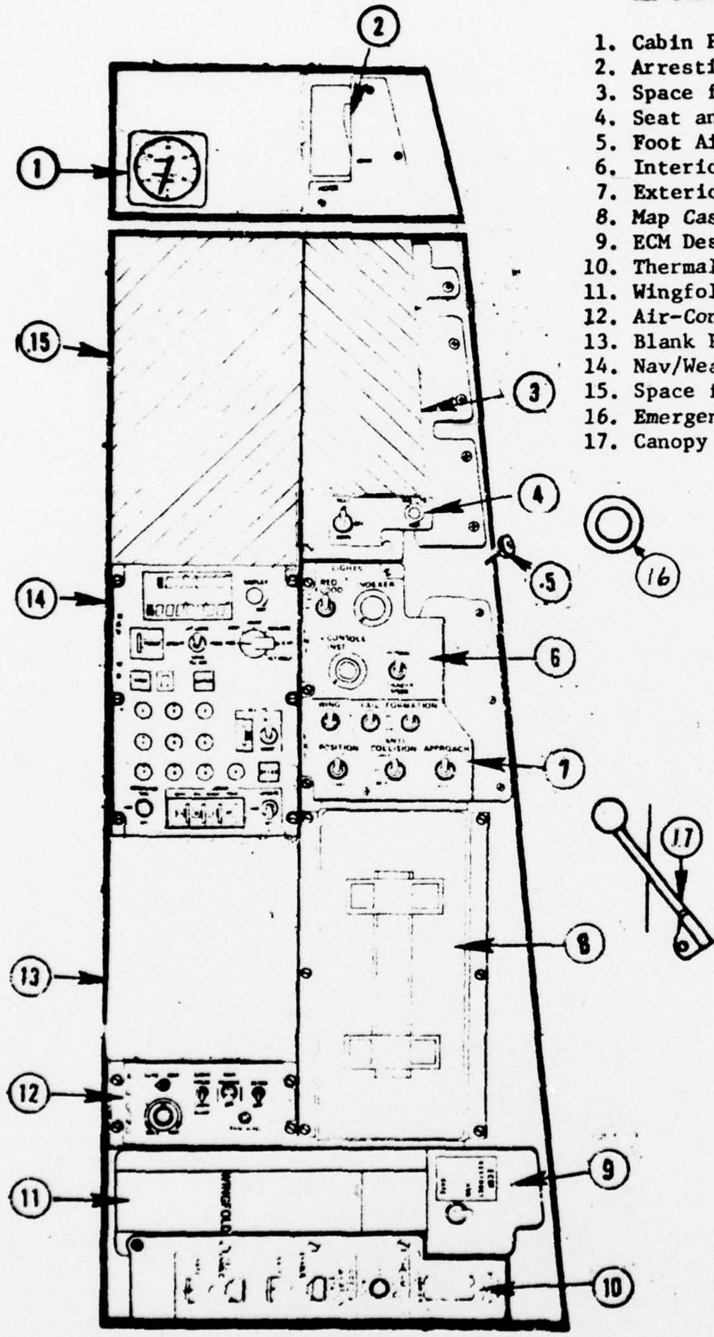


FIGURE 2-5 LEFT CONSOLE



RH CONSOLE ARRANGEMENT

1. Cabin Pressure Alt
2. Arresting Hook Control
3. Space for Integrated Control Panel
4. Seat and Indicator Light Test Switches
5. Foot Air Vent Control
6. Interior Lights Control Panel
7. Exterior Lights Control Panel
8. Map Case
9. ECM Destruct
10. Thermal Closure, Special Weapons, Hook Bypass
11. Wingfold
12. Air-Conditioning Control Panel
13. Blank Panel
14. Nav/Weapon Computer Panel
15. Space for Integrated Control Panel
16. Emergency Vent Air Control
17. Canopy Lock Handle

FIGURE 2-6 RIGHT CONSOLE

configuration will restrict the Integrated Display Control Panels (IDCP) form factor to MS25212 dimensions and the VSD front dimensions to 6 x 8 inches. These items are discussed in detail in paragraph 2.1.4.1 of this report.

The display and control function allocation for the AIDS cockpit are summarized in Table 2-1. Table 2-2 is a tabulation of the A-7E controls and displays that the AIDS system replaces.

2.1.3 AIDS Architecture

The present A-7E controls and displays architecture is depicted in Figure 2-7. The majority of the controls and displays have a direct, dedicated signal interface with the signal source and consist of AC and DC analog, three wire synchro, discretes, digital and pneumatic type signals. The TC-2 Navigation Weapon Delivery Computer (NWDC) receives inputs from other system sensors, operates on the signals and outputs flight data to the HUD, PMD, HSI, and ADI. The NWDC has available data that is presently not displayed but is accessible for AIDS.

An architectual concept to incorporate AIDS into an A-7E is shown in Figure 2-8. Since AIDS is designed to interface with a General Purpose Multiplex System (GPMS) per MIL-STD-1553A, the various A-7E display and control signals must be converted to this standard. A system signal interface unit (SSIU) will perform this function and will provide a two-way signal interface between the AIDS controls and the sensors, including engine sensors and discrete indications. A serial digital channel between the NWDC and SSIU will reduce the number of unique interfaces required. Figure 2-9 depicts the multiplex signal paths required for the incorporation of AIDS in the A-7E.

A power converter unit will also be required to convert the A-7E 115/207 VAC to 270 VDC required for AIDS EDM hardware design.

TABLE 2-1
DISPLAY AND CONTROL FUNCTION ALLOCATION

DISPLAY FUNCTIONS

HUD	-FLIGHT CONTROL, WEAPON DELIVERY, AND SENSOR
VSD	-FLIGHT CONTROL, WEAPON DELIVERY, AND SENSOR
HSD	-NAVIGATION, LIMITED SENSOR, AND ECM
LSAD	-ENGINE, ORDNANCE, CHECKLISTS, AND PROCEDURES
RSAD	-SYSTEM STATUS, COMMUNICATION, IFF, ECM, CHECKLISTS, PROCEDURES, AND CAUTION-ADVISORY

CONTROL FUNCTIONS

DISCRETE	ICS
SYSTEM MODES	DISPLAY MODES
KEYSET	SENSOR
DISPLAY CONTROLS	NAVIGATION
WEAPONS SELECT/RELEASE CONTROLS	COMMUNICATION
CURSOR	ECM
	WEAPONS MANAGEMENT

EMERGENCY/STANDBY INSTRUMENTS

AIRSPEED
ALTIMETER
ANGLE OF ATTACK
ATTITUDE
ENGINE SPEED
EXHAUST GAS TEMP.
FUEL FLOW
FUEL QUANTITY
OIL PRESSURE
STANDBY COMPASS

TABLE 2-2
A-7E CONTROLS/DISPLAYS REPLACED BY AIDS

AFCS TRIM INDICATORS
LEADING EDGE FLAPS POSITION INDICATOR
TRAILING EDGE FLAPS POSITION INDICATOR
RADAR CONTROL
UHF CONTROL PANEL
DATA LINK
UHF/ADF RADIO
AUDIO CONTROL PANEL
TRIM POSITION INDICATOR
PC-1 PRESSURE INDICATOR
PC-2 PRESSURE INDICATOR
PC-3 PRESSURE INDICATOR
TRUE AIRSPEED INDICATOR
ADVISORY LIGHTS
CAUTION LIGHTS
RADAR BEACON CONTROL
IMS CONTROL PANEL
TACAN CONTROL PANEL
RADAR HOMING AND WARNING CONTROL PANEL
ECM CONTROL PANEL
DOPPLER RADAR CONTROL PANEL
HEAD-UP DISPLAY
ARMAMENT ADVISORY LIGHTS
UHF REMOTE CHANNEL INDICATOR
DATA LINK DISCRETE LIGHTS
RADAR SCOPE
RADAR RANGE SET CONTROLS
SHRIKE SWITCH
DATA LINK DISCRETE LIGHTS
TAKEOFF CHECKLIST
PROJECTED MAP DISPLAY
ATTITUDE DIRECTOR INDICATOR
HORIZONTAL SITUAION INDICATOR

TABLE 2-2
A-7E CONTROLS/DISPLAYS REPLACED BY AIDS (Continued)

ARMAMENT RELEASE PANEL
HEADING MODE SWITCH
AIRSPEED INDICATOR
FUEL QUANTITY INDICATOR
ACCELEROMETER
OIL PRESSURE INDICATOR
FUEL FLOW INDICATOR
OIL QUANTITY INDICATOR
TURBINE OUTLET PRESSURE INDICATOR
LANDING CHECKLIST
AUXILIARY JETTISON SWITCH
TURBINE OUTLET TEMPERATURE INDICATOR
SELECT JETTISON SWITCH
TACHOMETER
MASTER FUNCTION SELECTION
ARMAMENT ADVISORY LIGHTS
VERTICAL VELOCITY INDICATOR
SPEED BRAKE POSITION INDICATOR
SERVOED ALTIMETER
RADAR ALTIMETER

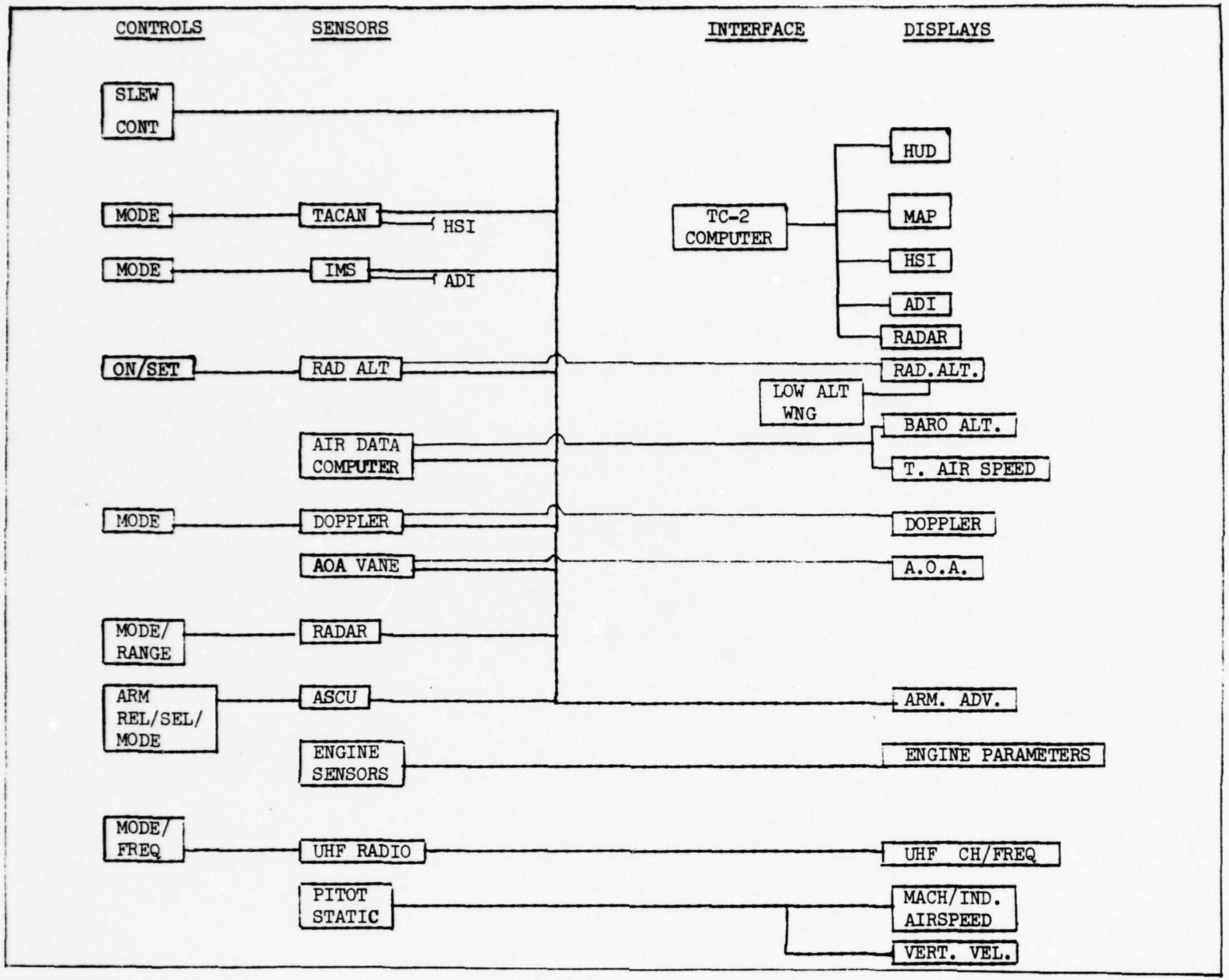


FIGURE 2-7 CURRENT A-7E DISPLAY ARCHITECTURE

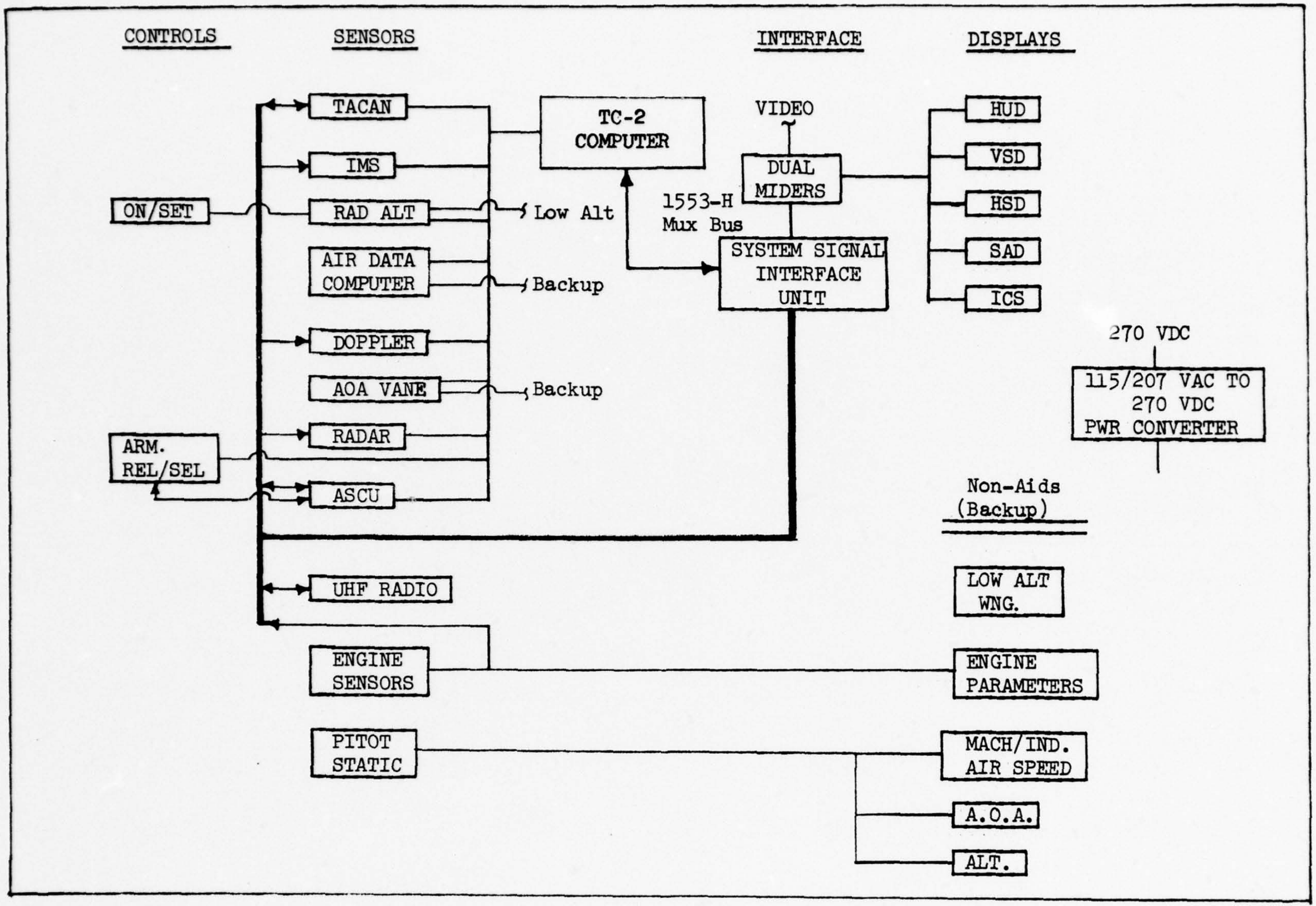


FIGURE 2-8 DISPLAY ARCHITECTURE WITH AIDS

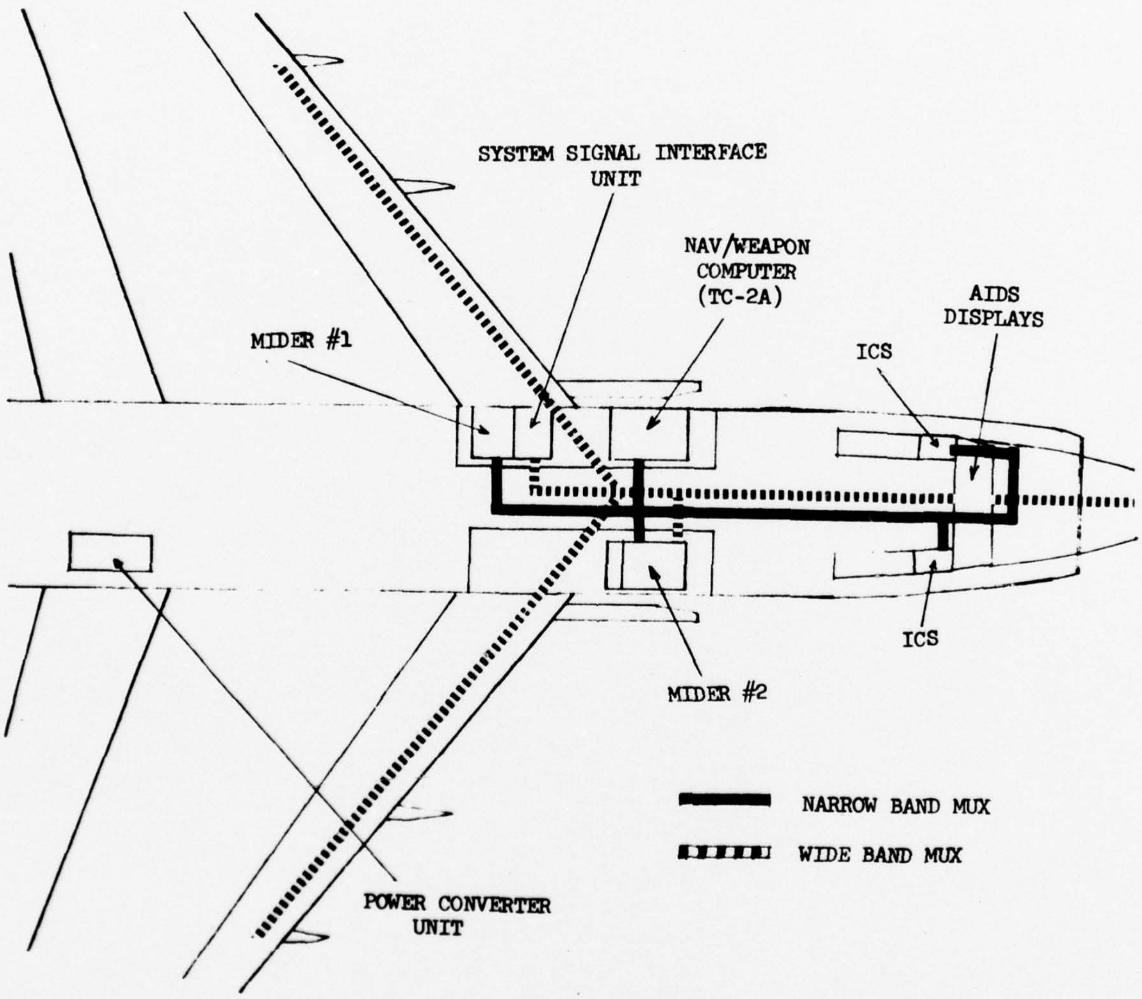


FIGURE 2-9 A-7E/AIDS MULTIPLEX REQUIREMENTS

2.1.4 AIDS/A-7E Physical Interfaces

The Operational AIDS Baseline configuration (EDM) was used as a reference to conduct the physical interface study. The documents used for reference in defining the AIDS EDM configuration were General Electric Report titled "Advanced Integrated Display System (AIDS), System Design Interim Report No. 2," dated 31 March 1977 and General Electric data titled "AIDS Technical Review," dated 26, 27 January 1977. Table 2-3 is a tabulation of the physical characteristics for each of the components used to integrate AIDS into an A-7E aircraft. These data are based on the 1/2 ATR (D2) SEM configuration. The System Signal Interface Unit (SSIU) and Power Converter were estimated. The SSIU is estimated to have physical characteristics identical to the MIDERs.

The AIDS installation impact on volume, weight, power consumption, and cooling requirements is discussed in the following paragraphs. The effects can best be evaluated by separating the cockpit hardware from those items that are located remotely in the avionic or other bays. The impact on the cooling system is discussed in paragraph 2.1.4.3.

2.1.4.1 Cockpit Impact

With the AIDS configured A-7E cockpit configuration described in paragraph 2.1.2, and the list of equipment to be removed from the current configuration, a summary table of weight, volume, and power delta's was developed for an overall comparison of current and projected configurations. The AIDS equipped cockpit results in a lower weight and power consumption but shows a small increase in volume required. The results shown in Table 2-4 are summarized as follows:

- o Weight -18 lbs.
- o Volume +0.02 ft^3
- o Power -267 watts

TABLE 2-3 AIDS PHYSICAL CHARACTERISTICS

HARDWARE DESCRIPTION	TYPE	WEIGHT (Pounds)	POWER (Watts)	VOLUME (in.) H x W x L	COOLING REQUIREMENTS	COOLING VOLUME lb/min.
Head-Up Display	Holo-Graphic	40	100	5.5 x 8 x 24 (.60 ft^3)	Cockpit Air Selective Direction	0.27
VSD	CRT	25	100	6.5 x 8.5 x 13 (.42 ft^3)	Cockpit Air Selective Direction	0.27
HSD	Holo-Graphic	40	500	10 x 7 x 25 (1.013 ft^3)	Forced Convection Conditioned Air	1.8
LSAD/RSAD	LCD	10	25	8 x 6 x 6 (.167 ft^3)	Natural Convection	--
INTEGRATED CONTROL SET	Mode Control	2	5	5 x 2.5 x 2.5 (.02 ft^3)	Natural Convection	--
	ICP #1	7.5	40	6 x 6 x 10 (.21 ft^3)	Natural Convection	--
	ICP #2	7.5	40	6 x 6 x 10 (.21 ft^3)	Natural Convection	--
BIED	--	9	20	5 x '7.5 x 4.5 (.1 ft^3)	Natural Convection	--
MIDERS	A	38.5	240	7.6 x 7.5 x 19.6 (0.65 Ft^3)	Conditioned Air	0.86
	B	40	240	(0.65 Ft^3)	Conditioned Air	0.86
SSIU		50	240	(0.65 Ft^3)	Forced Convection	--
POWER CONVERTER		20	400	(0.3 Ft^3)	Forced Convection	--

TABLE 2-4 AIDS EDM WEIGHT, VOLUME AND POWER VS. CURRENT A-7E INSTRUMENTATION

CURRENT A-7E				AIDS EDM			
	Weight (Lbs)	Volume (Ft^3)	Power (Watts)		Weight (Lbs)	Volume (Ft^3)	Power (Watts)
COCKPIT				COCKPIT			
HUD DISPLAY	41	0.80	300	HUD	40	0.61	100
FLR INDICATOR	20	0.32	190	VSD	25	.42	100
PMDS DISPLAY	23	0.55	184	HSD	40	1.01	500
ADI	10	0.12	28	RSAD	10	0.17	25
HSI	10	0.11	20	LSAD	10	0.17	25
				Integ Cont (2)	15	0.42	80
2" Gauge (9 ea.)	13	0.09	90	Mode Cont.	2	0.02	5
3-1/4" Gauge (4 ea.)	10	0.16	40	BIED	9	0.10	20
SMALL IND. (10 ea.)	7	0.05	50	2" Gauge (3 ea.)	4	0.03	30
CONT. PNLS (17 ea.)	34	0.50	150	Eng. Std By	2	0.02	5
ADVISORY LTS	6	0.20	100				
SLEW CONTROL	1	0.05	5				
SUB-TOTAL	175	2.95	1157		157	2.97	890
AVIONICS BAYS				AVIONICS BAYS			
HUD SDP	25	0.68	300	Mider (A)	39	0.65	240
PMDS SDC	19	0.55	120	Mider (B)	40	0.65	240
SUB-TOTAL	44	1.23	420	Sys Signal Interface	40	0.65	240
				Pwr Convtr	20	0.30	400
				SUB-TOTAL	139	2.25	1120
TOTAL	219	4.18	1577	TOTAL	296	5.22	2010

The investigation of the actual mechanical installation of the AIDS equipment into the A-7E revealed the cockpit can accommodate all AIDS components provided the following provisions are met:

- A new instrument board casting compatible with the AIDS displays arrangement will be required.

- A tension tie bar currently exists behind the instrument board for structural support and as presently designed would interfere with the HSD installation. A redesign of the tension tie bar and/or supporting structure would be required to provide the necessary space for the HSD installation.

- The VSD installation shown in Figure 2-4 was accomplished only after reducing the front panel dimensions from 8 x 10 inches to 6.5 x 8.5 inches. These dimensions must be maintained in the final EDM configuration for proper installation in the A-7E.

- The non-standard width of the currently proposed IDCP (10 inches) would require a complex redesign of the A-7E consoles in order to achieve a satisfactory installation. The consoles are designed to accept two rows standard 6.0 inch panels, and a redesigned console to accept the 10 inch IDCP would require cutting the center rail which is a structural member. It is recommended, therefore, that the IDCP design be given further consideration at this time in an attempt to standardize the external dimensions to those called out in MS25212.

- The depth of the consoles also vary with regard to available panel mounting space, and therefore, additional study will be required when the final IDCP locations are defined to insure adequate mounting depth in a particular location in the console. However, per MS25212 the depth of the IDCP should not exceed 6.5 inches.

2.1.4.2 Avionic Bays Impact

The existing A-7E HUD and PMDS have a Signal Data Processor (SDP) and Signal Data Converter (SDC), respectively, that are located in remote avionic bays. These units will be removed for the AIDS installation to provide space for the installation of the four AIDS components to be located remote from the cockpit. The units to be added are two MIDERs, a System Signal Interface Unit (SSIU), and a power converter unit. The weight, volume, and power characteristics for these components are itemized in Table 2-4. Figures 2-10 and 2-11 show the left and right avionic bays, respectively, and where the SDP and SDC are located. These photographs also depict the fact that the avionic bays are filled and that adequate available space can be obtained by removal of the current SDP and SDC units.

The volume attainable from the SDP and SDC removal is shown in Figures 2-12 and 2-13. The volume required for each of the MIDERs is shown in Figure 2-14, and shows that the MIDER length requirement of 19.56 inches exceeds the volume vacated by either the SDP or SDC. The MIDER width of 7.5 inches is compatible with the SDP width but not the SDC. The height requirements of 7.62 inches is compatible with both the SDP and SDC volume, and therefore, since the volumes made available by the SDP and SDC are not compatible with the MIDER volume requirements shown in Figure 2-14, an alternate MIDER configuration using improved 2A SEM modules was required.

Figure 2-15 is a MIDER configuration proposed by General Electric which uses improved 2A SEM modules in lieu of 1/2 ATR (D2) SEMS. The volume of this MIDER configuration is compatible with the available space and is, therefore, required for the A-7E installation.

It has been estimated that the SSIU will require a volume approximately equivalent to a MIDER and it is recommended, therefore, that the SSIU be designed using "improved 2A SEM" design configuration and be limited to 4.5 inches width. This will allow the installation of a MIDER and the SSIU (on a common rack) in the space vacated by the SDP. The other MIDER can be installed in the space vacated by the SDC, as shown in Figure 2-10.

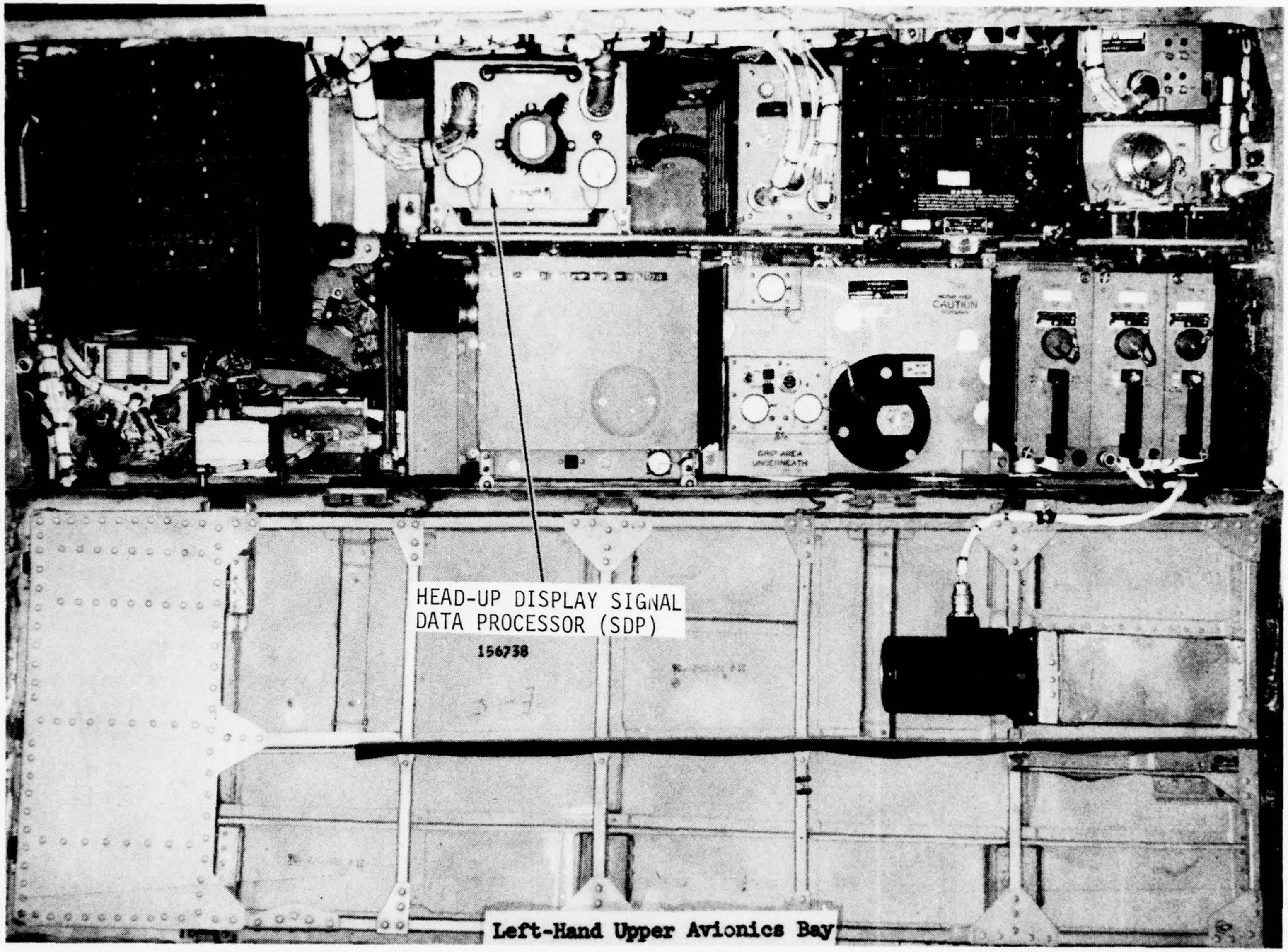
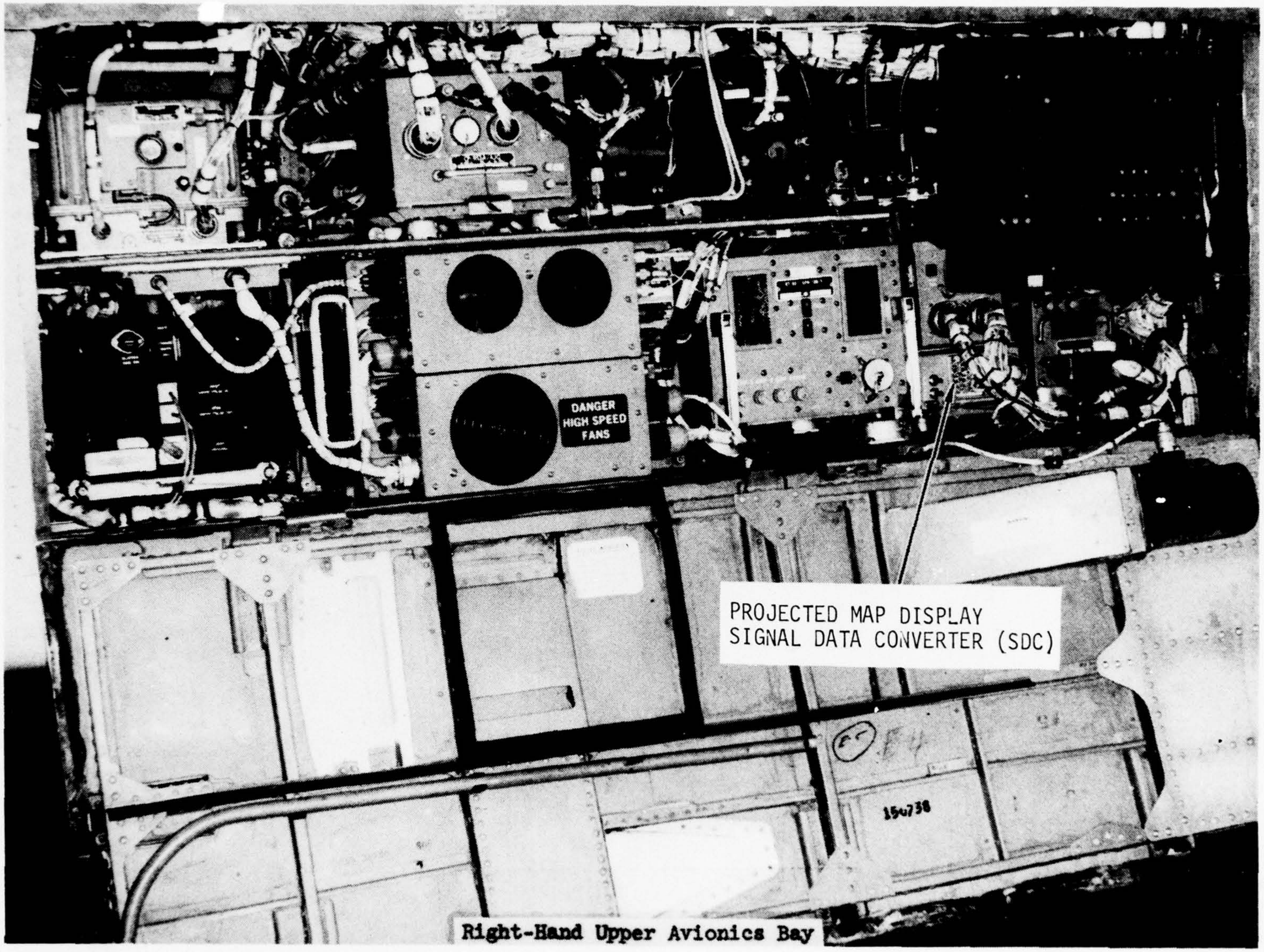

HEAD-UP DISPLAY SIGNAL
DATA PROCESSOR (SDP)
156738
CAUTION
DIRT AREA
UNDERNEATH
Left-Hand Upper Avionics Bay

FIGURE 2-10



Right-Hand Upper Avionics Bay

FIGURE 2-11

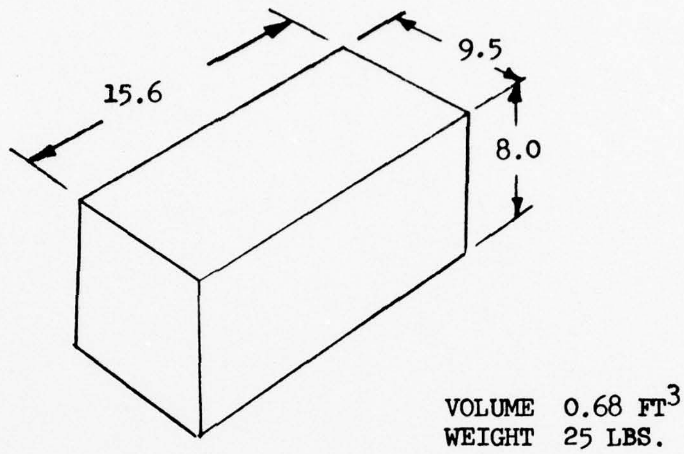


FIGURE 2-12 SDP VOLUME/WT.

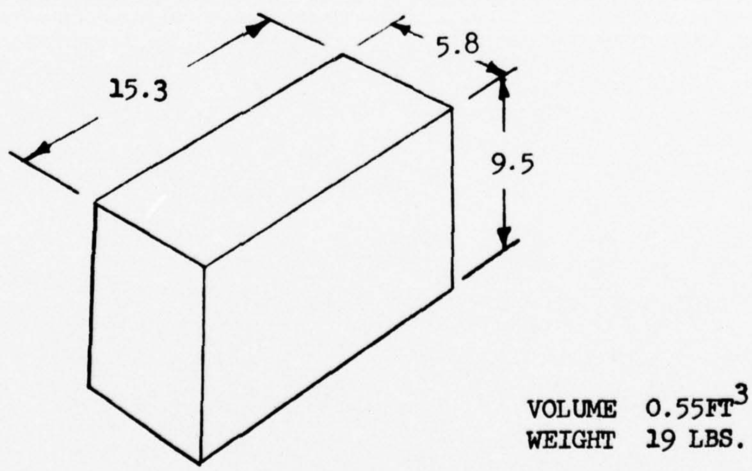


FIGURE 2-13 SDC VOLUME/WEIGHT

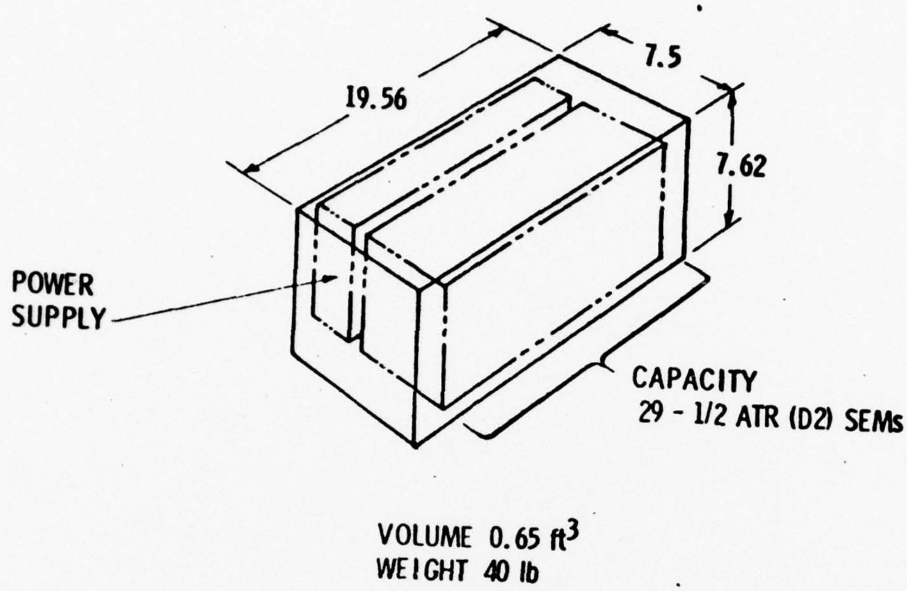


FIGURE 2-14 MIDER - 1/2 ATR (D2) SEM VERSION

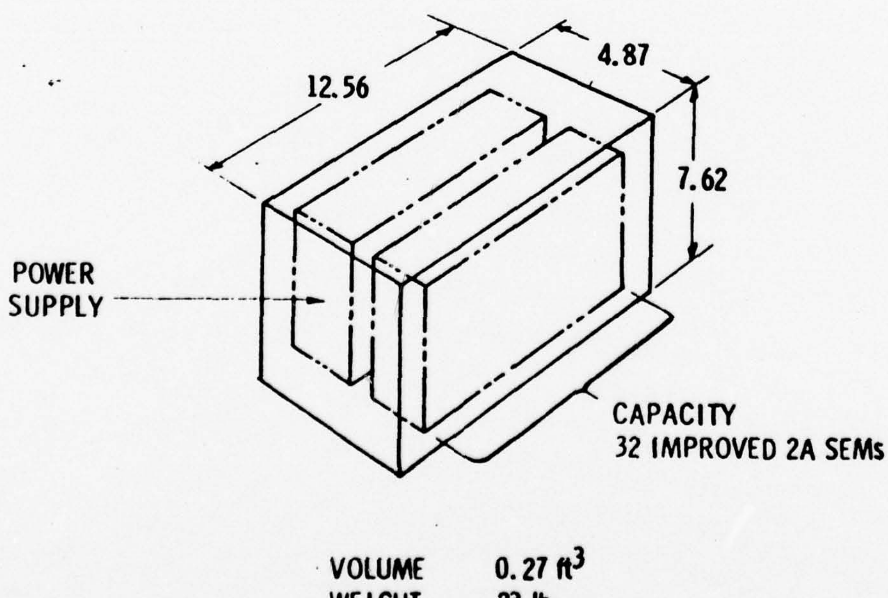


FIGURE 2-15 MIDER - IMPROVED 2A SEM VERSION

The Power Converter Unit, which converts the 115/207 VAC power to the required 270 VDC, can be located in a small avionics compartment located in the right hand engine bay, as shown in Figure 2-9.

2.1.4.3 Cooling System Impact

The A-7E air conditioning system is presently operating at capacity and the cooling system is a delicately balanced system. Therefore, any change in cooling requirements and/or loads will require the system to be re-balanced.

As was noted in paragraph 2.1.4.1 the cockpit power dissipation loads are approximately 267 watts less with AIDS than the existing A-7E cockpit loads, but the load distribution and air flow requirements are different. Cockpit cooling air enters from the sides of the cockpit and exits to the nose radar compartment through a pressure relief valve.

The current displays and controls are cooled by natural convection or by forced convection using fans which use cockpit ambient air. The HUD display unit has a fan to provide the necessary cooling air and it would be desirable to use cooling techniques for the AIDS hardware that are compatible with the A-7E. It is assumed that the HUD, VSD, and L/R SAD's can be adequately cooled by natural convection or forced flow of cockpit air. However, the HSD will require a fan to provide adequate air flow to dissipate the 500 watts. The fan could be located remote to the HSD or packaged integrally, but it is recommended that the fan be integrated with the HSD for most efficient heat transfer.

In the event AIDS is installed in the A-7E, the cockpit cooling system would require a mockup to establish best air flow and rebalance the cooling system.

The HUD and PMDS processors presently use fans to provide a mixture of refrigerated and ambient compartment air for forced cooling. It is assumed that the MIDERs and the System Signal Interface Unit will utilize a similar cooling technique. The use of the improved 2A SEM version MIDERs and SSIU described in paragraph 2.1.4.2 will allow the placement of fans at either the front or aft end of the units. Since the MIDERs and SSIU dissipate approximately 300 watts more power than the SDP and SDC, a cooling system study is required to redistribute the available refrigerated air.

The power converter unit can be cooled by natural convection and/or ram air.

2.1.5 Conclusion

The AIDS system can be installed in an A-7E. The cockpit is adaptable to the AIDS displays and controls arrangement provided the IDCP is designed to the standard MS25212 dimensions and the VSD is reduced in size. The installation of AIDS in the A-7E will require the remotely located MIDERs and SSIU to be configured using the improved 2A SEMS configurations because of limited space. An additional problem will be to provide proper cooling with the available conditioned air.

2.2 APPLICATION OF AIDS TO V/STOL

For the evaluation of AIDS in a selected future tactical aircraft, the Type "A" V/STOL was determined to be the most likely candidate for the next production application of the AIDS, and therefore, the remainder of this study effort is devoted to the evaluation of the AIDS in the Type "A" V/STOL. The system interface characteristics evaluation consists of a mission requirements analysis, followed by special V/STOL considerations unique to the AIDS application. In addition to the avionics, the human factors considerations share an important role in the adaptation of the AIDS concept to a V/STOL type aircraft, and accordingly, a closely coordinated human engineering effort has been conducted as a part of this study effort.

2.2.1 Mission Requirements

Mission requirements analysis is the foundation of the V/STOL portion of this study and serves as a point of departure for the rest of the study. From the definition of mission requirements; such things as crew sizing, crew station layout and arrangement, displayed information requirements, interface and processing requirements, etc., are developed. The ASW mission variant of the Type "A" V/STOL design being developed by Vought was selected for this mission requirements analysis. This single mission evaluation allowed a more detailed analysis of the AIDS integration into the Type "A" V/STOL aircraft and the results will be applicable in large measure to other V/STOL mission variants from the standpoint of weight, power, volume, cooling requirements and human factors considerations due to AIDS display commonality.

Selection of a study mission allowed definition of specific mission phases. The mission phases were chosen to encompass the typical ASW mission with emphasis on those mission phases most affecting the V/STOL configuration and the AIDS installation. The AIDS installation is seen as a means to compensate for the increased pilot workload caused by V-mode operation.

The following anti-submarine warfare (ASW) mission phases were selected for analysis and evaluation of mission requirements:

- o Pre Take-Off
- o Take-Off - Climb-Out
- o Enroute to Station
- o Search and Classification
- o Localization
- o Tracking and Attack
- o Climb-Out - Return to Ship
- o Let Down
- o Initial Approach
- o Final Approach/Transition
- o Hover/Landing

This mission phase listing was designed to emphasize vertical take-off and landing and is not presented as a complete ASW mission. It was developed to evaluate what were considered the most critical crew station requirements. The flight phases listed encompass most ASW missions and require exercising all of the aircraft systems and avionics equipment normally used during a mission.

2.2.1.1 Analysis of the Air Crew Requirements

Analysis of the air crew functional requirements for each mission phase allows estimation of crew sizing requirements and the allocation of system functional responsibilities to each crew member. Because of the limited scope of this study, it was agreed to forego crew loading analysis and concentrate on crew sizing requirements. The co-pilot requirement was eliminated as a result of past in-house studies involving mission duration, operational requirements, and predictions of mission avionics processing capabilities in the Type "A" V/STOL. Operator 1/TACCO will occupy the co-pilot position and also serve as safety of flight monitor during critical mission phases. This decision was also partially based on the assumption that much of the manned processing and target classification required with current ASW and AEW tactics and equipment will be done automatically by the advanced equipment of the Type A V/STOL IOC time period. An example is magnetic anomaly detection (MAD) equipments in the S-3A ASW aircraft. This system requires adjustment and compensation that should not be required in newer towed-body MAD equipment.

An analysis of each of the selected mission phases was conducted using current S-3A four crew station functional allocations for a typical ASW mission. Functional allocations for the three crew stations were developed. This required that the functional responsibilities be redistributed among the three crew stations for each mission phase. The assumption (actually a requirement) was made that additional automatic processing would be available for the Type A V/STOL IOC time period. This will be a requirement because currently the S-3A co-pilot is required to function more as a dedicated mission systems operator than as a co-pilot. Reduction of crew size from four to three does not eliminate only the co-pilot function but also eliminates a nearly full-time operator function. This operator function has been distributed among the remaining crew members. The increase in individual crew member workload must be compensated for by allocating additional processing functions to mission systems and AIDS. Based on the increased automatic processing capability, the mission phase functional responsibilities have been distributed as shown in Tables 2-5, 2-6, (crew functional responsibilities-anti-submarine warfare), for each of the 11 selected mission phases. Table 2-5 provides a gross preliminary equitable division of crew workload during the selected mission phases.

TABLE 2-5
GROSS CREW FUNCTIONAL RESPONSIBILITIES - ANTISUBMARINE WARFARE

PILOT	OPERATOR #1 (TACCO/SOFM)	OPERATOR #2 (SENSO)
Aircraft Control	Safety of Flight Monitor	Acoustic Sensors Operations
Configuration Management	Directs Tactical Mission	Non-Acoustic Sensors Operations
Energy Management	Monitor Sensor Displays	Monitor Sensor Displays
Navigation		
Communication		
Stores Management		

Examination of Table 2-6 resulted in definition of four distinct categories of displayed information for the selected mission phases. These are flight information, engine health and status, tactical information, and aircraft-equipment status. Each displayed information category contains several types of information. Table 2-7, (Information Distribution Requirements), presents the types of information required under each information category for each crew member for each mission phase.

Table 2-7 represents a significant data base which will be the basis for a number of specific analyses. Figure 2-16 depicts potential analyses that use the information presented in Table 2-7. Items marked with an asterisk denote those items undertaken during this study.

A requirement of this study was to define the pilot's primary display. This included definition of required information, display format and symbology. A literature search was conducted to define the detailed information required for each of the types of information listed under the categories of Table 2-7. Existing "checklists" of required information for conventional and particularly for V/STOL aircraft were used to expand and detail each of the information types. A detailed listing of information type for each information category is shown in Table 2-8. From data found during the literature search used to develop the table, information required for the pilot's primary display during the vertical take-off and landing operations was defined. The pilot's primary display information requirements and associated rationale are contained in Section 5.1, "Development of Display Format and Symbology".

2.2.1.2 Analysis of Crew Station Requirements

From the mission requirements analysis and the crew function allocations, a preliminary AIDS equipped V/STOL crew station arrangement was defined, based on a three man crew ASW mission. The layout is shown in Figure 2-17. The side-by-side arrangement with the pilot station on the right side is typical of the current Vought Type "A" V/STOL configuration. The Vought decision to place the pilot in the right seat in the V/STOL design was based on extensive in-house studies and interviews with the V/STOL community.

TABLE 2-6

DETAILED CREW FUNCTIONAL RESPONSIBILITIES - ANTISUBMARINE WARFARE

PRETAKE-OFF

Pilot

- o Take-off Checklist
- o Nav Entries
- o Aircraft Systems Functions Check
- o Ordnance Load Checks
- o Align Inertial Navigation System

TACCO/SOFM

- o Take-off Checklist
- o Nav Entries
- o Tactical Systems Functional Checks
- o Mission Entries
- o Ensure Operational Program Loaded
- o Monitor Sensor System Status

SENSO

- o Tactical Systems Functional Checks
- o Mission Entries
- o Perform Operational Program/System Functional Checks

TABLE 2-6

DETAILED CREW FUNCTIONAL RESPONSIBILITIES - ANTISUBMARINE WARFARE (CONT'D)

VERTICAL TAKE-OFF TRANSITION/CLIMB OUT

Pilot

- Configuration Management for Take-off/Transition/Climb Out
- Communication as Necessary (Unless Passive Mission Conditions (PMC) are Followed)
- Navigation Entries/Selection
- Monitor Flight Information
- Respond to Safety of Flight or Out of Tolerance Conditions

TACCO/SOFM

- Monitor Flight Information for Safety of Flight or Out of Tolerance Conditions
- Communication Task as Allocated by Pilot

SENSO

- Energize Radar to Monitor and Catalog Surface Contacts

TABLE 2-6

DETAILED CREW FUNCTIONAL RESPONSIBILITIES - ANTISUBMARINE WARFARE (CONT'D)

ENROUTE TO STATION

Pilot

- o Control Aircraft
- o Navigate
- o Check Non-acoustic System Readiness
- o Monitor Threat Warning System

TACCO/SOFM

- o Direct Operation of Desired Sensors
- o Configure Pilot's Display
- o Update/Insert Desired FTP (Fly to Points)
- o Monitor Radar

SENSO

- o Check Acoustic System Readiness
- o Operate Sensors as TACCO Directs
- o Operate Radar
- o Configure Displays

TABLE 2-6

DETAILED CREW FUNCTIONAL RESPONSIBILITIES - ANTISUBMARINE WARFARE (CONT'D)

SEARCH AND CLASSIFICATION

Pilot

- o Control Aircraft
- o Plan for Time on Station, Bingo Fuel, Etc.
- o Update Navigation, as Required
- o Operate Radar if Workload Permits
- o Communicate as Required

TACCO/SOFM

- o Maintain Proper Tactical Plot
- o Direct Use of Sensors to Detect/Classify and Fix Contacts as Briefed
- o Direct Desired Altitude and Airspeed
- o Monitor Acoustical and Nonacoustical Sensor Displays
- o Monitor Nav and Drop Search Stores

SENSO

- o Operate Analog Tape Recorder (ATR) as Directed
- o Use Acoustic Sensors to Detect/Classify and Fix Contacts
- o Operate Radar if Required

TABLE 2-6

DETAILED CREW FUNCTIONAL RESPONSIBILITIES - ANTISUBMARINE WARFARE (CONT'D)

LOCALIZATION

Pilot

- o Control Aircraft
- o Navigate as Directed by TACCO
- o Set Up Attack Stores as Directed by TACCO
- o Monitor Time on Station, Fuel, State, Etc.

TACCO/SOFM

- o Direct Mission and Use of Sensors
- o Monitor Sensor Displays
- o Update Nav
- o Drop Active Search Stores
- o Fix Contact
- o Maintain Tactical Plot

SENSO

- o Operate Sensors as Directed by TACCO
- o Monitor Sensor Displays

TABLE 2-6

DETAILED CREW FUNCTIONAL RESPONSIBILITIES - ANTISUBMARINE WARFARE (CONT'D)

TRACKING AND ATTACK

Pilot

- Control Aircraft
- Has Sole Control of Master Arm
- Monitor Selection and Release of Attack Stores
- Select and Release Visual Attack and Forward Firing Weapons
- Monitor Time on Station, Fuel State, Etc.

TACCO/SOFM

- Maintain Tactical Plot
- Direct Attack
- Select and Release Free-Fall Stores
- Verify Kill

SENSO

- Operate Sensors as Directed
- Monitor Sensor Displays
- Verify Kill

TABLE 2-6

DETAILED CREW FUNCTIONAL RESPONSIBILITIES - ANTISUBMARINE WARFARE (CONT'D)

CLIMB OUT - RETURN TO SHIP

Pilot

- o Configure Aircraft for Climb Out and Return Cruise
- o Navigate
- o Estalbish Communications with Appropriate Control Agencies
- o Determine Landing Weight and Fuel Requirements

TACCO/SOFM

- o Monitor/Enter Nav FTP's
- o Monitor Return Profile
- o Monitor Flight Data, Fuel, Out of Tolerance Conditions
- o Assist Pilot with Communications

SENSO

- o Extract Search Stores Inventory Tableau
- o Operate/Monitor Nonacoustic Sensors as Directed by TACCO
- o Rewind Analog Tape Recorder (ATR)

TABLE 2-6

DETAILED CREW FUNCTIONAL RESPONSIBILITIES - ANTISUBMARINE WARFARE (CONT'D)

LETDOWN

Pilot

- Configuration Management to Establish Letdown to Initial Approach
- Navigation
- Communication
- Energy Management
- Perform Required Checklists
- Plan for Initial Approach - Landing

TACCO/SOFM

- Monitor Flight Path and Altitude and Call Out Altitude
- Monitor Radar Approach
- Monitor and Assist Checklist Compliance
- Assist in Navigation and Communication

SENSO

- Monitor and Assist Checklist Compliance

TABLE 2-6

DETAILED CREW FUNCTIONAL RESPONSIBILITIES - ANTISUBMARINE WARFARE (CONT'D)

INITIAL APPROACH

Pilot

- Control Airspeed
- Energy Management
- Configuration Management
- Navigation
- Communication
- Perform Required Checklists
- Determine Landing Weight and Fuel

TACCO/SOFM

- Maintain Look-Out Doctrine
- Assist in Checklist
- Assist in Communication/Navigation
- Monitor Approach on Radar
- Call Out Critical Flight Parameters
- Monitor Fuel

SENSO

- Mointor and Assist Checklist Compliance

TABLE 2-6

DETAILED CREW FUNCTIONAL RESPONSIBILITIES - ANTISUBMARINE WARFARE (CONT'D)

FINAL APPROACH/TRANSITION

Pilot

- o Control Angle of Attack
- o Configuration Management
- o Energy Management
- o Navigation
- o Communication

TACCO/SOFM

- o Maintain Look-Out Doctrine
- o Assist Nav/Comm
- o Report on Progress
- o CAll Out Critical Flight Parameters
- o Provide Pilot with Missed Approach, Wave-Off, and Emergency Procedures as Required

SENSO

- o Assist as Directed

TABLE 2-6

DETAILED CREW FUNCTIONAL RESPONSIBILITIES - ANTISUBMARINE WARFARE (CONT'D)

LANDING/HOVER

Pilot

- Landing Mode Switching
- Configuration Management
- Control Sink Rate
- Monitor Limit and Margin Information and Take Corrective Action
- Position Control with Respect to Ship
- Communication with Shipboard Handlers
- Secure Checklist Compliance

TACCO/SOFM

- Maintain Look-Out Doctrine
- Monitor Progress
- Call Out Critical Flight Parameters, Margins and Limits
- Assist in Secure Checklist Compliance

SENSO

- Assist in Secure Checklist Compliance

TABLE 2-7

INFORMATION DISTRIBUTION REQUIREMENTS

MISSION PHASE	SIGNAL INTERFACE DATA	PILOT	OPERATOR #1	OPERATOR #2
Pre Take Off	FLIGHT INFORMATION			
	Safety of Flight			
	Position (Flight Profile)			
	Navigation	X	X	
	Energy Management	X	X	
	Communication	X	X	
	ENGINE HEALTH			
	Speeds	X	X	
	Temperatures	X	X	
	Oil Condition	X	X	
	TACTICAL INFORMATION			
	Position (Tactical)		X	X
	Navigation (Global)	X	X	X
	Non-Acoustic Sensors		X	X
	Acoustic Sensors		X	X
	Contact Status (Target)			
	Contact Status (Threat)			
	Stores Status	X	X	
	AIRCRAFT/EQUIPMENT STATUS			
	Aircraft Configuration	X	X	
	Systems Status	X	X	X

TABLE 2-7

INFORMATION DISTRIBUTION REQUIREMENTS CONT'D.

MISSION PHASE	SIGNAL INTERFACE DATA	PILOT	OPERATOR #1	OPERATOR #2
Take Off and Climb Out	FLIGHT INFORMATION			
	Safety of Flight	X	X	
	Position (Flight Profile)	X		
	Navigation	X	X	
	Energy Management	X	X	
	Communication	X	X	
	ENGINE HEALTH			
	Speeds	X	X	
	Temperatures	X	X	
	Oil Condition	X	X	
	TACTICAL INFORMATION			
	Position (Tactical)		X	X
	Navigation (Global)	X	X	X
	Non-Acoustic Sensors		X	X
	Acoustic Sensors			
	Contact Status (Target)			
	Contact Status (Threat)	X	X	
	Stores Status			
	AIRCRAFT/EQUIPMENT STATUS			
	Aircraft Configuration	X	X	
	Systems Status	X	X	X

TABLE 2-7

INFORMATION DISTRIBUTION REQUIREMENTS CONT'D

MISSION PHASE	SIGNAL INTERFACE DATA	PILOT	OPERATOR #1	OPERATOR #2
Enroute to Station	FLIGHT INFORMATION			
	Safety of Flight	X		
	Position (Flight Profile)			
	Navigation	X		
	Energy Management	X		
	Communication	X		
	ENGINE HEALTH			
	Speeds	X		
	Temperatures	X		
	Oil Condition	X		
	TACTICAL INFORMATION			
	Position (Tactical)		X	X
	Navigation (Global)	X	X	X
	Non-Acoustic Sensors		X	X
	Acoustic Sensors		X	X
	Contact Status (Target)			
	Contact Status (Threat)	X	X	
	Stores Status			
	AIRCRAFT/EQUIPMENT STATUS			
	Aircraft Configuration			
	Systems Status	X	X	

TABLE 2-7

INFORMATION DISTRIBUTION REQUIREMENTS CONT'D.

MISSION PHASE	SIGNAL INTERFACE DATA	PILOT	OPERATOR #1	OPERATOR #2
Search and Classification	FLIGHT INFORMATION			
	Safety of Flight	X		
	Position (Flight Profile)	X	X	
	Navigation	X	X	
	Energy Management	X		
	Communication	X		
	ENGINE HEALTH			
	Speeds	X		
	Temperatures	X		
	Oil Condition	X		
	TACTICAL INFORMATION			
	Position (Tactical)	X	X	X
	Navigation (Global)			
	Non-Acoustic Sensors	X	X	X
	Acoustic Sensors		X	X
	Contact Status (Target)		X	X
	Contact Status (Threat)	X	X	X
	Stores Status		X	X
	AIRCRAFT/EQUIPMENT STATUS			
	Aircraft Configuration	X		
	Systems Status	X		

TABLE 2-7

INFORMATION DISTRIBUTION REQUIREMENTS CONT'D.

MISSION PHASE	SIGNAL INTERFACE DATA	PILOT	OPERATOR #1	OPERATOR #2
Localization	FLIGHT INFORMATION			
	Safety of Flight	X		
	Position (Flight Profile)	X		
	Navigation	X		
	Energy Management	X		
	Communication			
	ENGINE HEALTH			
	Speeds	X		
	Temperatures	X		
	Oil Condition	X		
	TACTICAL INFORMATION			
	Position (Tactical)	X	X	X
	Navigation (Global)		X	X
	Non-Acoustic Sensors		X	X
	Acoustic Sensors		X	X
	Contact Status (Target)		X	X
	Contact Status (Threat)	X	X	X
	Stores Status	X	X	X
	AIRCRAFT/EQUIPMENT STATUS			
	Aircraft Configuration	X		
	Systems Status	X		

TABLE 2-7

INFORMATION DISTRIBUTION REQUIREMENTS CONT'D.

MISSION PHASE	SIGNAL INTERFACE DATA	PILOT	OPERATOR #1	OPERATOR #2
Tracking and Attack	FLIGHT INFORMATION			
	Safety of Flight	X		
	Position (Flight Profile)	X		
	Navigation	X		
	Energy Management	X		
	Communication			
	ENGINE HEALTH			
	Speeds	X		
	Temperatures	X		
	Oil Condition	X		
	TACTICAL INFORMATION			
	Position (Tactical)	X	X	X
	Navigation (Global)		X	X
	Non-Acoustic Sensors		X	X
	Acoustic Sensors		X	X
	Contact Status (Target)		X	X
	Contact Status (Threat)	X	X	X
	Stores Status	X	X	X
	AIRCRAFT/EQUIPMENT STATUS			
	Aircraft Configuration	X		
	Systems Status	X		

TABLE 2-7

INFORMATION DISTRIBUTION REQUIREMENTS CONT'D.

MISSION PHASE	SIGNAL INTERFACE DATA	PILOT	OPERATOR #1	OPERATOR #2
Climb Out and Return to Ship	FLIGHT INFORMATION			
	Safety of Flight	X	X	
	Position (Flight Profile)	X		
	Navigation	X	X	
	Energy Management	X	X	
	Communication	X	X	
	ENGINE HEALTH			
	Speeds	X		
	Temperatures	X		
	Oil Condition	X		
	TACTICAL INFORMATION			
	Position (Tactical)			X
	Navigation (Global)			
	Non-Acoustic Sensors			X
	Acoustic Sensors			
	Contact Status (Target)			X
	Contact Status (Threat)	X	X	X
	Stores Status			
	AIRCRAFT/EQUIPMENT STATUS			
	Aircraft Configuration	X	X	
	Systems Status	X	X	

TABLE 2-7

INFORMATION DISTRIBUTION REQUIREMENTS CONT'D.

MISSION PHASE	SIGNAL INTERFACE DATA	PILOT	OPERATOR #1	OPERATOR #2
Letdown	FLIGHT INFORMATION			
	Safety of Flight	X	X	
	Position (Flight Profile)	X	X	
	Navigation	X	X	
	Energy Management	X	X	
	Communication	X	X	
	ENGINE HEALTH			
	Speeds	X	X	
	Temperatures	X	X	
	Oil Condition	X	X	
	TACTICAL INFORMATION			
	Position (Tactical)			
	Navigation (Global)			
	Non-Acoustic Sensors		X	X
	Acoustic Sensors			X
	Contact Status (Target)			
	Contact Status (Threat)			
	Stores Status			
	AIRCRAFT/EQUIPMENT STATUS			
	Aircraft Configuration	X	X	
	Systems Status	X	X	X

TABLE 2-7

INFORMATION DISTRIBUTION REQUIREMENTS CONT'D.

MISSION PHASE	SIGNAL INTERFACE DATA	PILOT	OPERATOR #1	OPERATOR #2
Initial Approach	FLIGHT INFORMATION			
	Safety of Flight	X	X	
	Position (Flight Profile)	X	X	
	Navigation	X	X	
	Energy Management	X	X	
	Communication	X	X	
	ENGINE HEALTH			
	Speeds	X	X	
	Temperatures	X	X	
	Oil Condition	X	X	
	TACTICAL INFORMATION			
	Position (Tactical)			
	Navigation (Global)			
	Non-Acoustic Sensors		X	X
	Acoustic Sensors			X
	Contact Status (Target)			
	Contact Status (Threat)			
	Stores Status			
	AIRCRAFT/EQUIPMENT STATUS			
	Aircraft Configuration	X	X	
	Systems Status	X	X	X

TABLE 2-7

INFORMATION DISTRIBUTION REQUIREMENTS CONT'D.

MISSION PHASE	SIGNAL INTERFACE DATA	PILOT	OPERATOR #1	OPERATOR #2
Final Approach and Transition	FLIGHT INFORMATION			
	Safety of Flight	X	X	
	Position (Flight Profile)	X	X	
	Navigation	X	X	
	Energy Management	X	X	
	Communication	X	X	
	ENGINE HEALTH			
	Speeds	X	X	
	Temperatures	X	X	
	Oil Condition	X	X	
	TACTICAL INFORMATION			
	Position (Tactical)			
	Navigation (Global)			
	Non-Acoustic Sensors			
	Acoustic Sensors			
	Contact Status (Target)			
	Contact Status (Threat)			
	Stores Status			
	AIRCRAFT/EQUIPMENT STATUS			
	Aircraft Configuration	X	X	
	Systems Status	X	X	

TABLE 2-7

INFORMATION DISTRIBUTION REQUIREMENTS CONT'D.

MISSION PHASE	SIGNAL INTERFACE DATA	PILOT	OPERATOR #1	OPERATOR #2
Hover and Landing	FLIGHT INFORMATION			
	Safety of Flight	X	X	
	Position (Flight Profile)	X	X	
	Navigation	X	X	
	Energy Management	X	X	
	Communication	X	X	
	ENGINE HEALTH			
	Speeds	X	X	
	Temperatures	X	X	
	Oil Condition	X	X	
	TACTICAL INFORMATION			
	Position (Tactical)			
	Navigation (Global)			
	Non-Acoustic Sensors			
	Acoustic Sensors			
	Contact Status (Target)			
	Contact Status (Threat)			
	Stores Status			
	AIRCRAFT/EQUIPMENT STATUS			
	Aircraft Configuration	X	X	
	Systems Status	X	X	

FIGURE 2-16 POTENTIAL AIDS STUDY SEQUENCE

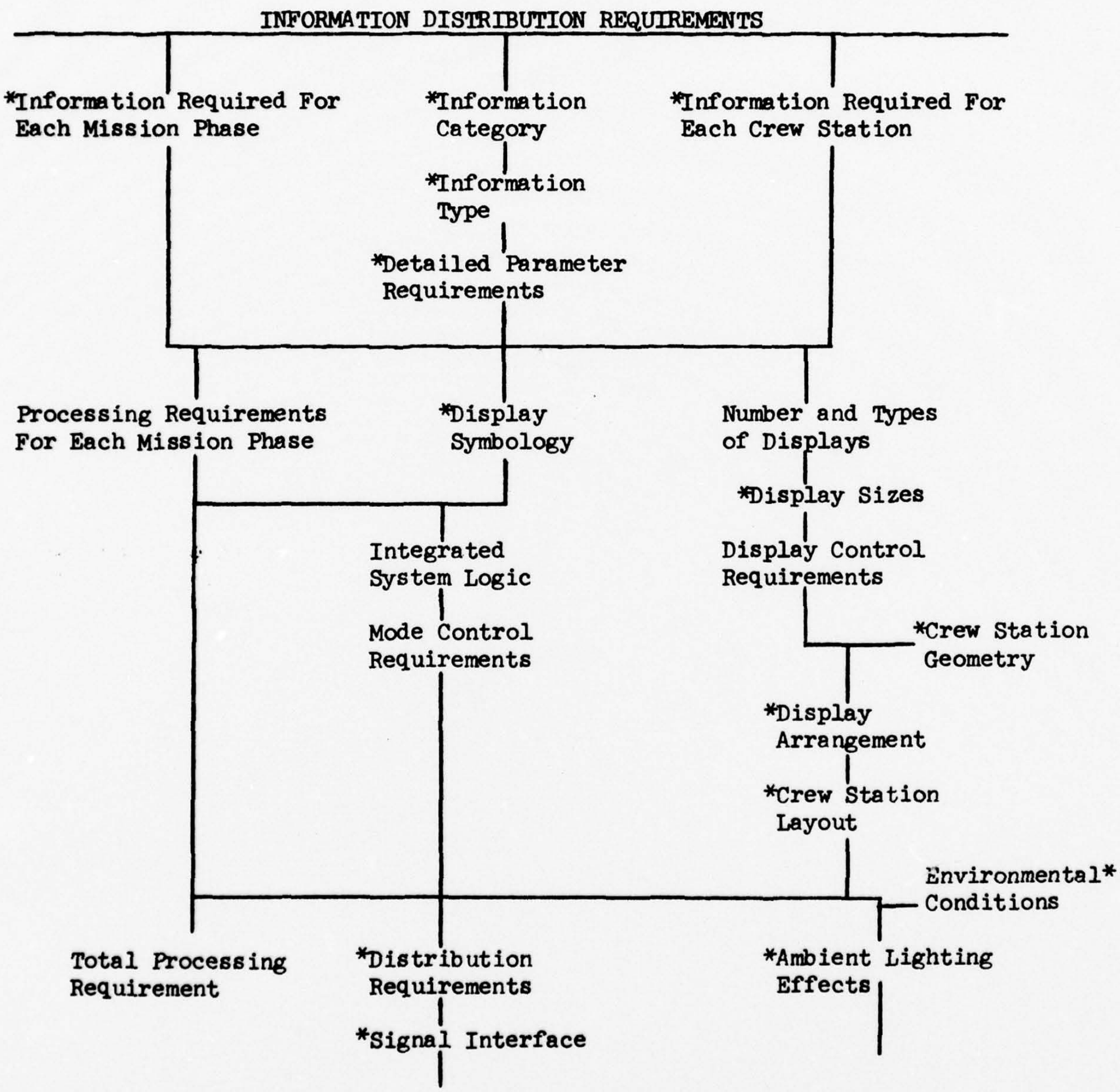


TABLE 2-8

PRIMARY ASW MISSION AND FLIGHT PARAMETERS

ENGINE PARAMETERS

- Engine Core Speeds
- EPR
- Fuel Flow Rates
- Turbine Inlet Temp./Turbine Outlet Temp.
- Oil Temp.
- Oil Pressure
- Oil Quantity

NAV/FLIGHT PARAMETERS

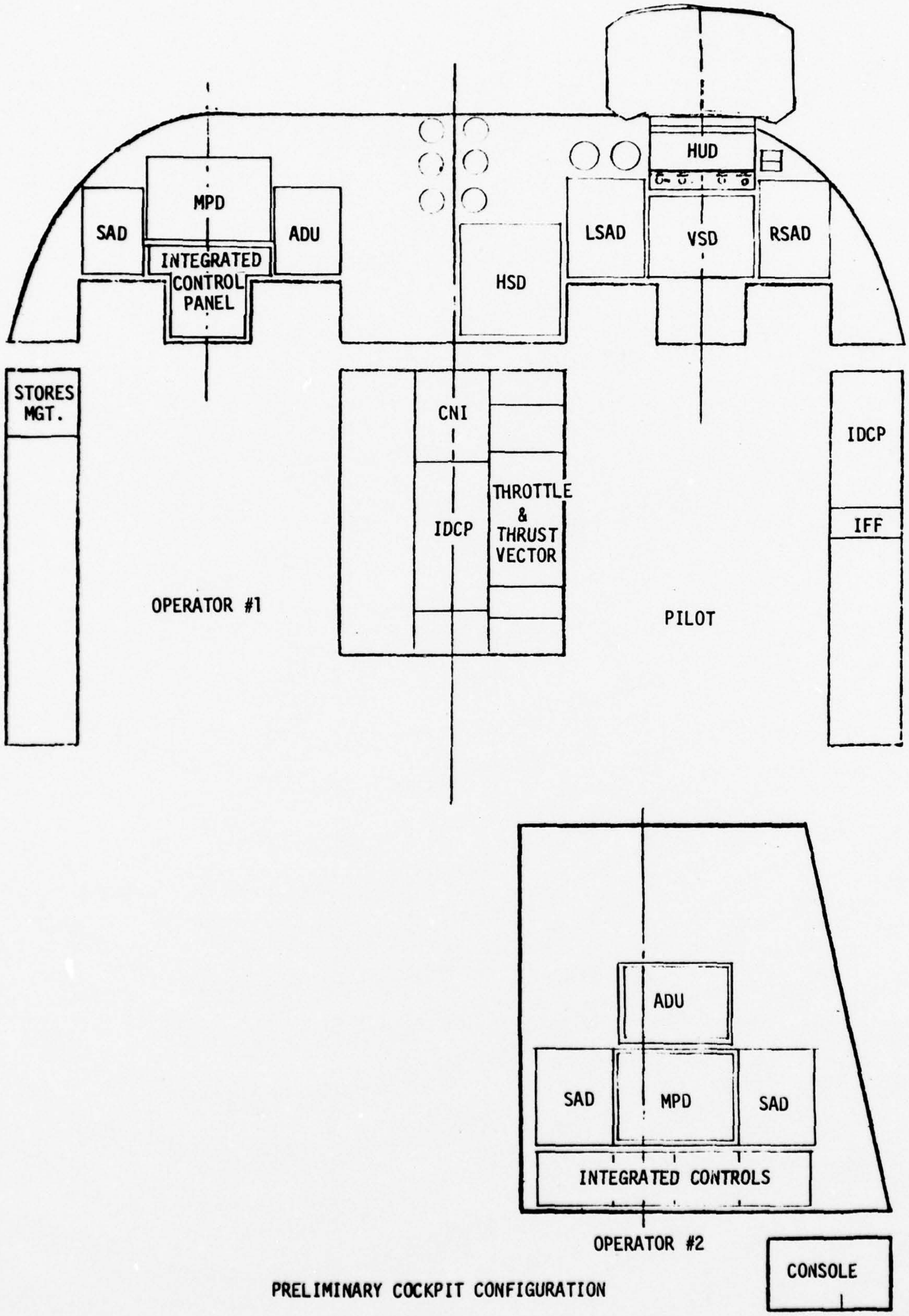
- Attitude
- Angle of Attack
- Baro Alt.
- Radar Alt.
- Airspeed Indicated
- Airspeed, Mach
- Ground Speed - Direction
- Rate of Turn
- Lateral Acceleration
- Steering-Command
- Vertical Velocity
- Vertical Flightpath Deviation
- Lateral Flightpath Deviation
- Heading
- Distance to Landing Site
- Map Location
- Translational Velocities
- Wind Speed - Direction
- Communication Frequencies
- Landing Site Relative to A/C Position
- LORAN Information
- TACAN Information
- Thrust Vector Angle
- INS Information
- Control Authority Remaining (Margins)
- How-Goes-It (Mission Progress)
- Horizon Line
- COMSAT Information

TACTICAL INFORMATION

- JTIDS Information
- TIES Information
- Map
- Radar
- FLIR
- ESM Information
- L^3TV
- Search Stores
- Attack Stores
- Localization Track
- Search Mode
- Data Link
- ECM
- Sonobuoy Information
- MAD
- Checkpoints
- Aircraft Position
- Aircraft Track
- Contact Classification
- Contact Information
- Commands, Computed
- Heading
- Ground Track
- Course
- Ground Speed
- Range to Objective
- Command Time to Objective
- Checklists
- IFF

STATUS

- Landing Gear Status
- Flap Position
- Trim Position
- Master Systems Status
- Flight Control System Status
- Fuel Status
- Electrical System Status
- Hydraulic System Status
- Nav/Comm System Status



PRELIMINARY COCKPIT CONFIGURATION

FIGURE 2-17

Briefly, the major factor in this decision was the poor height perception over the water while translating inboard from the port (left) side of aviation ships (carriers) if the pilot is in the left seat. The approach is made from the port side of the ship to avoid the island. Height perception from the right seat is much better because the pilot can see the deck.

Initial findings related to the preliminary cockpit layout indicated that the display locations and instrument board area is greatly influenced by the large over-the-nose vision requirements for the Type "A" V/STOL as imposed by MIL-STD-850. Preliminary indications are that the currently proposed AIDS hardware may offer several areas of physical incompatibilities in the instrument panel and consoles. One obvious inconsistency with regard to physical dimensions and mounting visibility is the Integrated Display Control Panel (IDCP). The currently proposed IDCP is 8.5 inches wide and 15.5 inches long and in, therefore, incompatible with the standard six inch wide consoles called out in MS25212. Further investigation into the proposed IDCP revealed the switch size and spacing does not comply with MIL-STD-1472, and if redesigned to meet this specification, the panel size would grow ever larger. Based on the preliminary findings associated with IDCP physical characteristics, it is recommended that the AIDS system design contractor evaluate a modular control panel concept, compatible with MIL-SPEC requirements, in order to reduce the console mounted panels to the required standard dimensions. Some modules may have to be mounted remotely. A standard modular design concept would yield not only the desired installation versatility for the V/STOL application, but would also lend itself to possible application to other currently operational Navy aircraft. The physical characteristics of the AIDS hardware as it applies to the V/STOL installation is evaluated in further detail in Section 2.2.3.

2.2.2 V-Mode Considerations

During the application of the current AIDS concepts to the Type A V/STOL, particular attention was given to the V/STOL vertical mode requirements. Unique V-mode display requirements were evaluated first from the standpoint of AIDS hardware installation in the current Vought V/STOL design. Such things as volume limitations, display size, viewing distance and over-the-nose vision were considered. Next, the HUD field-of-view (FOV) and accuracy requirements were evaluated and compared to V/STOL vision plots and V/STOL flight test data. Finally, the Helmet Mounted Display (HMD) was considered as a possible supplementary display for the V/STOL application of AIDS, both from a requirements and utilization standpoint.

2.2.2.1 AIDS Display Size Considerations

A preliminary look at an installation of the proposed AIDS Holographic HUD and VSD into the current Vought Type "A" V/STOL design revealed certain incompatibilities. It should be noted that the incompatabilities are not peculiar to the Vought design, but are the result of currently specified vision and cockpit geometry requirements. The vertical field-of-view (FOV) of the HUD, for example, is specified as 20° (Reference 9) and the over-the-nose vision requirement for the V/STOL is 25° (MIL-STD-850). Also, as shown in Figure 2-18, the HUD installation extends over two inches into the ejection envelope with a 24 inch viewing distance from the flight eye position. In order to obtain the specified 22 inch viewing distance the HUD would extend over 4 inches into the ejection envelope. The minimum acceptable vertical FOV for the HUD should be 3° above the horizontal and 25° down, or a total instantaneous vertical FOV of 28°. In order to achieve this vertical FOV and move the HUD forward out of the ejection envelope, the viewing distance would increase to approximately 27 inches and require a considerable increase in the size of the Holographic lens or combining glass. Also from Figure 2-18 it can be seen that with the HUD protruding into the cockpit to obtain the minimum pilot viewing distance, a portion of the instrument panel is blocked from view, requiring the VSD installation to be lowered some 3 inches for full visibility by the pilot. A plan view of the instrument panel with the HUD and VSD installed is shown in Figure 2-19. The plan view also shows the 8-1/2 inch width of the VSD extends into the leg slots because of the 3 inch lower installation requirement. Further study of the installation will be required prior to an optimum recommendation for corrective action, however, such things as raising the HUD above the cowl line and allowing an acceptable

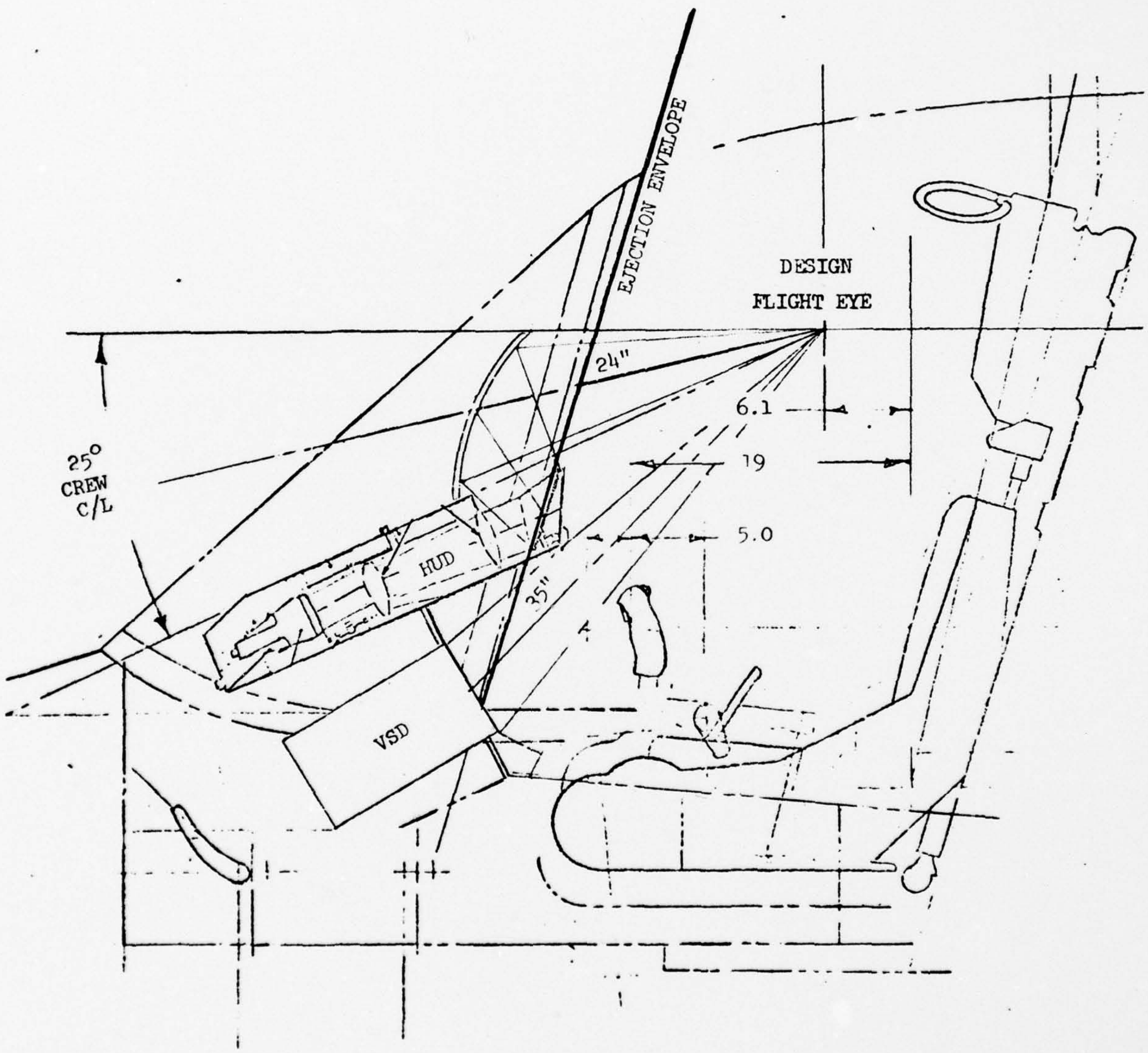


FIGURE 2-18 HUD INSTALLATION - V/STOL

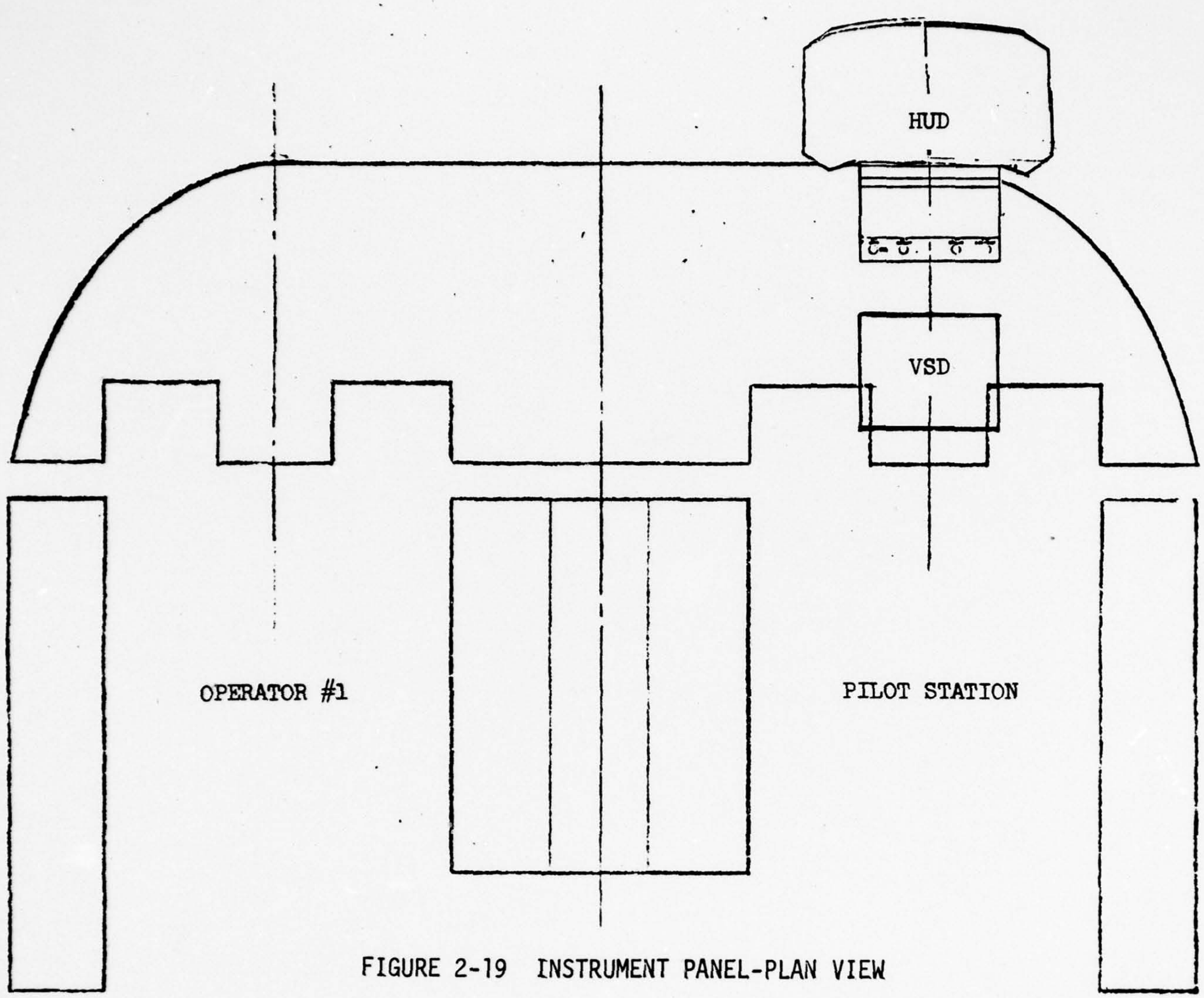


FIGURE 2-19 INSTRUMENT PANEL-PLAN VIEW

encroachment into the ejection envelope, or the possibility of a swiveled HUD mount, are areas to be considered. Also, a physical reconfiguration of the AIDS hardware to allow the installation of the full AIDS complement of displays into the V/STOL pilot station may be considered.

2.2.2.2 AIDS HUD Field of View and HMD Considerations

The HUD vertical field-of-view (FOV) requirements were discussed briefly in the previous section. From the standpoint of the horizontal FOV, the proposed AIDS HUD specifies a 35° instantaneous horizontal FOV at a viewing distance of 22 inches (Reference 9). When considering the pilot of a V/STOL type aircraft in a slow speed flight regime or hover mode, the maximum attainable lateral field-of-view for the HUD must be a primary goal in the original design. As reported in reference (1), the limited lateral FOV of the HUD was a major restriction in the approach and landing operation of the V/STOL (CL-84) aircraft instrument approach evaluation. The 35° horizontal FOV reportedly attainable with the proposed holographic HUD is a major improvement over the current CRT/Refractive optics type and should yield extended HUD capability for V-mode operations. Figure 2-20 is an external vision plot of the Vought V-530 V/STOL design showing the holographic HUD combining glass superimposed in the pilot's external vision. Figure 2-21 is an expanded scale plot of the V-530 pilot's view of a DD 963 air capable ship, showing the pilot's view as seen 250 feet from touchdown, 82 feet altitude and 30° from the ship's heading. The holographic HUD combiner has been superimposed on the plot as a representation of the improved field-of-view and thus the usefulness of the HUD in a V/STOL type aircraft. The calculator plot is also presented as an example of the calculator/plotter technique of investigating the relationship of external vision to cockpit geometry and HUD field-of-view, as well as Helmet Mounted Display utilization techniques.

Considering further the utilization of a fixed HUD in a V/STOL type aircraft, it becomes obvious that the HUD usefulness will be restricted to conventional flight operations and to some extent the slow flight regimes during STOL operations on carriers and landing strips. For V-mode operation such as transition from normal flight to hover and vertical landing, the use

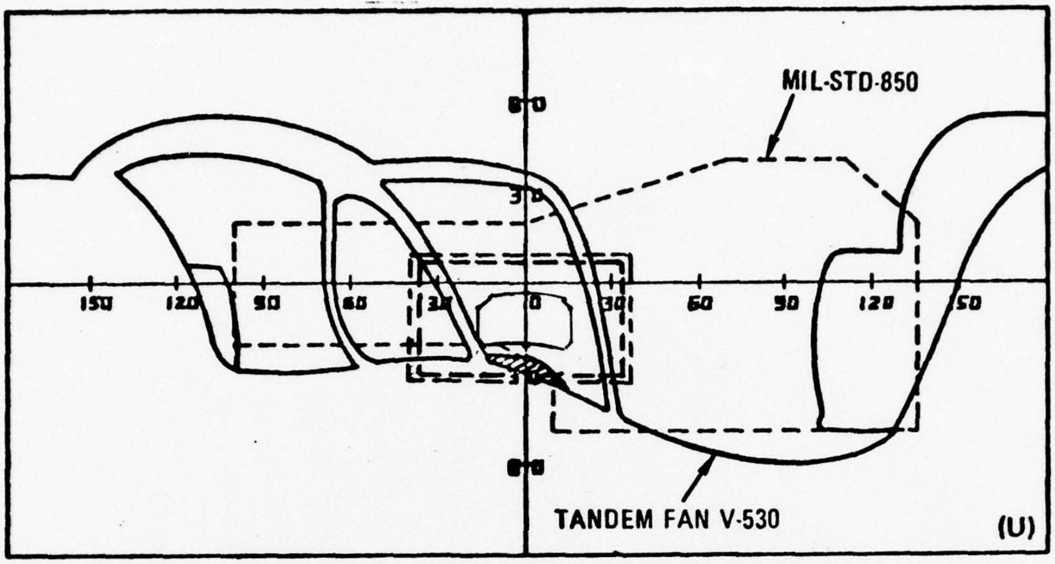


FIGURE 2-20 VOUGHT TANDEM FAN V-530 EXTERNAL VISION PLOT WITH HOLOGRAPHIC HUD COMBINING GLASS SUPERIMPOSED.

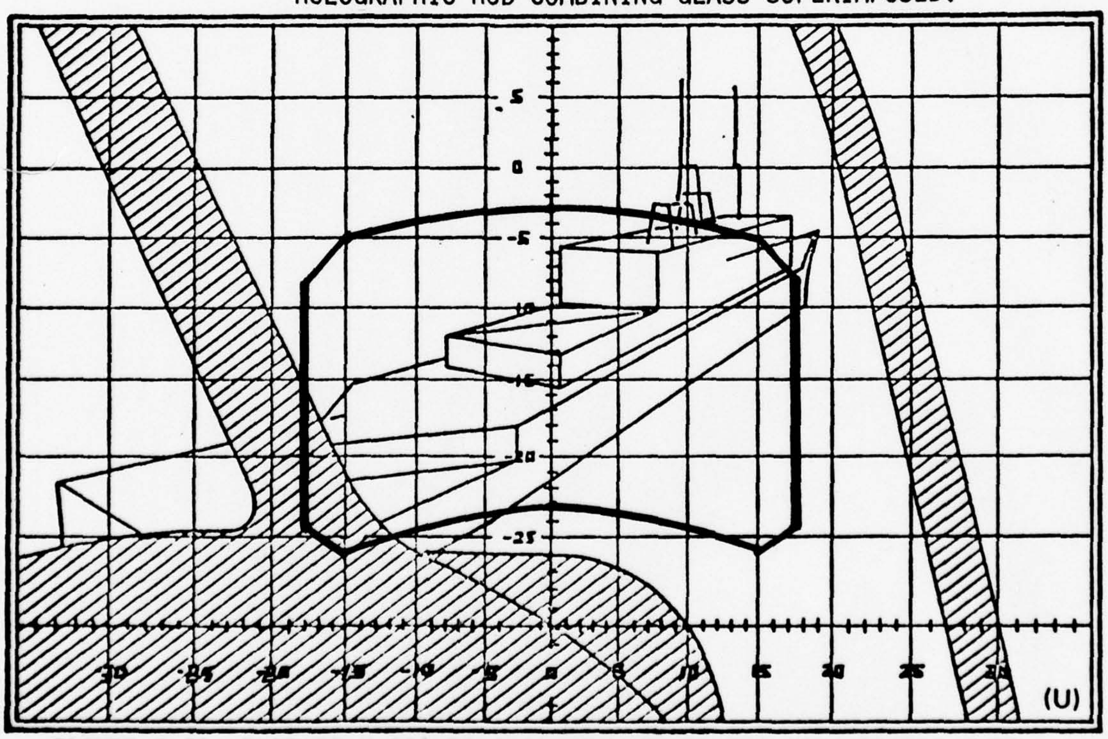


FIGURE 2-21 PLOT OF V-530 PILOT'S VIEW OF DD 963 AIR CAPABLE SHIP SHOWS PILOT'S VIEW 250 FEET FROM TOUCHDOWN POINT, 82 FEET ALTITUDE ABOVE WATER, 30° FROM SHIP HEADING AND AT LEVEL ATTITUDE. CALCULATOR-PLOTTER TECHNIQUE CAN BE USED TO INVESTIGATE EXTERNAL VISION VERSUS COCKPIT GEOMETRY AND HUD FIELD-OF-VIEW. HELMET MOUNTED DISPLAY UTILIZATION MAY ALSO BE INVESTIGATED.

of a Helmet Mounted Display (HMD) to supplement the head-up pilot cueing requirement, appears to be a manditory feature. The HMD requirements and utilization in a V/STOL type aircraft was given only a cursory evaluation in this study because the HMD was not identified as a part of the AIDS when this study was initiated. However, the HMD evaluation yielded several factors which made it a candidate for inclusion into the list of required AIDS displays. The HMD accurach requirement for the V/STOL is not as stringent as that for a fighter/attack role. This is because the helment display in the V/STOL would not be for weapon aiming but rather a head-up pilot cueing and command following device to interact with the flight control system during IFR and/or V-mode operations. The HMD utilization would be for aircraft operations where the pilot's line-of-sight is out of the field-of-view of the HUD and would be electronically cross coupled with the HUD such that as the pilot's line-of-sight swept from aircraft boresight to 90° starboard and down 45°, the HUD symbology would be automatically blanked and the helmet display would brighten-up as the pilot's line-of-sight increased to greater than 20° to starboard. The symbology repertoire for the helmet display would be limited to aircraft systems and flying qualities information such as energy management (fuel low warning), sink rate, altitude, position over landing spot, translational velocity vectors oriented to the real world, and system status such as flight control system health monitor. Symbology for the HMD as well as integrated system logic and use are subjects requiring extensive additional study and simulation before incorporation as a useful aid to the pilot of V/STOL type aircraft during V-mode operations. It is suggested that a starting point for further HMD studies applicable to V/STOL aircraft would be to extend the new calculator/plotter vision technique described earlier to include the HUD and HMD utilization and symbology development for V-mode operations.

2.2.3 Physical Characteristics

Using the NADC supplied AIDS Advanced Development Model (ADM) design data, a conceptual description of an AIDS configuration in the current Vought Type "A" V/STOL was developed from the standpoint of size, weight, volume and cooling compatibility. The evaluation was divided into three separate categories to allow specific attention to each of the AIDS components. The pilot's station with the associated AIDS displays and controls was considered first, followed by the installation of the Modular Integrated Display Electronics Racks (MIDER's) and associated processors in the avionics bay, and finally the weight, power and cooling requirements for the ADM hardware were considered, as they apply to the Type "A" V/STOL prototype aircraft. The latest information available on the physical characteristics of the ADM version of the AIDS hardware was compiled in tabular form (see Table 2-9) for this evaluation. Where recent design changes in the ADM hardware have been made, the original concept as well as the alternate approach were included in the table for comparison. For example, the Situation Advisory Displays (SAD's) were originally planned to be flat panel liquid crystal displays for the ADM, but have not been designated as CRT devices. The physical characteristics of both are shown in the table. In the case of the AIDS processing elements, the ADM hardware will include two AYK-14 processors external to the MIDER's, thus both types of hardware and the physical characteristics of each are included in the table.

Installation of the proposed AIDS hardware into the V/STOL pilot's station was evaluated using the current Vought proposed V/STOL design concept as a baseline configuration. In the preceding portion of this study under V-mode considerations, it was determined that only the HUD and VSD could be installed on the centerline of the pilot's field-of-view because of the twenty-five degree over-the-nose vision requirement and the consequential reduction in instrument panel area. Therefore, the location of the HSD and the two SAD's for optimum pilot viewing became the major area of concern for installation of AIDS in the V/STOL pilot station. Figure 2-22 shows the installation of the five major pilot displays in the V/STOL pilot station, and emphasizes the incompatibility between the large displays and the relatively small instrument panel. The 6 inch x 8 inch SAD's are the liquid crystal type and are obviously incompatible with the space available. The VSD shown in the figure is only 7 inches by 9 inches because that is the maximum space available, even though the proposed dimensions are 8 x 10 inches. The maximum width of a console between the pilot's knees is seven inches. The HSD has been placed to the left side of the instrument panel simply because of installation restrictions. The shaded area represents that area

TABLE 2-9 AIDS - ADM - PHYSICAL CHARACTERISTICS

HARDWARE DESCRIPTION	NO. PER SYSTEM	TYPE	WEIGHT (POUNDS)	POWER (WATTS)	VOLUME (INCHES) H X W X L	COOLING REQUIREMENTS	COOLING VOLUME (LBS./MIN.)
H.U.D.	ONE	HOLOGRAPHIC	40	100	5.5 X 8 X 2.4"	Cockpit Air Fan	0.27
V.S.D.	ONE	CRT	20	100	7 X 8.5 X 13	Cockpit Air Fan	0.27
H.S.D.	ONE	HOLOGRAPHIC	40	475	11 X 7 X 25	Forced Convection Conditioned Air	1.80
S.A.D.	TWO	LCD	10	25	8 X 6 X 6	Natural Convection	--
		CRT	10 /20	100	9 X 8 X 19	Cockpit Air Fan	0.27
MODE CONTROL PANEL	ONE	LCD	4	5	2.75X5.5X3.125	Natural Convection	--
INTEGRATED CONTROL PANEL	TWO	LCD	24 /48	66	7.5 X10 X10.5	Natural Convection	--
B.I.E.D	ONE	TAPE	*	*	8 X 8.5 X15.5	Natural Convection	--
MIDER	TWO	ADM	38.5 /77	240	15.4X7X15.6/ 1.94	Conditioned Air	0.86
AYK-14	TWO	--	45 /90	450	0.873 ft^3/ 1.75	Forced Convection	*
VIDEO RECORDER	ONE	--	* /25	*	* /1.0	*	*
MASS MEMORY	TWO	BUBBLE	35 /70	109	0.69 ft^3/1.38	Forced Convection	*
H.M.D.	ONE	NADC/ POLHEMUS	8	200	0.68 ft^3	*	*
TOTAL	--	--	442	2835	9.90 ft^3	--	3.47

* DATA NOT AVAILABLE

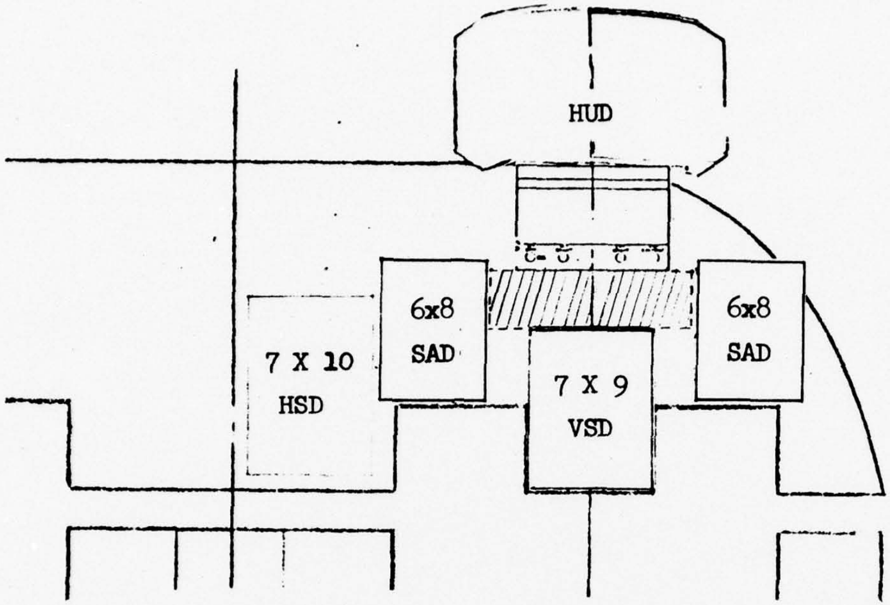


FIGURE 2-22 V/STOL PILOT STATION-LIQUID CRYSTAL SAD'S

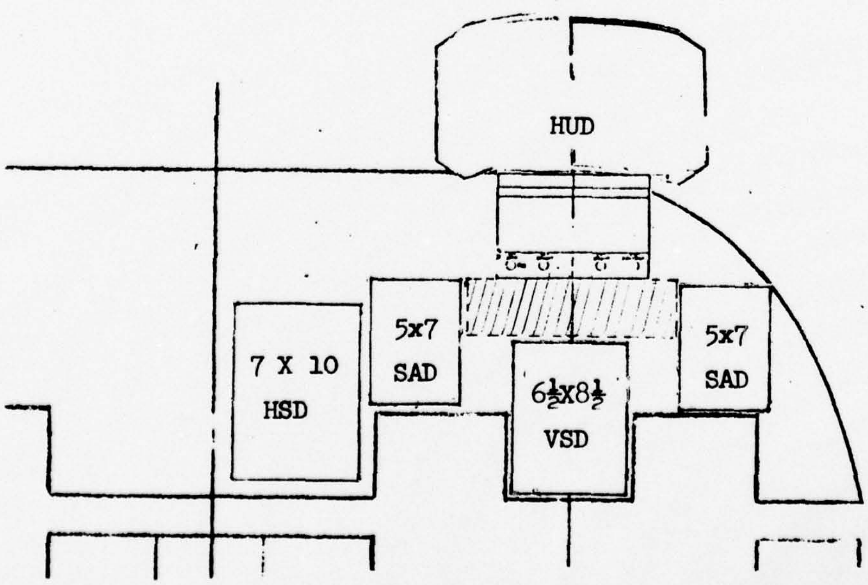


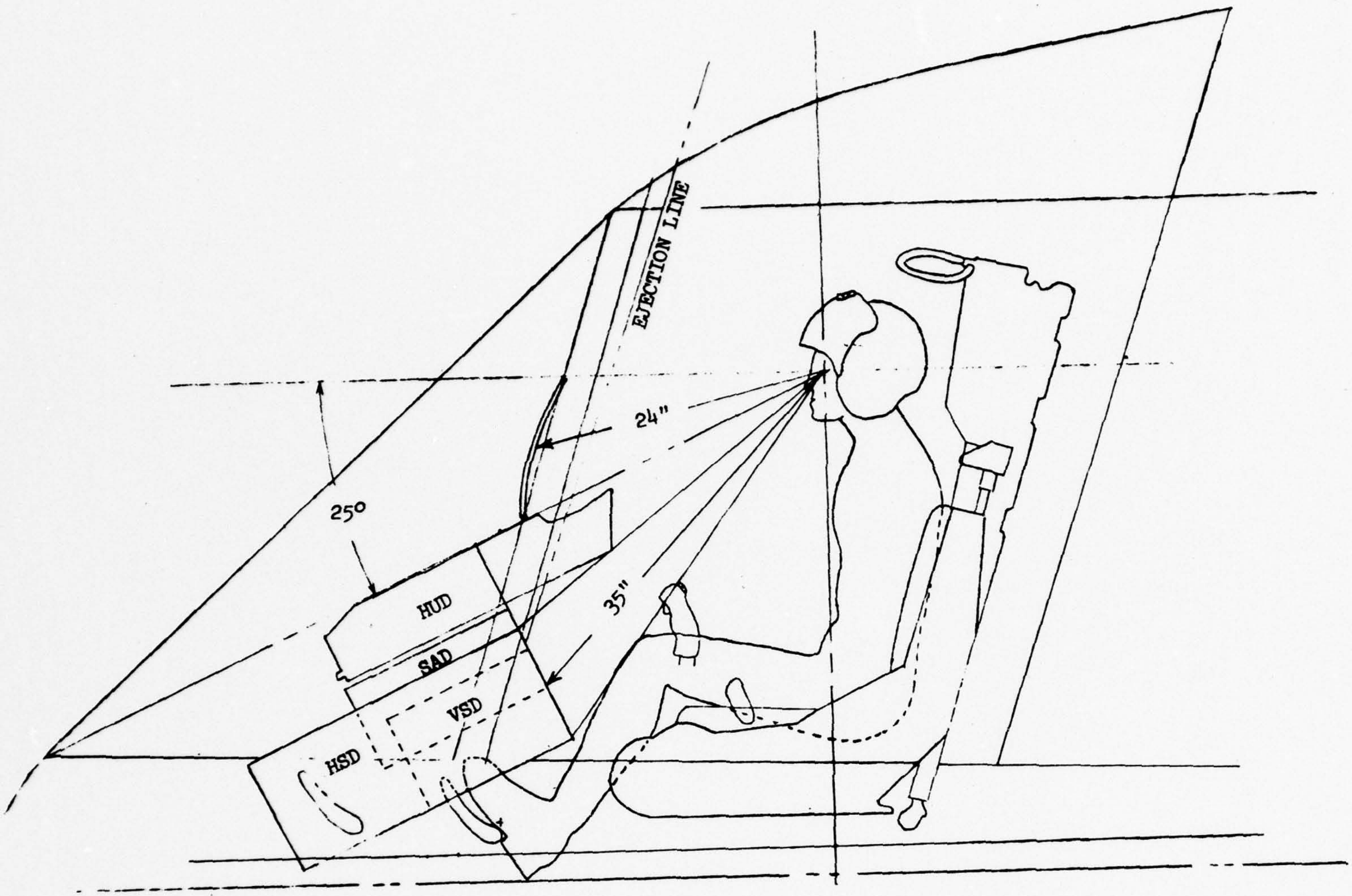
FIGURE 2-23 V/STOL PILOT STATION-CRT TYPE SAD'S

obscured from the pilot's view by the HUD which projects from the instrument board surface.

Figure 2-23 represents a proposed installation of the AIDS hardware in the V/STOL pilot's station based on certain assumptions and alterations to the currently proposed hardware design. The VSD has been reduced in size to 6.5 x 8.5 inches to allow for structural mounting provisions. The two SAD's have been reduced to 5 x 7 inches, which is the proposed dimension for the CRT type SAD, however, the depth of the proposed CRT display is estimated at 15 inches minimum, which extends the SAD into the pilot's leg envelope and obstructs pilot accessibility to the rudder pedals. Figure 2-24 is a scaled layout of the AIDS equipment in the pilot's station, and illustrates the SAD interference with access to the rudder pedals. As mentioned previously, the HUD installation and vertical field-of-view restrictions were discussed in the preceding section on V-mode consideration, however, it should be noted, the viewing distance of 35 inches from the flight eye position to the VSD as well as the down angle is a possible problem area and will require further investigation.

The top view of the V/STOL crew station shown in Figure 2-25 illustrates the off-axis viewing angle of the HSD and SAD. The specification for the HSD calls for a viewing angle of ±15° and in this proposed location the viewing angle is 35° off axis. While directional brightness could be compensated for by the use of a special Fresnel lens, such an adaptation for the pilot's use would eliminate the optional viewing of the HSD by the other crew member in the left seat. The viewing angle for the two SAD's may also present a problem if a CRT type display is selected for use. The viewing angle for a CRT display is usually restricted to ±15°, which in this case is marginal at 20°, and should a contrast filter be used, the normal viewing angle characteristics will vary depending on the type of filter, and if a special Fresnel lens is used for directional brightness, then the two SAD's would not be interchangeable.

As a possible solution to the cockpit installation problems discussed herein, several alternative hardware configurations were considered based on



AIDS INSTALLATION IN V/STOL PILOT'S STATION

FIGURE 2- 24

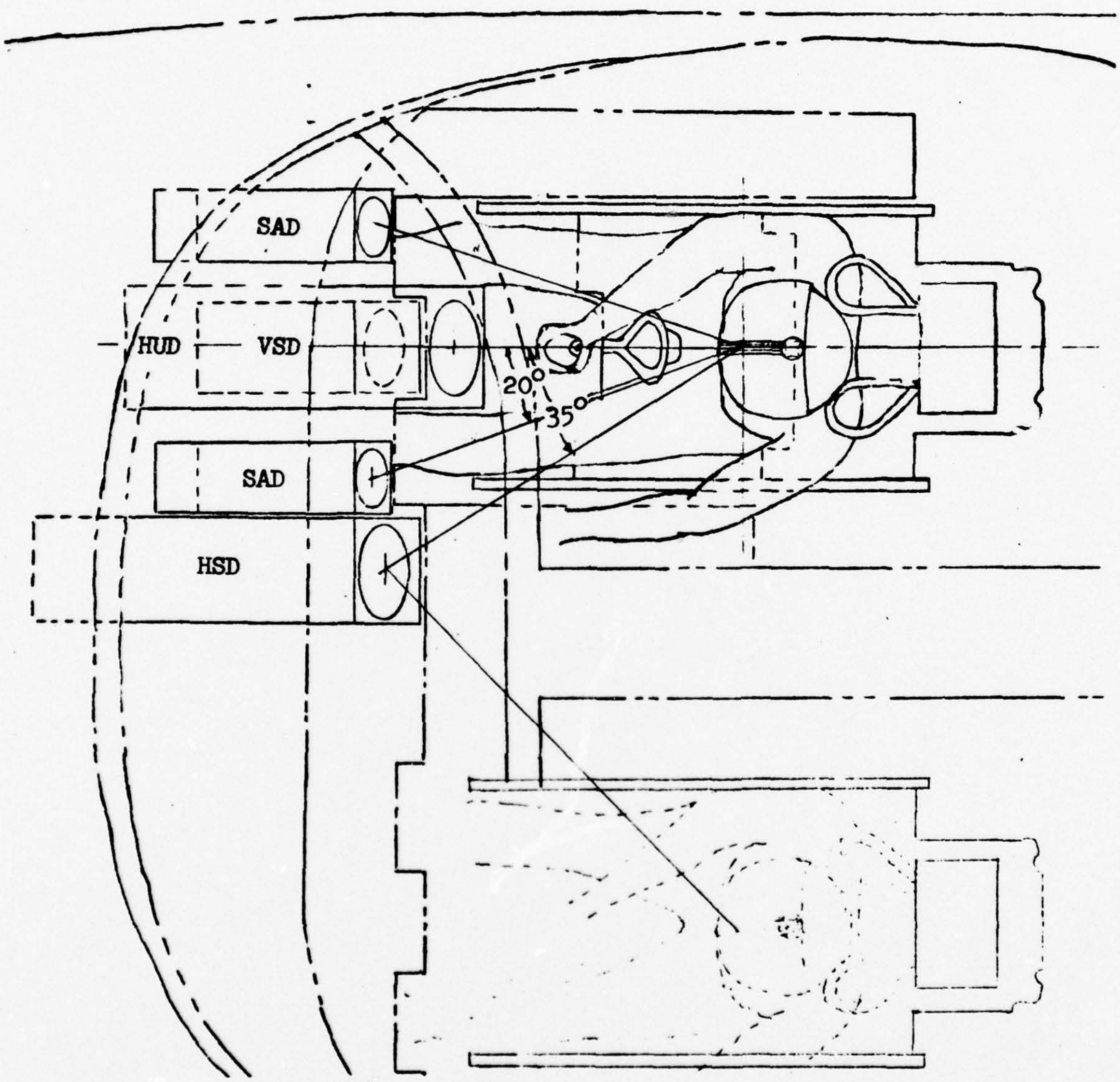


FIGURE 2-25 V/STOL PILOT STATION-TOP VIEW

the three major constraints which are: the physical size of the HUD, the depth of the CRT type SAD, and the overall size of the HSD. The first solution considered in this evaluation was a reconfiguration of the HUD design, this reconfiguration was based on an alternate design suggestion presented by the General Electric Co. in the AIDS System Design Interim Report No. 2 (Reference 9). In the alternate design, the HUD display unit was separated from the holographic combining lens and placed below the VSD. The symbology is projected vertically past the VSD to the combining glass which is mounted independently on the cowling. This configuration would reclaim the obscured instrument panel space, but was found to yield insufficient space saving. Considering the severity of the problems associated with installation and boresighting of the remotely located combining glass as well as relative motion between the two components due to vibration, this approach was set aside as a low priority alternative.

The second alternative considered as a possible solution to the space problem was elimination of the HUD. If the HUD were removed it is quite possible the HSD and VSD could be installed on the centerline of the pilot's vision in the space available. A Helmet Mounted Display (HMD) would then be used for head-up operations and pilot cueing rather than the HUD. However, based on the development status and questions related to operational usage, sole reliance on an HMD system was considered a high risk solution. It was concluded, therefore, that the optimum solution at this point in time was to recommend a serious effort be initiated to reduce the overall size of the AIDS displays for the specific application to a V/STOL type aircraft.

Considering again the AIDS integrated control set (see paragraph 2.2.1.2), it should be pointed out that the width of the integrated control panels as well as the Briefing Information Entry Device (BIED) are currently specified as 10 inches and 8.5 inches in width, respectively, and the specified or standard width for console mounted control panels is six inches per MS25212. It is, therefore, recommended that the design of the console mounted control panels for the AIDS be kept to a standard width to preclude non-standard aircraft design features for AIDS equipment installation.

2.2.3.1 Avionics Bay Installation

Referring again to Table 1-1, the volume for the bay mounted equipment (which includes two MIDER's, two AYK-14's, a video recorder, two mass memory units and the processor for the HMD), is equal to 6.67 cubit feet assuming one cubic foot for the video recorder. A volume of 6.67 cubit feet for the bay equipment in the V/STOL should be no problem at all. However, the mounting location in the aircraft may be the determining factor based on the weight of the equipment and the effect on the center of gravity.

The bay equipment installation evaluation revealed a 19 cubic feet area for avionics equipment installation just below the pilot and operator seats, however, because of the critical nature of the C.G. in the V/STOL, the estimated 270 lbs. of AIDS bay equipment will require installation in the rear avionics bay. Again, volume is no problem in the rear bay with 124 cubic feet available, but the distance to the cockpit is approximately thirty feet, and long cable runs may prove to be a problem area between the AIDS processors and the cockpit displays, especially for the video multiplex busses, and low level digital channels.

2.2.3.2 Weight, Power and Cooling Considerations

The estimated total weight for the AIDS equipped pilot station and the associated bay mounted equipment came to 442 pounds as shown in Table 2-9. The total weight assumed a nominal 25 pounds for the, as yet undefined, video recorder and no estimation was made for the BIED. The total weight of 442 pounds does not seem excessive for the ADM hardware, which will probably fly in the V/STOL prototype aircraft. However, for an operational V/STOL the EDM hardware would require an approximate 25% reduction in overall system weight to meet the target weight established for the pilot displays and controls in the Vought response to the V/STOL RFQ/I. The 25% reduction for the EDM does not appear a critical factor even though it is an important consideration for the V/STOL design.

A possible incompatibility exists from the standpoint of type of power required for the AIDS Advanced Development Model (ADM) hardware. The proposed Vought V/STOL design is equipped with an "Advanced Aircraft Electrical System" (AAES) for which the power generation system is a 270 VDC power source, and at this time it appears that certain of the ADM hardware is not compatible with high voltage DC power. The AYK-14 processors for example will require a separate 3-phase 400 Hz power. The AYK-14 processors for example, will require a separate 3-phase 400 Hz power input unit for each of two processors.

Total power requirement for AIDS does not appear excessive for the proposed V/STOL prototype aircraft, but for the EDM hardware and/or the operational version, the total avionics requirements including mission and core avionics will require an overall weapons system versus generator size study.

Cooling requirements for the ADM hardware are also consolidated in Table 2-9, showing the type of heat transfer recommended for each component and, where applicable, the volume of cooling air required. No major cooling incompatibilities between the V/STOL prototype and the ADM hardware are predicted at this time, however, as the ADM cooling requirements become better defined, additional design work will be required in sizing the aircraft air conditioning capacity.

3.0 INTERFACE INFORMATION

3.1 SIGNAL INTERFACE DATA REVIEW

Prior to actual evaluation of the AIDS Signal Interface Data document, a brief review of current AIDS application alternatives was conducted to clarify possible interface variations. The results revealed four identifiable configurations of AIDS for which the interface requirements could and/or should be evaluated for a specific developmental application. The four alternative configurations for an AIDS interface requirements analysis are listed in Table 3-1 with the major system architectural differences noted. Reference is also made under each alternative to the appropriate figure, which shows the AIDS configuration for that particular application. Table 3-1, and Figures 3-1 through 3-4 emphasize the versatility of the AIDS concept for application to a developmental aircraft. For example, the baseline configuration shown in Figure 3-1 for a single seat attack aircraft, has only to be modified by the addition of two MIDER extension units and one additional set of displays and controls for an extra crew station to yield the developmental V/STOL simulator functional configuration shown in Figure 3-2. For the V/STOL prototype program, the baseline AIDS architecture is again modified as shown in Figure 3-3 and is interfaced with the basic avionics subsystems necessary for the flight characteristics evaluation of the prototype V/STOL. It is anticipated for the V/STOL prototype program, that only flight proven hardware will be used for the flight test phase; therefore, even though the basic AIDS architectural concept is unaltered, several hardware substitutions will be necessary, such as the type of processors and the addition of a co-pilot station equipped with conventional displays and controls for the experimental flight test program. For the operational V/STOL, a conceptual AIDS EDM configuration is shown in Figure 3-4 for an ASW mission. The basic AIDS architecture has again been maintained but with additional capability achieved by the addition of one MIDER and a third crew station.

Having identified the four current alternative applications for AIDS, the subject of interface requirements became a question of priority for the continuing development of the overall concept. The operational version of the

TABLE 3-1
AIDS APPLICATION ALTERNATIVES

(1) Single Seat Attack Aircraft
Hypothetical EDM Configuration
Ref. Aircraft/Equipment Parameters List (Exhibit "B" - Reference 13)
Ref. Figure 3-1

(2) NADC Simulator Configuration
V/STOL Application - ADM Expanded
Ref. Figure 3-2

(3) V/STOL Prototype Program
Single AIDS Equipped Pilot Station
V/STOL ADM Non-Expanded
Ref. Figure 3-3

(4) V/STOL Operational Version
EDM Expanded
Multi-mission Application
Ref. Figure 3-4

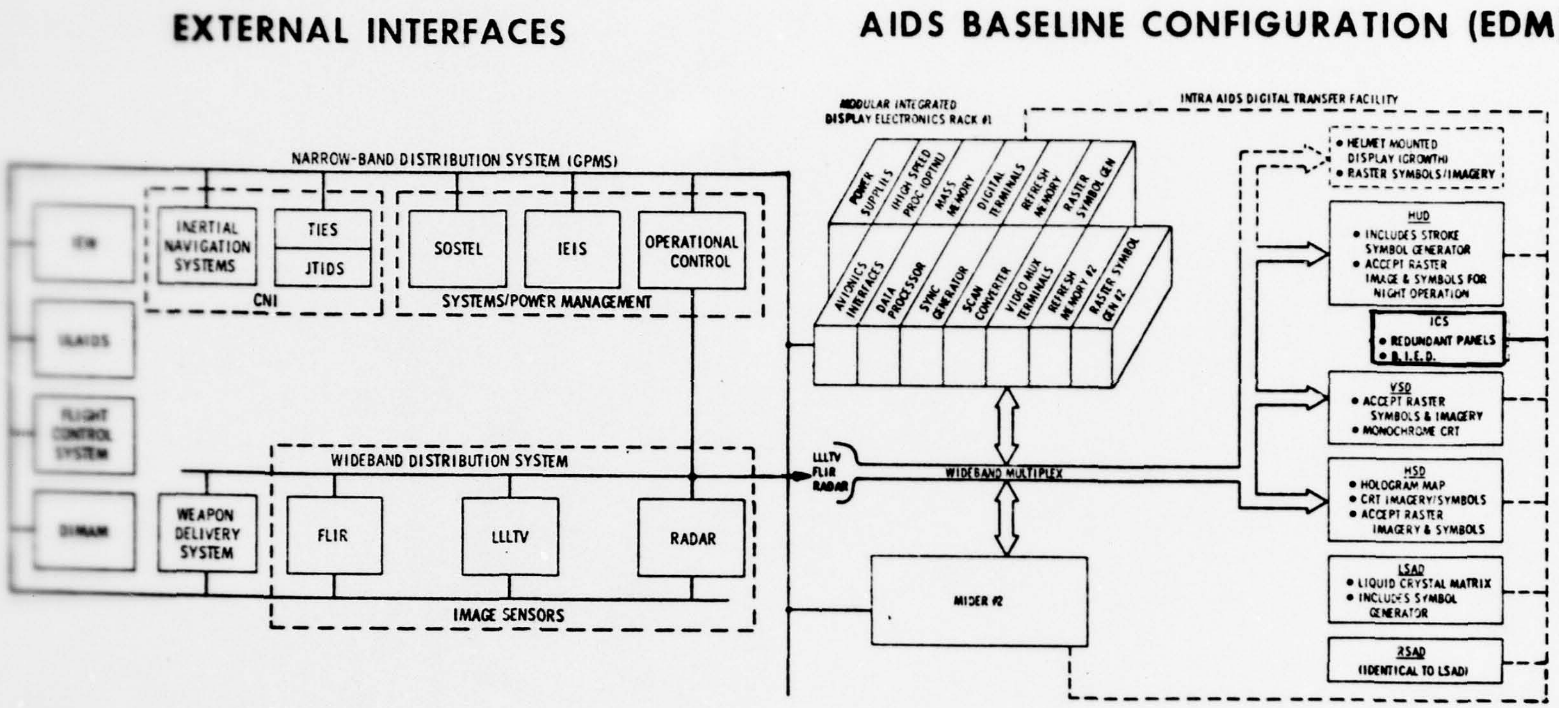


FIGURE 3-1 AIDS APPLICATION-SINGLE SEAT ATTACK

AIDS ADM BLOCK DIAGRAM (REVISED)

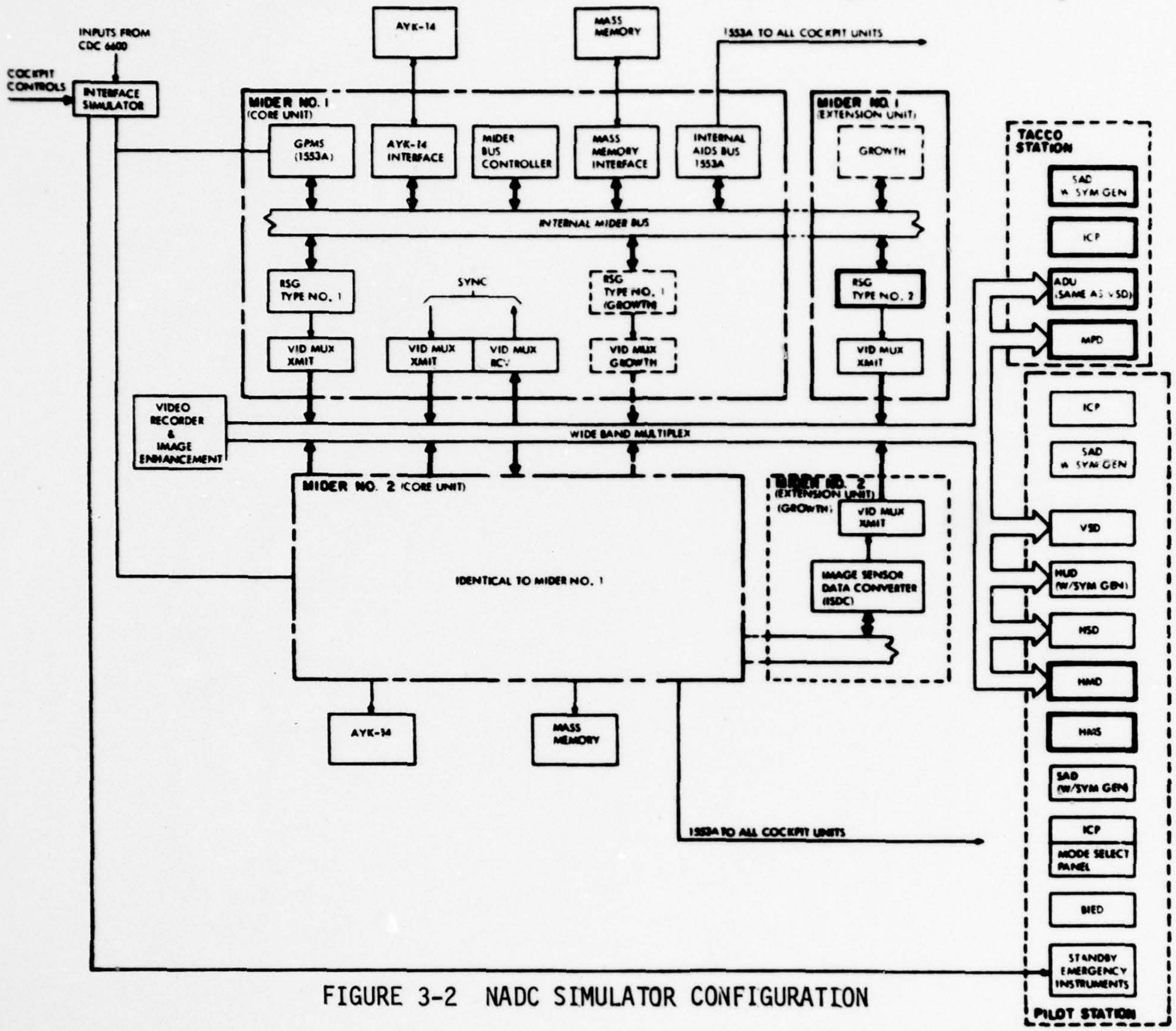


FIGURE 3-2 NADC SIMULATOR CONFIGURATION

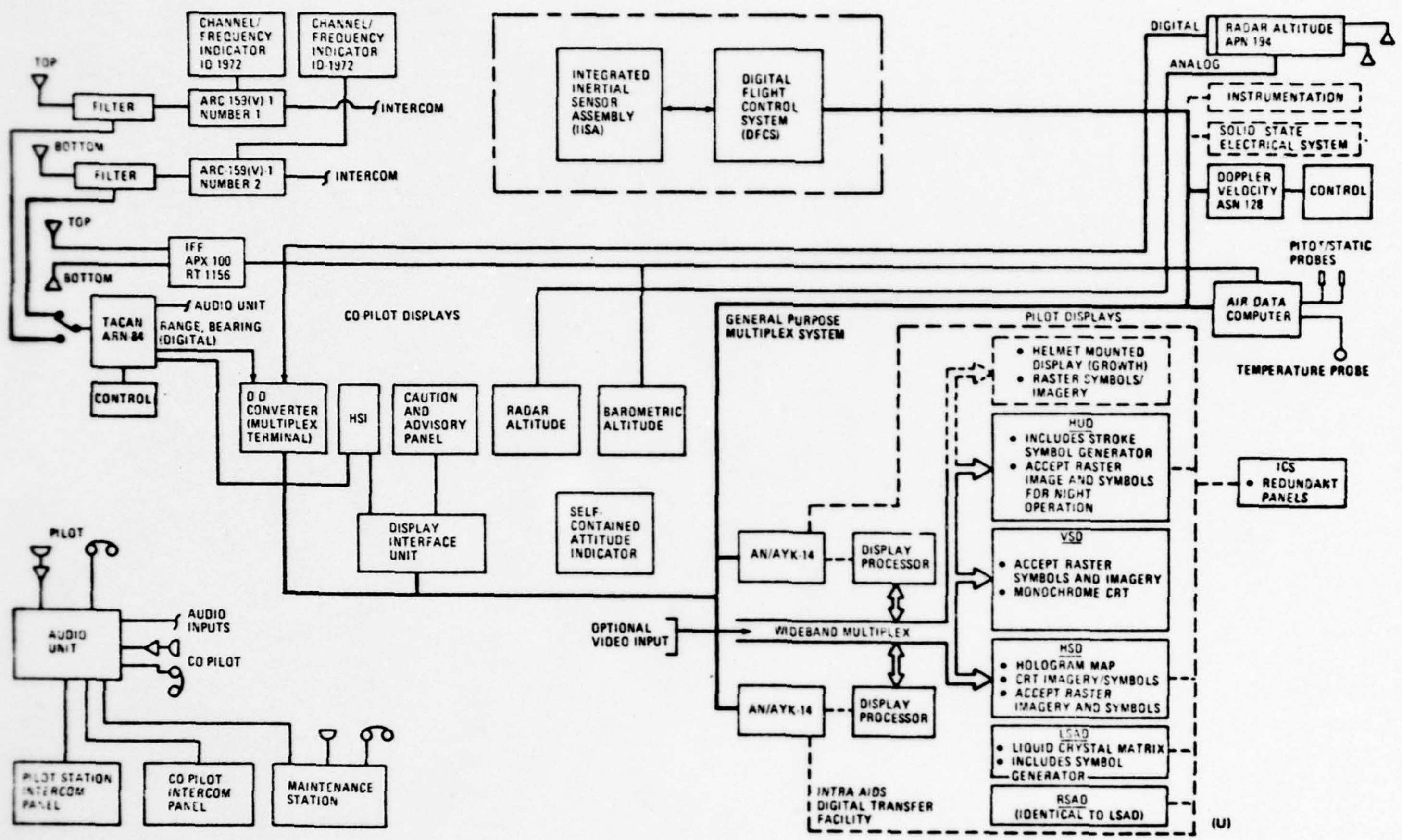


FIGURE 3-3 V/STOL PROTOTYPE PROGRAM

AIDS ASW EDM CONFIGURATION

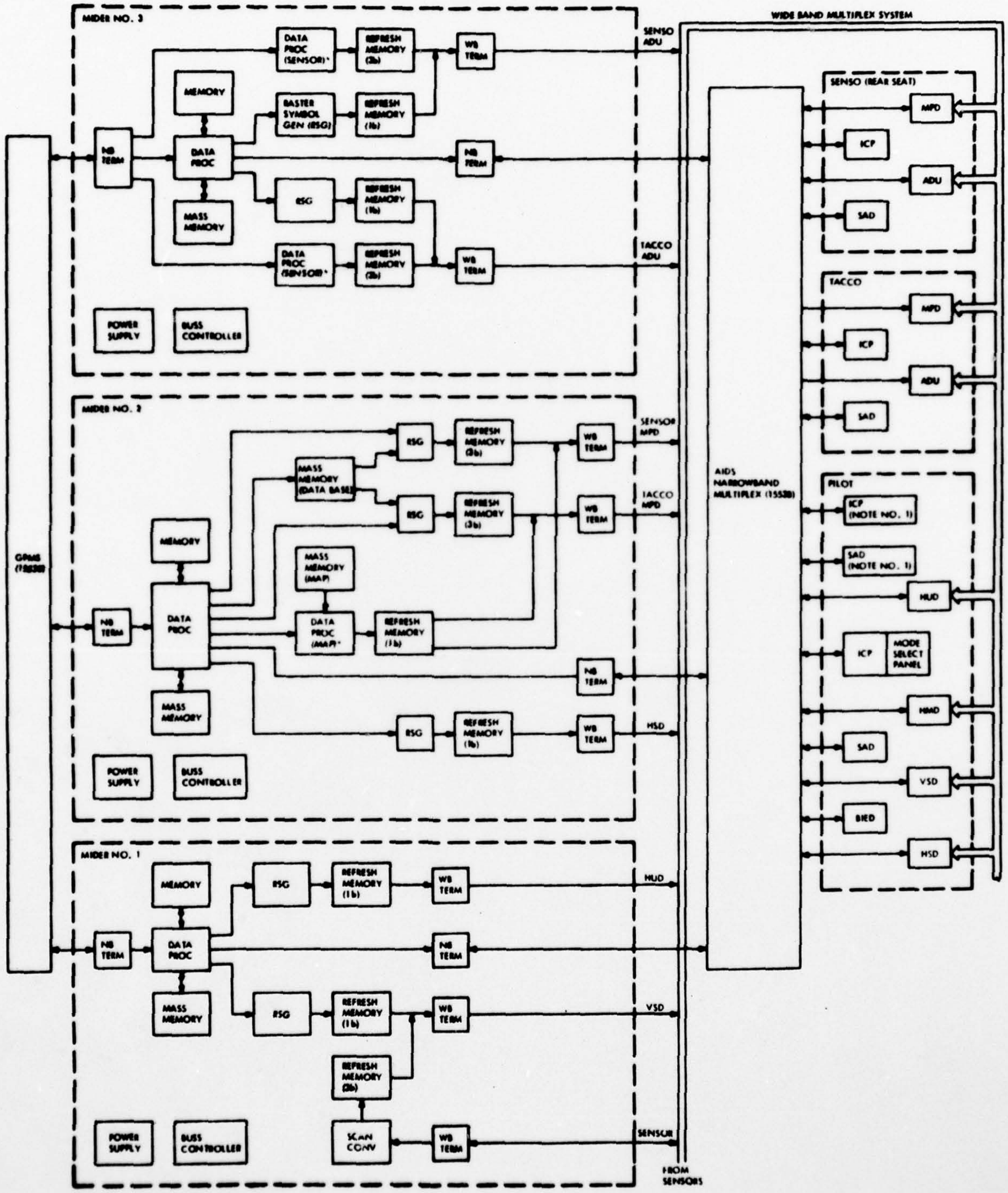


FIGURE 3-4 V/STOL OPERATIONAL VERSION

V/STOL is projected for the late 1980's with the prototype development phase in the early 80's, and, therefore, the most immediate need for an AIDS interface requirements evaluation would be for the development of a V/STOL simulator program, which will require that the AIDS interfaces be accurately and completely defined for programming the base station processors.

It was concluded therefore, that the best approach for an AIDS interface information requirements analysis would be a generic review of the latest AIDS Input Signal Description document (Ref. 9) published by General Electric in March 1977 which is an updated and revised version of the original AIMIS Advanced Development Requirements Document dated September 1975, and submitted to Vought as Appendix "B" to this study contract.

3.1.1 Data Review

A review of the existing AIDS interface information document was conducted with two specific purposes in mind, first for completeness of available/required sensor information and secondly to identify additional inputs available or required for display and/or processing by AIDS.

From a strictly generic standpoint the interface evaluation revealed a very thorough compilation of aircraft subsystems and the associated sensors and data required to establish the AIDS equipped pilot as the overall command station for control and monitoring of all aircraft flight functions. The interface data consisted of six categories of aircraft equipment and/or subsystems at the AIDS interface, including:

(1) Flight Data Parameters
(2) Tactical Data
(3) Aircraft/Equipment Parameters
(4) Engine Parameters
(5) Weapon Stores
(6) Electronic Warfare

Comments regarding suggested changes or required additional inputs for the AIDS development are non-existant when the interface requirements are reviewed with a general AIDS application in mind. However, considering a specific application of AIDS to the Type "A" V/STOL, certain changes and additions to the interface requirements are apparent which will directly affect the AIDS processing requirements. Since the additional interface requirements are unique to the V/STOL application, the subject might best be discussed under task three of this study which considers unique V/STOL requirements. However, for the sake of continuity it will be covered in this section and again under task three.

For V/STOL application, it is recommended that an additional column be added to the interface data lists for the Flight Data Parameters and the Engine Parameters. The column to be added should define the margin and limits for certain data which is critical to the V/STOL operation in transition, hover and landing modes. For example, roll attitude in normal flight is not a critical input for stable flight. However, during hover, roll attitude as well as roll rate become critical parameters and the allowable margin and/or maximum limits for each of these V/STOL related flight and energy management parameters will require serious consideration.

In addition to the margin/limit column in the AIDS interface list, the related software and AIDS processing associated with vertical mode operations will require unique data interface changes. An example of this type of unique data requirement is best illustrated using airspeed as a flight data input. Indicated airspeed is displayed during conventional flight modes. However, when transition phase is selected on the Master Mode Control Panel, and airspeed drops below a predetermined level, say power off stall speed, the AIDS processors should automatically alter the display to phase out indicated airspeed and phase in ground speed. Such unique data transfer requirements as well as additional flight data parameters will add significantly to the processing requirements for AIDS when applied to a V/STOL type aircraft.

Concerning the accuracy of data transfer reflected in the signal interface data document, the measurement parameter was compared with the value of the least significant bit (LSB) in the precision column as a review of the adequacy of data transfer accuracy. No significant incompatibilities were noted during the review except that the data is incomplete in the Aircraft/Equipment parameters listing as well as some of the engine data.

3.1.2 Summary

In summary, it should be pointed out that for a strictly generic review of the interface information, the document appears quite thorough, however for a specific V/STOL application, several changes and additions will be required to assure adequate sensor information peculiar to V-mode requirements. Further discussion of peculiar V/STOL characteristics and the effect on the AIDS processing burden is contained in the following section.

4.0 UNIQUE REQUIREMENTS

Identification of the unique V/STOL requirements which have a bearing on the AIDS development program is the primary objective of this task. Some AIDS related V/STOL requirements have been mentioned in the previous sections under Mission Requirements and Interface Data. In order to consolidate unique requirements into one section, discussion of some previously addressed requirements will be contained herein.

Unique display and processing requirements for a V/STOL aircraft are naturally related to the unique flying characteristics, which in this case is the ability to rise vertically and transition to wing borne or conventional flight with the reverse capability for landing. It is the transition, hover and landing modes (V-mode operations) of the V/STOL which make additional flight sensors and stability augmentation devices necessary. The ability to display critical flight parameters to the pilot during V-mode operations is an essential part of AIDS development as well as the aircraft itself, and therefore, the following display requirements are considered unique to the V/STOL application of AIDS.

4.1 CONTROL POWER MARGIN

In the thrust supported flight regime, an indication of remaining or excess control power is of paramount importance to the pilot. Control Power is the ability to provide airframe angular acceleration (3-axis) and aircraft stabilization in a turbulent environment or unstable flight vehicle condition by providing control response to pilot commands for maneuvering. The high AV-8A accident rate can be traced to pilot workload, flight control system authority, and inadequate control power. Type A V/STOL will have increased control power, but in a turbulent environment where the automatic stabilization functions are using control power, the pilot must be advised of the control power remaining for his command inputs to the control system. Excess control power for this flight regime can be computed from engine power settings, fan face pressures, fan speed and inlet guide vane or fan pitch position with respect to choke and surge limits. All of the information required for computation of excess control power will be available from the redundant flight control computers. However, this additional display requirement increases the processing burden of the AIDS processors and is, therefore, worthy of recognition in this section.

4.2 BETA (β) CORRIDOR

During the transition from wingborne flight to hovering there exists a critical airspeed region which is traversed at low power settings. During this period V/STOL aircraft are susceptible to inlet flow separation if the sideslip angle (β) becomes too great. For this reason approach to vertical landing will require flying a "corridor" of limited sideslip angle during the period of low power settings. A presentation to the pilot will be required to illustrate his margin of safety. The margin of safety will be a function of both power setting and maximum sideslip angle. The addition of this display requirement for the application of AIDS to V/STOL will add to the processing burden and the mode selection monitoring by the AIDS.

4.3 TRANSITION CONTROL CONFIGURATION MANAGEMENT

V/STOL aircraft which require external configuration changes as a function of flight conditions during transition, will require information to be displayed to the pilot so that the specific configuration may be both monitored and controlled. Tilt nacelle aircraft, for example, must maintain position of the nacelle within a margin/limit which is a function of angle of attack, airspeed and power setting, to avoid inlet flow separation. Nacelle inlet airstream angle-of-attack is therefore another unique display parameter for variable configuration type V/STOL aircraft which will add complexity to the current AIDS processing burden and display requirements.

4.4 OTHER UNIQUE V/STOL DISPLAY REQUIREMENTS

In addition to those previously mentioned, there are several other unique V/STOL related sensor and display requirements which will have a direct bearing on the current AIDS development program, both from the standpoint of information presentation requirements as well as software development and the AIDS processing burden.

The additional unique V-mode display and sensor requirements, some of which are discussed later under AIDS Standby Instrument Evaluation, include the following:

(1) Rate Data - In addition to the pitch roll and yaw angles specified in the signal interface data document, the rate of change of pitch, roll and yaw must also be a sensor parameter for V-mode operations. Rate data is a necessary parameter for computation of hover stability margin.

(2) Angle-of-Attack (AOA) - plus the acceptable limits - must be displayed not only for the aircraft, but also for the nacelle inlet airstream.

(3) Vertical Velocity plus defined limits - the vertical velocity indication displayed in conventional aircraft is an air data measurement with several seconds of lag in the system and as such is unsatisfactory for V-mode operations. The vertical velocity readout for V/STOL must be inertial, to assure accurate measurement of sink rates in order that control margin may be computed and displayed to the pilot.

(4) Lateral Acceleration plus defined limits - the limits of lateral acceleration must be monitored to avoid a requirement for more control power than is available. Limits must be proportional to the available control power, with pilot cue for control power limit warning.

(5) Ground Speed - an indication of ground speed and direction (velocity vector) may be obtained using doppler or inertial techniques and is required for hover stability and precision landings.

(6) Translational Velocities - this is similar to the ground speed requirement, except for the three-axis requirement. This parameter is again related to computation of control margin.

(7) Wind Direction and Velocity - this parameter will most likely be transmitted to the air vehicle through a V/STOL landing aid such as NAV-TO-LAND.

(8) Thrust Vector Angle - in the case of the Vought V/STOL design, this parameter will have four independent vector angles, however, to simplify the pilot workload, the average thrust vector angle will be displayed while the four individual vectors will be used in computing control margin for translational velocities, etc.

4.5 SUMMARY

In summary, the unique flight characteristics associated with V-mode operations generate a special need for unique sensors and displays not heretofore considered a requirement to AIDS. It is recommended, therefore, that additional consideration be given to the incorporation of these unique V/STOL requirements into the AIDS as a firm required capability.

5.0 HUMAN FACTORS

This section consists of those study tasks with primary emphasis on human factors analysis. The tasks are:

5.1 - AIDS Human Factors Program Plan Review - This task was to review and recommend changes to the ADM phase human factors program plan prepared by NADC. (Appendix A)

5.2 - Development of Display Format and Symbology - The objective of this task was to develop a pilot's display format and symbology for transitioning from conventional flight to vertical landing.

5.3 - Cockpit Ambient Lighting Assessment - This task examined four ambient lighting conditions and assessed the impact of the ambient lighting on AIDS displays.

5.4 - AIDS Standby Instrument Evaluation - A list of standby information requirements was reviewed and additions were made unique to V/STOL operations.

5.1 AIDS HUMAN ENGINEERING PROGRAM PLAN REVIEW

5.1.1 General Comments

The objective of this phase of the study was to review and comment on the preliminary AIDS Human Factors Program Plan dated 9 November 1977, developed by the Human Factors Engineering Division of NADC and included herein as Appendix A. This plan covers the general tasks and responsibilities of Naval Air Development Center Human Factors (NADCHF), General Electric Human Factors (GEHF), a Human Factors Support Contractor (HFSC), and Air Force DAIS Human Factors (AFHF), during development of AIDS for Type A V/STOL aircraft. The Type A V/STOL aircraft mission will be primarily ASW and AEW. The major difference between a current ASW/AEW aircraft and the Type A V/STOL will be vertical operation during the take-off and landing phases. Vertical operation requires reduced aircraft weights in order to meet range, loiter, payload and shipboard requirements.

One area where weight reduction can be made is in the number of crew members. Weight saved through reduction in crew size becomes significant when the total weight of the crew member, personal equipment, escape system installation, consumables, controls, displays, consoles, and associated structure is taken into account.

Reduction in crew size requires that the mission task loading be redistributed among the remaining crew members. This presents a difficult task because air crews are currently near workload saturation during tactical operations. In one current ASW aircraft (S-3A) the co-pilot serves primarily as an operator and safety of flight monitor. Some squadrons have considered replacing the co-pilot with an operator.

In the E-2C (AEW) aircraft, the operator workload is so high that there is need of an additional dedicated operator. In both these cases, the high tactical operational workload points to an increase in crew size rather than a decrease.

If future tactical operations remain similar to the present, crew workload must be reduced by increased automatic sensor data processing. The AIDS will allow display of more integrated displayed information and will interface with sensor data processors to reduce crew workload by presenting information that requires less mental processing. Development of the integration, display and control techniques required by AIDS is critical if crew size is to be reduced.

The primary human factors problem regarding Type A V/STOL is then two fold.

(1) Display and control of the displayed information required by the pilot during vertical and transitioning flight that will result in acceptable workload levels.

(2) Display and control of the displayed information required by the crew during operational ASW and AEW missions that will result in acceptable workload levels.

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Both of these areas are biased by the desire to reduce crew size. This is opposed by current trends.

It appears that the logical crew member to be removed is the co-pilot. A brief analysis of current and projected mission durations indicates that future V/STOL ASW/AEW missions may be slightly reduced in duration so that the primary flying task will remain about the same. Eliminating the co-pilot position means that those co-pilot functions not related to aircraft control will have to be distributed among the remaining crew. In order for the crew workload to remain within acceptable limits, automatic data processing must increase significantly. Therefore, it is recommended that an in-depth study be conducted to define the specific areas of required automatic data processing (functional allocation between man and machine). This should be done for both the ASW and AEW mission and also to predict when the required advanced technology will become available. The operator #1 position, (left cockpit seat), will also be required to function as safety-of-flight monitor during critical flight phases and must have the appropriate displays to fulfill this function.

The significant increase in pilot workload will come from the vertical and transition flight phases. During these flight phases, pilot workload will be significantly affected by the level of flight control system augmentation. It is estimated that three axis rate stabilization with nearly one-hundred percent control authority will be required. Once a minimum, or greater, level of flight control system augmentation is attained, further reduction in pilot workload can be achieved by displayed information integration and presentation techniques. Definition of the vertical flight phase displayed information requirements should be conducted independently of the mission specific displayed information requirements. This can be begun after a minimal scenario development phase and will apply to both the ASW and AEW mission. Mission specific displayed flight information can be defined following the mission specific scenario development and task analysis tasks.

5.1.2 Comments on NADCHF Tasks (Task numbers correspond to plan)

1. MONITOR GEHF ACTIVITIES

This task description is generally what is expected of the contracting agency and establishes NADCHF as focal point for management and coordination of human factors activities associated with AIDS. Task description is sufficient.

2. INFORMATION REQUIREMENTS

It is recommended that this task be separated into two parts. One part addressing only pilot and safety of flight monitor information requirements during vertical and transition flight phases. A minimal scenario development by NADCHF or a HFSC would be necessary as much literature is currently available.

The second part or crew information requirements could begin later based upon the GEHF ASW/AEW mission scenarios. This part of the task will be heavily biased by prediction of Type A V/STOL IOC time period advanced sensor/processing avionic technology. These predictions may be included in the GEHF System Function Allocation task, but should be stated explicitly.

3. DISPLAY FORMATS

It is recommended that this task receive heavy emphasis. At no time in the past has it been possible to display processed and integrated information to the extent made possible by AIDS. Existing display formats may be of little value. This task could warrent a separate HFSC study contract. It is recommended that this task be accomplished in two parts also. Pilot and safety of flight monitor displayed information formats and mission specific displayed information formats.

4. DISPLAY ALLOCATION

Task description is sufficient.

5. HF EXPERIMENTS

Task description is sufficient.

6. SENSOR STATION DESIGN

Task description is sufficient.

7. PSYCHOPHYSICAL MEASUREMENTS

Task description is sufficient.

8. ICS CONTROLS

It is recommended that the integrated control set receive increased emphasis not only in design criteria development and general operating logic, but especially in the area of integrated system logic. There is a requirement for a baseline study of Type A V/STOL ICS integrated system logic. This study should be performed concurrent with pilot and safety of flight monitor, integrated displayed information requirements and format studies. i.e., define the integrated system logic required that allows the pilot and safety of flight monitor to call up data and reconfigure integrated display formats during critical flight phases without seriously increasing workload.

The ICS integrated system logic should also be established for the mission phases to allow the operators to take maximum advantage of sensor and processed information.

9. VRAS

Task description is sufficient.

10. WORKLOAD MEASUREMENT

Task description is sufficient. However, it is recommended that NADCHF conduct a comprehensive survey to determine the workload assessment methodology best suited for this specific application.

5.1.3 Comments on GEHF Tasks (Task numbers correspond to plan)

1. HUMAN FACTORS EVALUATION OF CONTROL/DISPLAY HARDWARE

Task description is sufficient. However, more detailed analysis of actual operational high ambient light environment should be conducted if CRT life is impacted by high ambient requirements. (See section on cockpit lighting assessment.)

2. MAINTAINABILITY/ACCESSIBILITY

Task description is sufficient.

3. DOCUMENTATION FOR PHASE I (HARDWARE) AND PHASE II (SYSTEMS INTEGRATION)

Task description is sufficient.

4. SYSTEM FUNCTION ALLOCATION

It is recommended that the function allocation task include a study to develop predictions of sensor/processing advanced technology available in the Type A V/STOL IOC time period. This study is required to determine if crew size reductions are feasible.

5. SYSTEM ENGINEERING DESIGN SUPPORT

Task description is sufficient.

6. CREW STATION ENVIRONMENT DESIGN EVALUATION

Suggest including 3.2.2.3.d of MIL-H-46855 (Acoustic Noise if cooling fans are included in cockpit AIDS equipment. Also, 3.2.2.3.m (Equipment handling provisions) from maintenance standpoint. Question the requirement of 3.2.2.3.p at this stage of system design and suggest 3.2.2.3.q be substituted. (This was probably a typo.)

7. SCENARIO DEVELOPMENT

Task description is sufficient for mission specific scenario. Should not include vertical and transition flight phases as these should be completed separately and earlier.

8. TASK ANALYSIS (ASW and AEW)

Task description is sufficient.

9. COCKPIT LAYOUT

Task description is sufficient. However, every attempt should be made to meet existing external vision and cockpit geometry specification requirements so that display size and arrangement problems will become evident early in the evaluation.

10. CONTROL/DISPLAY FORMAT EVALUATION

It is recommended that this task be assigned to NADCHF. NADCHF should then define specific tasks for GEHF and HFSC. NADCHF should retain management and control of this important test and evaluation phase. It is recommended that the NADCHF task #3 (Display Formats) be assigned to GEHF or HFSC and the GEHF #10 task be rewritten with primary responsibility assigned to NADCHF.

HUMAN FACTORS SUPPORT CONTRACTOR

Task description is sufficient.

SCHEDULES

It is recommended that more checkpoints and milestones be added to the schedules. Schedules reflect very high manloading as most tasks are concurrent. Schedules should reflect reasonable manloading.

MISCELLANEOUS

Schedule titles have been switched.

5.2 DEVELOPMENT OF DISPLAY FORMAT AND SYMBOLOGY

V/STOL approach, transition, hover, and landing present a higher pilot workload situation than CTOL approach and landing. Redundant controls for selection of flight path angle along with increased visual scanning requirements have resulted in increased and potentially dangerous workload levels. V/STOL capabilities for slow speed maneuvering should reduce the current requirement to follow standardized approaches to conventional landing sites and allow safer approach and descent into unconventional landing sites. However, practical considerations such as high rates of fuel consumption during thrust supported flight, tactical aircraft recovery rates, and the cumulative problem of time spent in ground effects dictate that transition to hover and descent to landing maneuvers be conducted so as to minimize time spent in hover and ground effect. It is reasonable then to predict that V/STOL operations from aviation (carriers) and air capable (ships with landing pads) Navy ships will require development of recommended approach, hover, and landing profiles and attitudes. These recommendations will likely differ significantly for each ship type. There is presently increased emphasis being placed upon development of Visual Landing Aids (VLA) for use during V/STOL landings aboard air capable ships. These aids will further constrain V/STOL flight envelopes during landing. The apparent freedom of vertical operations will, therefore, also be constrained. Display formats should be designed to allow maximum use of the operational V/STOL flight envelope.

This study is concerned with development of AIDS displayed information formats and symbology for visual meteorological conditions (VMC). Therefore, formats and symbology will be developed for the head-up display (HUD). The formats could also be displayed on the vertical situation display (VSD).

Display requirements should not be developed separately from flight control system requirements. Reference (2) states that the problem of high pilot workload during critical flight phases has its roots in the control aspects of the aircraft. Attempts to solve the problem by increased display sophistication alone have not been successful because the pilot's critical information processing load remains too high and the pilot remains overtaxed. Control/display tradeoffs become meaningfull only after certain minimum levels of vehicle stability and controllability are satisfied.

For purposes of this study, the level of control system sophistication assumed will be similar to the conceptual design of Vought's V-530 Type A V/STOL aircraft. The Vought design incorporates an attitude stabilization system with heading hold in the flight regime where flight is partially or wholly supported by thrust. Also, changes in thrust for height and speed control do not affect attitude in this region.

This level of control system sophistication is similar to the attitude command augmentation described in Reference (4). Reference (4) documents flight testing varying levels of control system sophistication and display system sophistication in combination to attempt to establish curves of constant pilot workload as suggested in Reference (3). Reference (4) recommended that specific flight information be displayed based upon the results of flight tests in the variable stability X-22A. Because of the similarity of flight control systems, Reference (4) was used as a guide to essential display elements peculiar to V/STOL.

An extensive literature search was conducted, as part of this task, to define and list displayed information requirements for V/STOL operations. Determination of current symbol useage and techniques to display integrated information were also part of the literature search. Conclusions drawn from the literature search are as follows:

(1) Accident records of present V/STOL operational aircraft indicate the requirement for a more sophisticated flight control system in order to contain pilot workload during critical flight phases.

(2) The present level of display system sophistication would suffice for visual meteorological conditions (VMC) landings except on some air capable ships, if a more sophisticated flight control system were used. Pilot workload would still be high because of the amount of information processing that the pilot must perform.

(3) A number of display formats used in simulation studies are not operationally acceptable because symbol shapes densities and dynamics could lead to confusion. Display formats must not only work well for a specific assigned task but must present options or alternate paths for guidance and control when far from the nominal or during in-flight emergencies.

(4) Sufficient testing has been conducted and reported so that reasonable estimates of required flight information to match flight control system sophistication can be made.

(5) Pure situation displays provide acceptable pilot workload but reduced accuracy. Pure director displays provide good accuracy but high pilot workload and anxiety.

(6) An acceptable display should provide status or situation information, command, and predictive information.

(7) Landing pad and track line symbols are very desirable for all approaches. The landing pad symbol does not have to overlay the real world landing area. In fact, during crosswind approaches it should not.

(8) Pilot must be able to quickly assess his status and the various alternatives available. Pilots have come to rely upon peripheral visual cues (because of high workload) as opposed to foveal visual cues to ascertain status and trends. Lone digital readouts require interpretation and this requires more time and attention (e.g. Reference (5)). Use digital display like A-7 heading or thermometer or moving tape.

(9) A profile display (Reference (6)) may be useful but is headdown and takes valuable instrument board space.

5.2.1 Information Requirements

Reference (3) has listed displayed flight information requirements for instrument meteorological conditions (IMC) approaches and landings. The present study was to consider day VMC approaches and landings. However, the displayed information study and analysis yielded sufficient information for including night visual approaches and landings. The study also presupposes the installation of a landing aid such that range to landing, wind at landing, and wind direction at the landing site could be displayed.

Following is a description of information requirements including rationale:

(1) Attitude - Pitch and Roll - Vought has had good success with velocity vector and flight path angle indications on conventional aircraft HUD's. However, for a V/STOL aircraft in the hover mode, presentation of the velocity vector and flight path angle will not give the required situation information. The pilot requires aircraft body axis pitch and roll attitude information and the component of the aircraft velocity vector parallel to the ground plane. These separate displays will allow the pilot to take advantage of the stability augmentation offered by the flight control system.

Display of thrust vector angle is required. Thrust vector angle can be controlled by two methods. First, the thrust vector angle can be controlled by the thrust vector angle controller while the flight control system maintains pitch attitude. Second, the thrust vector angle can be controlled by changing the pitch attitude with the control stick while the angle between the thrust vector and the aircraft pitch axis remains unchanged. The decision as to which of these two methods is used or if a combination is feasible, will depend upon the requirements for external vision, deceleration, height control, ground and fountain effects, etc.

Roll attitude is controlled by the control stick. Changing roll attitude also changes the lateral thrust vector angle with respect to the ground plane which results in lateral motion. Yaw during hover is controlled by the rudder pedals and is displayed as heading change.

(2) Vertical Velocity Including Limits - A display of vertical velocity status without command indications has been shown to extend the time of approach to hover, (Reference (7)). All V/STOL aircraft are subject to undesirable effects when hovering near to the ground. Therefore, it is necessary to pass through the area of ground effects

and exhaust air ingestion quickly. Also, V/STOL operational aircraft will be fuel limited in thrust supported flight modes and time spent during approach to hover and landing must be minimized. Reference (7) also pointed out that approach profiles requiring constant sink rates received the best pilot ratings, had lower overall workload demands and could be executed in the least time.

Vertical velocity indication should include both status and command information. Also, a sink rate limit or thrust remaining to arrest the sink rate indication should be displayed.

(3) Altitude - The pilot requires an indication of altitude during all flight phases. Digital altitude readouts are sufficient for high altitude operations. However, during IMC approaches, at low altitudes, there is a requirement to display smaller intervals of altitude and to provide trend information (Reference (8)). Also, it may become desirable for the pilot to be able to set indices specific to landing profiles for specific ships.

(4) Angle of Attack and Limits - Safe smooth reconversion from aerodynamic supported flight to thrust supported flight is dependent upon maintaining optimum aerodynamic lift from the wing as airspeed decreases. An indication of angle of attack, commands, and limits should be displayed. Angle of attack (AOA) limits are important during conversion in order that stall is prevented during aerodynamic flight. The transition from aerodynamic to powered flight can be smoother if optimum aerodynamic lift can be maintained as long as possible during the approach. Once powered lift has been established, AOA is not necessary. During conversion to aerodynamic flight, display of AOA is necessary to achieve aerodynamic flight as soon as possible for fuel economy. The entire angle of attack indication should be removed during very low speed flight because it has lost significance.

(5) Lateral Acceleration - Deflected thrust jet V/STOL aircraft present little aerodynamic drag to offset lateral accelerations. Intense involvement with other tasks can cause the pilot not to be alert to low levels of lateral acceleration before large lateral distances

or large values of side slip have occurred. Indication of lateral acceleration and definite limits should be displayed even through the flight control system will minimize dangerous yaw-roll coupling trends.

(6) Airspeed - During V/STOL take-off and conversion, airspeed becomes important as an indication of eminent wing stall or pitch up and also to indicate when aerodynamic flight has been achieved. During approach and transition, airspeed is an indication of the aircraft aerodynamic flight envelope limits. Airspeed is also a good cross check of angle of attack as the pilot maintains optimum angle of attack. As airspeed and angle of attack lose significance, (below power off stall speed of the aircraft), flight becomes wholly thrust supported and airspeed and angle of attack should be removed from the display. Empirical data (Reference (5)) indicate that a digital presentation of airspeed is acceptable. However, for rapidly changing conditions, trend and rate information is essential.

(7) Ground Speed and Direction - As the aircraft enters the transition flight phase, display of ground speed and ground speed direction becomes necessary. Ground speed and direction should appear on the display while angle of attack is still significant to flight so that the transition phase can be more effective. (i.e. time spent in transition and hover is fuel critical) Ground speed can be displayed in digital form. Ground speed direction is best displayed symbolically by a line whose length varies with rate.

(8) Range to Landing Site - An indication of the range to landing is essential because the pilot must have sufficient information to arrive at the landing site within strict speed limits. Reference (7) found that the best results were obtained when ground speed and direction were accurately displayed as a vector quantity.

(9) Heading - Display of heading is necessary for aiding navigation and orientation with respect to the wind. Also, heading is used as a status indication when course director information is being used. The heading presentation should indicate both status and trend information.

(10) Thrust Vector Angle Indication - Current V/STOL jet deflected thrust aircraft use rapid, stepped thrust vector angle deflections at certain points during the approach. This is done to contain pilot workload by not requiring continuous adjustment or monitoring. Workload considerations indicate that thrust vector angle control should be automatic. However, the pilot should have an indication of thrust vector angle status.

(11) Available Control Over Descent Rate - This indication is a safety of flight display. It could be a thrust to weight ratio indication or some other computed value. The limit can be associated with the vertical velocity limit.

(12) Critical Engine Parameters - The pilot needs an indication of critical engine parameters or approaching out of tolerance conditions.

(13) Vertical Flight Path Error - Assuming that a landing site based landing guidance system is available, some indication of flight path or flight path error should be displayed.

(14) Lateral Position - An indication of lateral position or lateral position error is required along with guidance to compensate for wind, avoid obstacles, etc.

5.2.2 Proposed Display Design (Ref. Figure 5-1)

Once the displayed information requirements were established, suitable symbols were selected to symbolize the required information. The symbols were selected on the basis of current CTOL and V/STOL display useage and experience and also from proposed V/STOL display formats found in the literature. Selection criteria included symbol use in simulation or flight tests and symbol suitability as a real world analogue. Symbol dynamics were considered although specific symbol excursions and scaling were not defined in detail. Following is a brief description of the selected symbols to satisfy the information requirements of section 5.2.1.

(1) Attitude - Pitch and Roll - Pitch attitude is displayed as a pitch ladder including a horizon line. The pitch ladder has 5 degree divisions referenced to a fixed aircraft symbol. Positive pitch

lines are solid. Negative pitch lines are dashed. Each pitch line has a mark at the end which points toward the horizon line. Each pitch line is numbered in 5 degree increments. The numbers remain fixed to the pitch lines to give an indication of inverted flight when the number is inverted.

Roll attitude is displayed implicitly as the angle the pitch lines form with respect to the aircraft symbol "wings".

(2) Vertical Velocity Including Limits - Vertical velocity is indicated against a vertical scale on the right side of the display. The scale displays situation, command and limit vertical velocity information. As the limits are approached, the limit indication should flash. This is an indication of thrust remaining or available control over descent rate. The range of displayed vertical velocity is plus or minus 2000 feet per minute. Scale indices represent 200 ft./min. Inboard indicator shows status. Outboard small lazy V shows limits. Horizontal line shows command. Commanded vertical velocity is computed to allow landing at the landing site with acceptable sink rate

(3) Altitude - Status altitude is displayed in digital form at upper right display area. Barometric altitude is distinguished from radar altitude. (RAD for radar altitude. BARO for barometric altitude.) Altitude trend, hover altitude and commanded altitude should be indicated for instrument conditions (IMC).

(4) Angle of Attack and Limits - Angle of attack is displayed against a scale at the left side of the display. Each of the ten increments of the scale will indicate one angle of attack unit. Scale range will be determined by the specific aircraft characteristics. The angle of attack limits will be indicated by lazy V's. Angle of attack loses significance during thrust supported flight and should be removed. The commanded angle of attack is computed for smooth transition from aerodynamic to thrust supported flight.

(5) Lateral Acceleration - The indication for lateral acceleration or side force is a ball referenced to the heading scale lubber line. Importance of the lateral acceleration indication is dependent upon

the flight control system sophistication and control authority and specific aircraft characteristics. The Vought V/STOL design will have sufficient flight control system sophistication and control authority such that undesirable yaw-roll coupling should not be a problem. However, lateral acceleration is important during thrust supported flight maneuvering and the pilot should be alerted to the approaching limits either by flashing the limits or by a warning tone. Indication of lateral acceleration is located near the top of the display so that the bottom display area will be less conjested as the aircraft approaches the landing site and the landing pad symbol and guidance displays move toward the bottom of the display.

(6) Airspeed - Status airspeed is displayed in digital form at the upper left display area. Airspeed is prefixed by the letters AS.

(7) Ground Speed and Direction - Status ground speed is displayed in digital form at the lower left of the display. Ground speed is designated by a GS prefix. Ground speed and direction is also displayed by a vector eminating from the aircraft symbol. This vector is the horizontal component of the aircraft velocity vector. As the aircraft is maneuvered so that the ground speed vector intersects the landing pad symbol, speed should be decreased to maintain the vector at the landing pad symbol. This will ensure the proper speed to hover over or touchdown on the landing pad.

(8) Range to Landing Site - The distance between the aircraft symbol and the landing pad symbol provides an analog indication of range to the landing site. Range rate is indicated by the closure rate of aircraft symbol and landing pad symbol. For IMC approaches, an analog or digital display of range to landing site may be required.

(9) Heading - Status and trend heading information is displayed by a horizontal tape at the top center of the display. The heading scale lubber line also serves as the lateral acceleration reference. Each heading numeric consists of two digits. The tape scale should appear as a window thru which the pilot can see headings written on the world.

(10) Thrust Vector Angle Indication - Thrust vector angle status is displayed in digital form at the lower right of the display. Thrust vector angle is designated by a TV prefix.

(11) Available Control Over Descent Rate - Descent rate limit is displayed by a small lazy V outboard of the vertical velocity display. The limit will vary according to computations involving descent rates, control authority, thrust to weight ratio available, etc. The resulting display will require pursuit tracking, making instantaneous vertical velocity inputs to the display mandatory.

(12) Critical Engine Parameters - Engine health and status displays are to be displayed on one of the situation advisory displays. However, caution and warning indications should be displayed at the bottom center of the display to at least alert the pilot to check other displays.

(13) Vertical Flight Path Error - Displayed information of airspeed, ground speed, vertical velocity and altitude are sufficient for VMC approaches. For IMC approaches, an indication of vertical flight path error is a requirement.

(14) Lateral Position - An indication of lateral position can be determined by the position of the landing pad relative to the aircraft symbol. Trend information is determined from direction of the horizontal velocity vector component eminating from the aircraft symbol.

Figure 5-1 presents the proposed format and symbology for the pilot's HUD or VSD. The VSD display should include fuel status, weapons status when necessary and other miscellaneous and supplemental information as required.

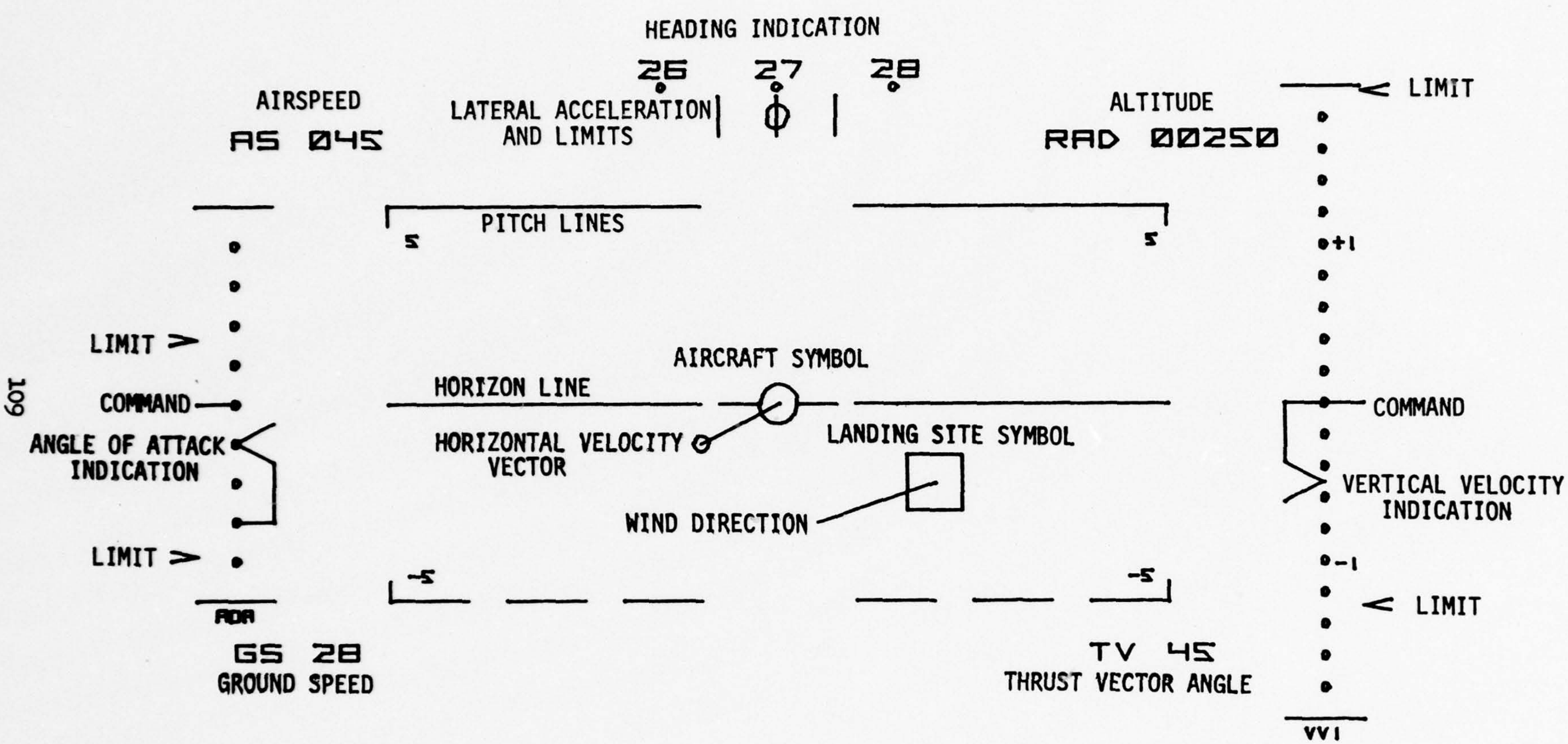

FIGURE 5-1a RECOMMENDED FORMAT AND SYMBOLS FOR PILOT'S DISPLAY
(Figure does not represent any specific condition)

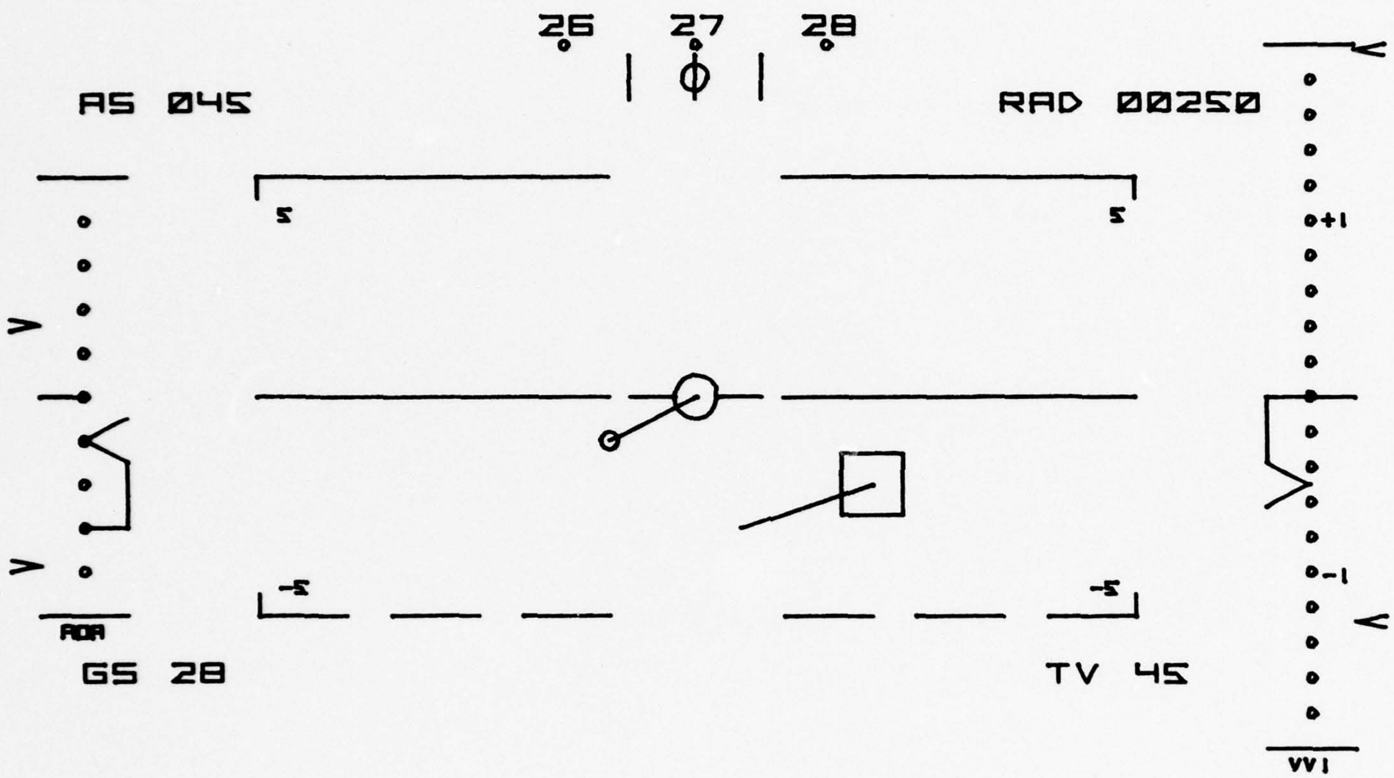

FIGURE 5-1b RECOMMENDED FORMAT AND SYMBOLS FOR PILOT'S DISPLAY
(Figure does not represent any specific condition)

5.3 COCKPIT AMBIENT LIGHTING ASSESSMENT

The objective of this task was to examine four extreme cockpit ambient lighting conditions and determine the impact on the proposed AIDS displays design. The four extreme ambient lighting conditions are as follows:

Condition 1 - High altitude, high ambient brightness, and worst angle of sun's rays.
Condition 2 - Same as Condition 1, but under emergency power.
Condition 3 - Black night operations.
Condition 4 - Same as Condition 3, but under emergency power.

The high ambient brightness, high altitude condition presents the most difficult display situation; requiring large dynamic ranges and high peak brightness from the displays. Cockpit geometry and aircraft configuration will have some effect on the maximum cockpit ambient brightness condition. The RFQ/I Vought V-530 Type A V/STOL design has a two place side by side front cockpit with an in-air refueling proble enclosure on the upper canopy centerline similar to the S-3A. The V-530 canopy and windshield glass lines have not been totally defined. However, past experience has shown that it is desirable to have at least a six inch clearance between the crewman's shoulder and any canopy structure. This criteria was used to define the extent of canopy glass when determining the maximum angle of the sun's rays incident to the display faces.

It should be noted that the large fuselage and side by side cockpit seating arrangement require a large area of windshield and canopy transparency. Also, the V/STOL external vision requirement results in additional transparent area. The high cockpit ambient brightness resulting from the large transparent areas imposes difficult design problems on displays, controls and legends and labels within the cockpit. A similar problem existed for the S-3A ASW aircraft. The solution was to limit the transmission of light to 3 percent for the overhead canopy, 45 percent for the canopy sides and 65 percent for the windscreen.

This reduced the display and controls brightness requirements. A similar solution would probably be required for operational V/STOL aircraft and would reduce display brightness requirements and also extend the life of the CRT's.

This study will assume high windscreen and canopy light transmission percentages in order that the cockpit ambient light levels will be comparable to the current AIDS requirements (10,000 ft. candles).

5.3.1 Condition 1 - High Ambient Light Level, High Altitude, Worst Angle Sun's Rays

5.3.1.1 Ambient Illumination

A number of references have agreed upon an approximate average maximum ambient illuminance of 11,000 ft. candles. This figure does not represent the maximum illuminance from direct sunlight that will be found at high altitudes; however, 11,000 ft. candles appears to be a good operational figure and its use avoids expensive over-design of displays to meet isolated environmental conditions. Also, for purposes of this analysis, "high altitude" means altitudes greater than 35,000 ft. and less than 50,000 ft.

The transmitivity of the canopy and windscreen is assumed to be about 90 percent. This means that the maximum illuminance that might be incident upon a display face is about 10,000 ft. candles.

5.3.1.2 Cockpit Geometry and Aircraft Configuration

The Type A V/STOL cockpit geometry shown in Figure 5-2 complies with MIL-STD-1333 and clearances as required per MS33573 and MS33574. External vision requirements of 25 degrees over the nose vision (per MIL-STD-850) significantly reduce instrument board height. To partially compensate for the loss of instrument board area, the bottom edge is lowered and cutouts for the pilots' and operators' legs are designed into the board in order to allow vertical arrangement of at least two displays on the crew station centerline. This requires the pilot to look down 55 degrees to the bottom of the instrument board. In this case, the bottom of the instrument board coincides with the bottom of the vertical situation display (VSD).

The preliminary Vought Type A V/STOL design shows the instrument board mounted perpendicular to the over-the-nose-vision line. This is usually the initial design configuration to ensure that the HUD and other long instruments won't protrude above the cowl line and that maximum use can be made of the instrument board cowl volume. Such instrument board placement has the potential to reflect images of the pilot's flight gear from the instrument faces back to the pilot's eye. If the instrument board angle is increased with respect to the vertical, such that it is perpendicular to the pilot's line of sight at the center of the instrument board, it also becomes nearly perpendicular to the sun's rays through the rear of the canopy. This means that the ambient sun illuminance can be incident upon the display faces and can be reflected back to the pilot's eyes. Increasing the instrument board angle requires that the top of the board be moved away from the pilot to preclude a serious shortening of the board because of ejection clearance line interference. This further complicates the HUD installation and causes the HUD to occlude more of the instrument board area. If the instrument board angle is decreased, (bottom moved forward), ambient light incident upon the displays is less of a problem, but the display faces are moved further away from the pilot which means larger display symbols will be required.

For purposes of this study, the instrument board will be assumed to be mounted perpendicular to the over-the-nose-vision lines as is shown in Figure 5-2.

Large side by side cockpits usually have centerline metallic structure. The Vought design incorporates a centerline installed aerial refueling probe. This structure is nine inches wide and nine inches in depth at the design flight eye station. This overhead structure is similar to the S-3A and can be used as an overhead console. The overhead structure will reduce the ambient light level in the cockpit, however, this reduction will be slight because of the large canopy area.

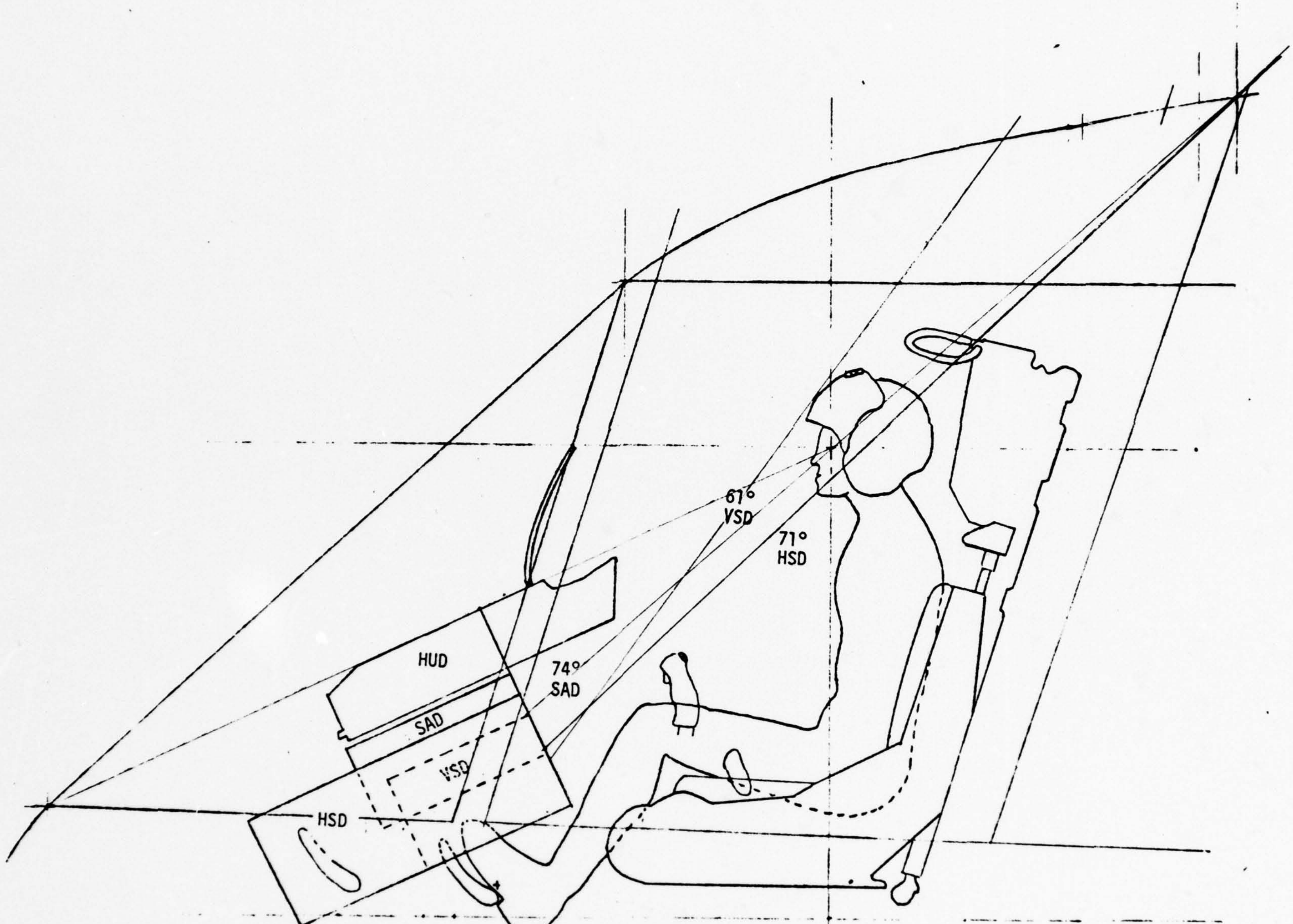

FIGURE 5-2 TYPE A V/STOL COCKPIT GEOMETRY

If only the necessary canopy structure and not the aerial refueling box is assumed, the structure will be six inches wide and one inch thick. This would allow a clearance of about seven inches between the edge of the seat and the canopy structure.

For the cockpit arrangement shown in Figure 5-2, the pilot and ejection seat structure will prevent sun rays from shining directly into the vertical situation and partially shield the two advisory displays. Only the horizontal situation display (HSD) is not shielded by the pilot's body or the ejection seat structure.

For the cockpit arrangement and aircraft configuration described above, direct sunlight thru the canopy can become incident upon the face of the VSD at an angle of about 61 degrees, upon the face of the two situation advisory displays at an angle of about 74 degrees and upon the face of the HSD at an angle of about 71 degrees. From Figures 5-2 and 5-3 it can be seen that the pilot's head helps to shield the VSD from incident sunlight. This is not the case for the SAD's and the HSD. The HSD will probably require a special faceplate to shield the display from incident sunlight and to direct the image toward the design flight eye. This may be similar to the faceplate on the A-7E projected map display.

The level of illuminance is measured in terms of the density of light flux incident upon a surface. The figure of 10,000 ft. candles has been assumed to be an operational value for ambient light levels that the pilot may experience at high altitudes.

From the cockpit geometry and aircraft configuration discussion above, it can be seen that the canopy, fuselage, and ejection seat structures will attenuate the illuminance in some areas of the cockpit. However, the large canopy area of the side-by-side cockpit will still allow a very high interior cockpit ambient of nearly 10,000 ft. candles.

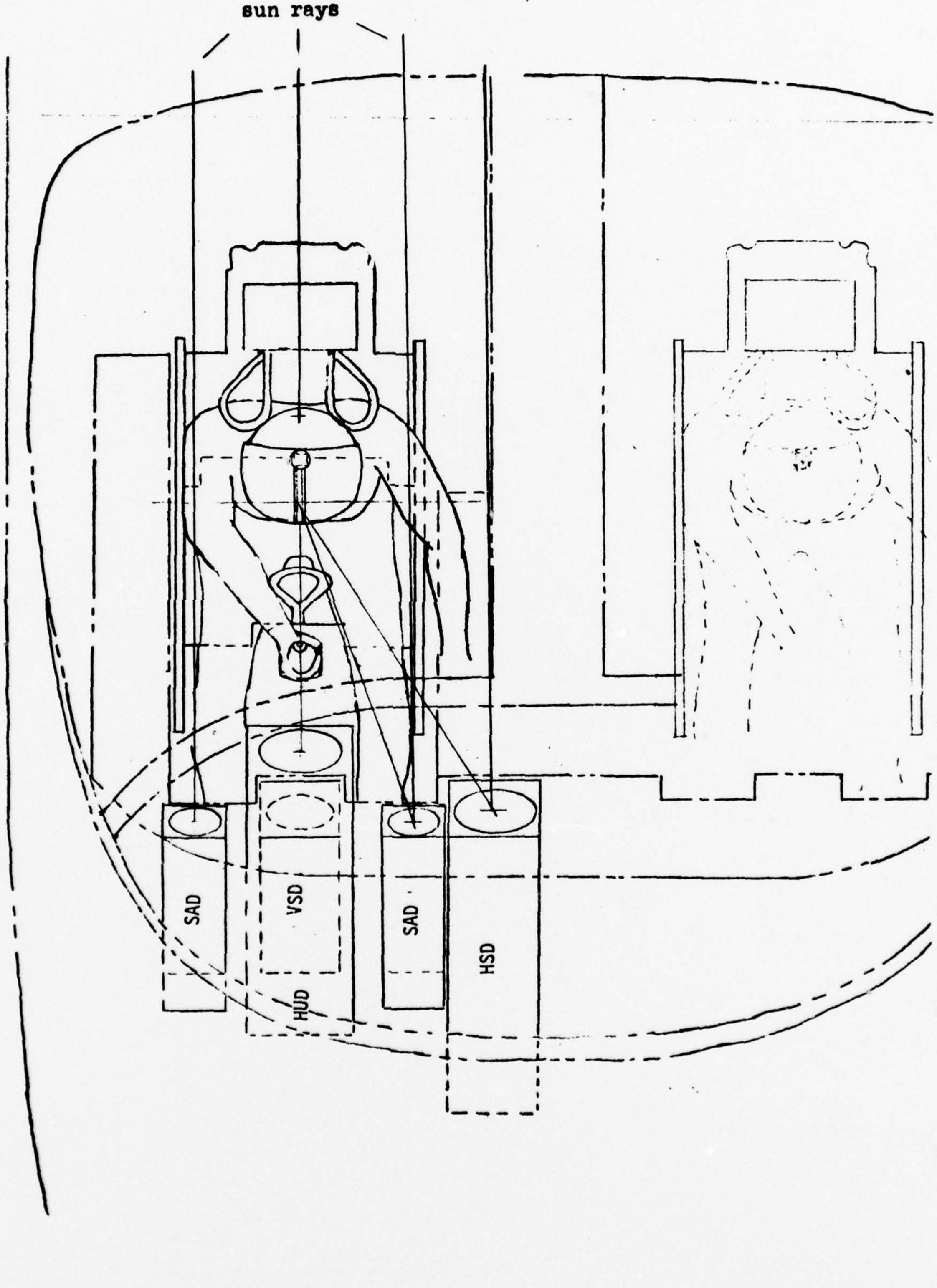

FIGURE 5-3 TYPE A V/STOL COCKPIT ARRANGEMENT

5.3.1.3 Display Requirements For High Ambient Cockpit Illumination

Cathode ray tube (CRT) displays operating in high ambient lighting conditions must be designed to present legible, visible flight information. The brute force technique of driving the tube harder to compensate for display washout (and also shortening tube life) has given way to contrast enhancement techniques resulting in legible displays and longer tube life.

Ambient light incident upon the CRT display impinges upon the phosphor and between 60-80 percent is reflected. This causes the phosphor background to provide luminance equal to 60-80 percent of the ambient light illuminating it. Any image on the tube face must then be bright (luminescent) enough to overcome the background or in other words the image must be of sufficient contrast to be visible and legible. The measured image luminance includes the background luminance. Basic contrast formulas take this into account.

$$C = \frac{B_{max} - B_{min}}{B_{min}}$$ with ambient illumination

B_{max} = Target Luminance

B_{min} = Background Luminance

For line drawn CRT displays, where the image is either present or not present, the required contrast can be estimated from available data. There are also factors available to adjust laboratory values to the operational environment. If the lines of the image are 1 milliradian (3.4 minutes of arc) wide, a contrast of about .015 (Reference (10)) is required for threshold detection (50% threshold) against a 7,000 ft. lambert (10,000 x .70) background. An adjustment factor of 30 (Reference (11)) is used to estimate contrast required for a "comfortable" image in an operational environment. The contrast required is then about 0.45. The required image brightness is then 10,150 ft. lamberts. This is obviously not a practical value and some type of ambient light filtering is required to maintain the required image contrast but at much lower highlight luminance levels. However, there is an operational limit to the highlight brightness filtering because of the high surrounding ambient light levels and the dynamic range of the eye. Studies have shown that if the surround (ambient) is brighter than the display background by a ratio of more than 100, significant increases in signal detection time will occur. If the ratio of surround to background is 10 or less, no increase in signal detection time occurs even at lower contrast ratios. Solutions are to increase the background brightness or to increase the image contrast. Therefore, the ratio of display background to surround brightness will determine the minimum display background and the maximum filtering. Contrast requirements will then determine display highlight brightness.

For V/STOL operations, where the pilot's visual workload can be excessive, contrast ratios must be large enough to overcome any degradation caused by an adaptation mismatch between the surround and display background brightness levels. For a surround/background ratio near 100, the contrast should be increased by a factor of about 2.5. This makes the required contrast ratio equal to 1.12 (2.5 x 0.45). Assuming that the phosphor reflects 70 percent of the ambient illumination the filter will require a transmission of about 12 percent at the principal phosphor output. The required display highlight brightness at the tube will be about 1800 ft. lamberts.

The above analysis is typical of the display requirements during operation at high altitude under high ambient lighting conditions. The contrast required for all displays should be greater than 1.00 for rapid detection and "comfortable" viewing under operational conditions. Use of the proper filters will allow acceptable CRT highlight brightness requirements while maintaining acceptable contrast levels.

5.3.2 Condition 2 - High Ambient Light Level, High Altitude, Worst Angle of Sun's Rays, Emergency Power

Type A V/STOL aircraft should have less requirement for emergency power provisions than conventional aircraft. The inherent high thrust to weight ratios required for vertical takeoff allow the engines to loaf during cruise flight. In addition, requirements of thrust to weight ratios greater than one, during one engine-out operation, result in a vast power reserve during cruise flight. In the event of an engine stall during cruise, a restart can be made from the remaining engine(s). The accessory drive load (including the electrical generators) is a small percentage (less than 1.0%) of the engine thrust. Engine RPM protective schemes and devices probably will not be required. Multi engine aircraft electrical system design normally includes two or more generators. In the event of a single generator failure, the remaining generator(s) will be capable of supplying the total electrical load. Present electrical system design requirements call for some type of auxiliary electrical power to energize an essential bus supplying necessary loads for night, icing, instrument flight conditions. In the event that the essential bus is reverted to, mission specific avionics would not be energized. Only those displays necessary for safe, controlled flight would be energized. This probably includes all of the AIDS displays because each display is required to be operating properly in order that acceptable pilot workload levels would not be exceeded during critical vertical flight phases. Degrading the pilot's primary displays could further degrade an already serious situation.

If the integrated display electronics (processing) must be degraded, the HUD, VSD, pilot's ICP, mode select panel, and at least one situation advisory display should be retained. The one situation advisory display must present prioritized system status and caution-advisory information. The display contrast requirements will remain unchanged under emergency power conditions.

5.3.3 Condition 3 - Black Night Operations

Cockpit ambient lighting levels during black night V/STOL operations are as critical or more critical than during V/STOL daylight operations. Vision, including acuity and depth perception, is degraded at night. AV-8A aircraft are restricted from conducting nighttime shipboard operations, primarily because of the heavy visual load of the V/STOL pilot.

5.3.3.1 Night or Dark Adapted Vision

The AIDS CRT displays will add to the cockpit ambient light level during black night operations. The total cockpit ambient light level should be such as to not unduly degrade the pilot's dark adaptation. The level of the dark adaptation is determined by the response of the retinal cells to ambient light. The retina of the eye contains both rod and cone cells. Cone cells are densest in the foveal area (nearer the optical axis) and are sensitive to color and high brightness. Cone cell vision (photopic) has best acuity (detail sensitivity). Rod cells are densest in the remaining retinal area (beyond five degrees of visual angle from optical axis) and are sensitive to low light levels. Both cone and rod cells become adapted to the prevailing light level. However, adaptation level can be regained in a matter of seconds by cone cells after brief exposure to higher luminance levels. Rod cells can require minutes to readapt after exposure to higher luminance levels. Rod cells have low relative sensitivity to red light. Therefore, low level red cockpit lighting is used where maximum dark adaptation is required.

Studies involving the effects of CRT displays on night vision have shown that exposure to low level red CRT screens result in the shortest recovery times and have least effect on visual range reduction during night vision operations. Green CRT screens have longest recovery times and significant visual range reduction.

One solution is to use red filters on green or white CRT displays for missions which require that dark adaptation be maintained. However, the proposed AIDS phosphor for HUD and VSD (P-43) has little red spectral response and will appear more orange than red when filtered. It is recommended that a different phosphor be considered for the HUD and VSD if the missions require dark adaptation.

Modern tactical aircraft have increasingly depended upon electro-optical sensor systems for target detection during night time operations. However, if the pilot desires to see the surface and horizon to ease the piloting task, a hign degree of dark adaptation is required and low level red cockpit lighting is recommended. Adequate display contrasts should be easily attainable in low level cockpit ambients.

Another area to be considered during night operations is the minimum highlight brightness required from the CRT display. The luminance level of the display should be adjustable over a logrithmic scale for linear control rotation from zero ft. lamberts thru a minimum luminance level of 0.015 ft. lamberts up to the maximum specified luminance level.

5.3.4 Condition 4 - Black Night Operations, Emergency Power

The same comments as stated under Condition 2 apply here. However, the case for retaining all of the AIDS displays on the essential bus is stronger because of the near absence of external visual cues during black night operations. The pilot will require all of the AIDS information present during normal flight operations.

5.4 AIDS STANDBY INSTRUMENT EVALUATION

The selection, location and information presentation of standby instrumentation is critical to safe V/STOL flight when using standby instruments. V/STOL operation in the vertical mode requires presentation of unique information even during VFR conditions. This includes vertical and translational velocities which need to be displayed because the pilot cannot accurately estimate these parameters. Standby instrumentation in conventionally (non-AIDS) equipped aircraft has usually been made up of smaller, slightly less sophisticated versions of the primary flight instruments. Information presented is similar in content and format to the primary instruments. The pilot is forced to change his scan patterns to accommodate standby instrument locations and is required to mentally process and integrate some additional information but, the overall increase in pilot workload is usually not excessive. Current operational V/STOL designs have simple instrumentation. The HUD is the primary flight instrument and conventional instruments make up the standby instrumentation. However, pilot workload is excessive and accident rates are high primarily because of inadequate stability augmentation, but also because of use of simple conventional flight instrumentation requiring excessive mental processing.

The objective of this task was to evaluate a list of standby information requirements for V/STOL (Exhibit C - Reference 14)

5.4.1 Standby Instrumentation Requirements

Safe vertical mode operation requires specialized flight information instrumentation and information processing. For example, presentation of instantaneous vertical velocity and acceptable limits is necessary, if not critical. Conventional vertical velocity indication systems have lags that are unacceptable for V/STOL operation. Therefore, both sensing and display of vertical velocity information require improvements for V/STOL use.

Pilot workload levels during critical V/STOL flight phases are so high that much of the mental processing load must be accomplished for the pilot if workload levels are to be contained. The AIDS system is ideal to meet this requirement. Information processing, integration and presentation can be accomplished in almost any manner desired. One area requiring special processing is margin or limit information. The pilot cannot be expected to memorize margins and limits and then to monitor quantitative displayed information and mentally calculate the proximity of safety of flight margins and limits. As long as the AIDS is in full operation, margin and limit information can be computed and appropriate cues and warnings displayed to the pilot. These cues can be displayed on the displayed scales for each parameter of interest and the limit indicators can be made to flash whenever a margin becomes critical or a limit is reached.

Reference (3) presents a list of V/STOL information requirements that has generally received wide acceptance. Several of the parameters listed also include a requirement that allowable limits be displayed.

For safe V/STOL operations, margin and limit information must be computed and displayed along with status and director information. The margin and limits information is especially necessary during primary AIDS display failures when the pilot must use standby instrumentation. This is because standby information is usually less integrated than the primary information and requires additional mental processing (increased workload) on the part of the pilot. Pilots of AIDS equipped Type A V/STOL aircraft will come to rely on AIDS displayed information. Standby instrumentation may not adequately display integrated information. In the event of primary AIDS display or processor failure, it may be necessary to restrict vertical operations under certain environmental conditions. Table 5-1 presents standby instrumentation displayed information requirements. Information requirements marked by an asterisk are not included in Exhibit C. (Exhibit C is reference list of standby information - Reference 14)

TABLE 5-1
REQUIRED STANDBY DISPLAYED INFORMATION

Flight Information	Engine Performance
Airspeed	Engine Speed
Altitude	Exhaust Gas or
Attitude	Turbine Inlet Temp.
Vertical Velocity + * Limits	Oil Pressure
Heading (Standby Compass)	Fuel Flow
*Lateral Acceleration + Limits	Fuel Quantity
*Angle of Attack + Limits	
Ground Speed and Direction	
*Translational Velocity	
*Wind Direction	
*Thrust Vector Angle	

Vertical velocity limits are required to ensure that uncontrollable sink rates will not be encountered. This parameter will require computing predictions of thrust required to arrest the rate of sink.

Lateral accelerations must be carefully controlled in current jet V/STOL aircraft to prevent a requirement for more control power than is available. Limits should be proportional to available control power and there should probably be some attention getting cue when limits are reached. One recommendation (Reference 3) is for a rudder pedal shaker which shakes only the rudder that the pilot should push. This results in a system that not only cues the pilot to a potential problem, but also directs the required corrective action.

Angle of attack information including limits is necessary to avoid stalling the aircraft at low airspeeds. As aerodynamic supported flight transitions to thrust supported flight, angle of attack loses importance.

Translational velocities are required no matter what level of control system sophistication is provided (Reference 4). The display of translational velocities using standby instrumentation may present a problem.

Thrust vector angle is usually displayed independent of other standby instrumentation. If continuous thrust vector angle control is required, the level of flight control system sophistication and display system sophistication needs to be increased to compensate for high pilot workload. The only operational V/STOL (AV-8A) does not require continuous thrust vector angle control but uses discrete settings at various parts of the approach when VFR. The aircraft has no IMC vertical landing capability. Even if thrust vector angle control is automatic, a display is required to cue the pilot.

The importance of wind direction information is dependent upon the aircraft's aerodynamic characteristics. However, wind direction should generally be displayed.

5.4.2 Location of Standby Instrumentation

The large surface area of the AIDS displays and controls and the reduced instrument board area caused by the 25° over-the-nose vision requirement does not allow for good standby instrumentation arrangement and location. Space is also required for a set of standby engine instruments for each engine. One solution may be to locate the standby engine instrumentation near to the tactical command station and allocate engine performance monitoring to the tactical commander. This allows for some reduction in the pilot workload during critical flight phases while on standby instrumentation.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 AIDS APPLICATION TO A-7E

The incorporation of AIDS into the A-7E aircraft is a feasible concept. The evaluation of weight, volume, and power allowables for AIDS component installation in the A-7E revealed adequate attainable space in the avionics bays for the data and display processors, or MIDERS, and, with major modifications to the instrument panel and consoles, a practical installation of the cockpit displays and controls can be achieved.

The major modifications include reconfiguring the instrument panel to accommodate AIDS. The modification also involves cockpit structural redesign and possible console redesign to allow adequate console depth for modularized Integrated Control Panels. Certain AIDS component physical dimensions were not identically replaceable counterparts for current A-7E components; however, from a strictly physical standpoint, the current EDM version of AIDS, as defined in Advanced Integrated Display System (AIDS) System Design Interim Report No. 2 dated 31 March 1977, is compatible with the weight, volume, and power capacities of the A-7E.

It is recommened that additional study and evaluation be conducted to define in detail the layout and location for reach and function, of the AIDS displays and particularly the Integrated Control Panels. Also, the integrated systems logic and AIDS integration with the existing A-7E navigation and weapons delivery system should be developed.

6.2 AIDS APPLICATION TO A SELECTED FUTURE TACTICAL AIRCRAFT (TYPE A V/STOL)

The study revealed that AIDS is particularly suitable for V/STOL aircraft. The increased pilot workload inherent in vertical operations and the increased aircrew workload of future tactical operations should be alleviated by the processing and display capability that AIDS offers.

Several hardware incompatibilities were noted during the physical characteristics evaluation with regard to installation of the pilot displays and controls in the relatively small instrument panel peculiar to the V/STOL type aircraft. However, if the special recommendations regarding reduced display sizes and pilot viewing constraints are considered during the AIDS hardware development phases, adaptation of the AIDS displays and controls hardware to the V/STOL should prove to be a simple task and will add to the system effectiveness of the overall weapons system.

The allowable center of gravity (C.G.) travel is considerably less for V/STOL aircraft than for conventional aircraft. Therefore, AIDS avionics may have to be located some distance from the cockpit to meet C.G. restrictions. It is recommended that the effect of long cable runs (approximately 30 ft.) from the AIDS processors to the cockpit displays be investigated.

Some unique V/STOL information requirements have been defined, particularly in sections 4.0 and 5.4, which will require processing and display. An example is display of control power margin which will require sensing specific engine and flight parameters and continuously computing control power margins.

There is also a need for a study of specific tactical mission sensor and processing avionics projected for the Type A V/STOL time period. Such a study is necessary for further definition of integrated system logic and AIDS processing and display requirements.

The human factors tasks also indicated areas that will require more extensive examination and analysis. One particular area, also stated above, is the processing and display of unique V/STOL requirements. Display of these unique V/STOL presentations will be simple for the AIDS displays but may present a difficult problem for the standby instrumentation because of the integrated information requirement. Integrated information presentation is required to contain pilot workload within acceptable levels.

Development of a pilot display format and symbology resulted in a listing of displayed information requirements and the rationale for symbol selection. The format and symbology proposed for the HUD or VSD is shown in Figure 5-1. This figure contains sufficient information for the transition from aerodynamic flight to vertical landing for a clear day, no wind, land based operation. Additional study and simulation are required to define symbol dynamics and format requirements for IMC conditions. Also, the display format and FOV requirements for HMD should be studied. FOV requirements can be determined by using a Vought developed calculator-plotter technique.

Cockpit ambient lighting assessment indicated that hardware is currently available to meet the legibility and contrast requirements. However, much can be done to reduce the cockpit ambient light levels in the large Type A V/STOL cockpit by attenuating the light transmission through the canopy and windscreen. This would alleviate the stringent highlight brightness and filter requirements and result in display cost savings. However, care must be taken to minimize canopy internal reflections and to not significantly reduce external visual clues, particularly at night. If the mission requires a high level of dark adaptation, selection of a HUD and VSD phosphor that contains sufficient red spectral response for red filtering is recommended.

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14. "Exhibit C", List of Standby Emergency Instruments included with study contract.

APPENDIX A

AIDS HUMAN FACTORS PROGRAM PLAN

9 NOVEMBER 1977

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CONTENTS

FIGURES

I. INTRODUCTION

The previous human factors efforts on the AIDS program have emphasized the equipment related aspects of the man-machine system. Such areas as the psychophysical criteria (contrast, brightness, refresh rate, etc.) were stressed. Also included were cockpit geometry based on equipment sizes, VSTOL constraints, and operator reach and visibility. While these areas will be continued and refined throughout this next phase, the emphasis will now be placed on the actual control/display information characteristics and how the AIDS will be actually used by the pilot/operator in the VSTOL type A aircraft. Among the questions that now need to be answered are the following:

What is the optimum crew size and composition?

What information is required by the pilot/operators in order for them to fulfill their ASW/AEW missions?

What information does the pilot require to help him fly a VSTOL aircraft?

In what format should the information be displayed?

What are the display interactions, especially among the HUD, HMD and VSD?

Should color be used? Where? How?

What function should the ICS have?

Which function should be dedicated and which should be on a multifunction switch?

What is the control logic that should be used in the ICS?

These questions, and any others that will arise during the next phase, will be answered through human factors literature searches, experimentation both with and without the AIDS ADM equipment, computer models, interviews with potential users, and by cooperation with Air Force DAIS human factors personnel. The following program plan will detail these methods for providing human factors support for the AIDS program.

II. IN-HOUSE HUMAN FACTORS SUPPORT ACTIVITIES FOR AIDS

1. MONITOR GEHF ACTIVITIES

NADCHF will monitor GEHF activities by suggesting specific means to accomplish their tasks, by reviewing GEHF documentation, and participating whenever possible in GEHF activities. NADCHF will also act as a focal point and liaison between GEHF and the Air Force and other Navy human factors groups for the exchange of information. From time-to-time NADCHF will issue position papers on certain controversial areas as the need arises. In addition, NADCHF will provide direct human factors consultation to other NADC AIDS personnel and will review all human factors documentation from other contractors.

2. INFORMATION REQUIREMENTS

Based on the results of GEHF's task analysis, information from the Air Force and airframe companies, and data from ASW/AEW mission documentation, NADCHF with assistance from HFSC will establish information requirements for the pilot and tactical crew.

3. DISPLAY FORMATS

Display formats will be collected from various sources (such as the Air Force, airframe companies, other Navy labs) for evaluation by operator performance and preference studies. Where no formats exist, new ones will be generated using a RAMTEK graphic display system. Suggestion will also be made for the use of color for coding certain display information. The candidate formats will then be made into 35mm slides for initial evaluation. Final evluation will be made on the AIDS dynamic simulator. Formal specification language software such as GRADS, ACOL, and AEDDL will be required for this evaluation. NADCHF will be assisted by HFSC in this task.

4. DISPLAY ALLOCATION

NADCHF will specify which information is to be displayed on each of the pilot's and tactical crew's displays. Also, the interaction between the displays (for example between the HMD and HUD) will be specified. The information needed for this task will be obtained from the Air Force and airframe companies.

5. HF EXPERIMENTS

NADCHF will provide the HFSC with the independent variables needed for evaluation of pilot/operator performance by experimental studies and of pilot/operator preferences by questionnaires. NADCHF will assist the HFSC in designing the experiments and the questionnaire.

6. SENSOR STATION DESIGN

NADCHF will design the crew station for the sensor operator. The design will include: display and control layout and arrangement, console geometry, and lighting. The number of sensor operators will be determined by the workload measurement (task 10).

7. PSYCHOPHYSICAL MEASUREMENTS

The psychophysical parameters (brightness, contrast, resolution, refresh rates, etc.) of the ADM display hardware will be measured to verify agreement with the human factors design criteria. Some measurements will be conducted exclusively by NADCHF, some by NADCHF with GEHF and HFSC assistance, some exclusively by GEHF, and some by GEHF with on-site representatives of NADCHF.

8. ICS CONTROLS

Initial human factors design criteria based on literature searches and analysis will be prepared for use in determining the acceptability of proposed control devices to be used in the ICS. Subsequent criteria will be developed based on in-house experimentation. Criteria will also be prepared for specifying control legends, to include labeling, abbreviations, size, color and brightness of switch lighting. AFHF will cooperate with NADCHF and GEHF in specifying the control logic to be used in the multifunction switches.

9. VRAS

An assessment will be made of the merits of using a VRAS (Voice Recognition and Synthesis System) for supplementing the AIDS displays and controls. In order to do this, NADCHF will design a demonstration for both voice recognition (control) and voice synthesis (display) for use with the AIDS simulator. An ASW mission scenario will be used for this demonstration.

10. WORKLOAD MEASUREMENT

NADCHF will evaluate different performance assessment methodologies to determine the one to be used for measuring the pilot/operator workload. Some examples are the WAM (Workload Assessment Model) and SAINT (System Analysis of Integrated Networks of Tasks). If the WAM is determined to be suitable, NADCHF will perform the workload measurement. The output of this task will be the flight/tactical crew size specification.

III. GENERAL ELECTRIC HUMAN FACTORS SUPPORT ACTIVITIES FOR AIDS

1. HUMAN FACTORS EVALUATION OF CONTROL/DISPLAY HARDWARE

Extensive use will be made of previous and current studies to expand the psychophysical design criteria. GEHF will ensure that these criteria are applied to all aspects of AIDS design and evaluation by continual liaison with the various hardware engineering groups, hardware evaluation, and by means of the formal and informal design review process.

GEHF will provide support to NADCHF in determining ICS component characteristics with regard to switch sensitivity, tactile feedback, and general operability in aircraft environments. In addition, the ICS ADM hardware will be evaluated to ensure that they satisfy the human factors criteria specified by NADCHF.

The display hardware will be tested for general readability of symbology under illumination levels of from .01 to 10,000 ft-candles at the display surface. For the HUD, a background luminance of 10,000 ft-lamberts must be provided. Also, photometric tests will be conducted by GEHF and NADCHF to ensure compliance with design criteria of the following parametric: resolution, contrast, minimum brightness, viewing angle, and combiner transmittance. Some of these tests will be done exclusively by GEHF, some exclusively by NADCHF, and some jointly.

2. MAINTAINABILITY/ACCESSIBILITY

The human engineering maintainability/accessibility criteria developed during the previous phase of the AIDS program will be applied during the ADM phase. GEHF will provide support to hardware design engineering for the application and evaluation of these criteria to the AIDS equipments during design, fabrication, and installation.

3. DOCUMENTATION FOR PHASE I (HARDWARE) AND PHASE II (SYSTEMS INTEGRATION)

This task includes the preparation of monthly reports, interim reports, final reports for each phase (hardware and system integration) and oral presentation material not included in the DD1423 documentation items.

4. SYSTEM FUNCTION ALLOCATION

The baseline AIDS VSTOL-A System configuration developed during the previous program phase will be analyzed by GEHF to verify the allocation of man/machine function. This analysis will consider system functional allocation as well as display/control allocation. The analysis will be an input for the task analysis effort.

5. SYSTEM ENGINEERING DESIGN SUPPORT

GEHF will provide design support to the system engineering to ensure human factors criteria are applied to all aspects of the AIDS design. This support will be achieved by GEHF having an active role in the design process through continual liaison with the various system engineering groups and by means of the formal and informal design review process.

6. CREW STATION ENVIRONMENT DESIGN EVALUATION

A crew station environment evaluation will be conducted to ensure that the design requirement of MIL-H-46855, paragraph 3.2.2.3 have been met. The following areas of paragraph 3.2.2.3 are applicable and will be evaluated: h, 1, n, o, p and g. Initially the evaluation will consider the baseline ADM cockpit; however, as this cockpit can be expected to change during the course of the ADM effort, the environmental evaluation will be conducted on each cockpit iteration throughout the ADM phase.

7. SCENARIO DEVELOPMENT

Two complete scenarios will be developed for the human factors ADM lab demonstration testing. The general ASW and AEW scenarios, generated during the V/STOL System Configuration Phase, will be expanded to make them more complete and comprehensive for both task analysis and operator performance testing. In particular the ASW/AEW mission segments (search, tracking, localization, engagement, interceptor control) will be expanded and the V/STOL flight regime segments will be modified to better reflect a V/STOL-A aircraft rather than the Harrier. Other scenario modifications would reflect anticipated aircraft, sensor, and weaponry capabilities for the 1980 - 1985 era.

8. <u>TASK ANALYSIS (ASW & AEW)</u>

Detailed task analysis will be performed and documented (per DI-H-2109) for the two cockpit positions on the ASW and AEW scenarios. These analyses will be the basis of the operator tasks to be evaluated during the AIDS lab demonstration tests. The task analysis will use related analyses, user interviews, and studies of future equipment capabilities. A general task analysis will be conducted on the non-flight stations to determine information transfer requirements. This limited crew station task analysis will make extensive use of existing task analysis (from Navy activities, airframe contractors, etc.)

9. <u>COCKPIT LAYOUT</u>

The cockpit layout as defined during the previous phase will be the baseline layout at the start of the ADM phase of the program. As the hardware design, fabrication, and testing efforts continue, this cockpit layout will continue to be evaluated and modified to maintain an optimum layout based on human factors criteria. This effort will continue throughout the AIDS ADM program.

10. <u>CONTROL/DISPLAY FORMAT EVALUATION</u>

This task will include the formulation, modification, and specification of display formats and control function requirements for AIDS throughout the ADM program.

NADCHF has agreed to act as a clearing house and has assumed responsibility for gathering all existing display formats and will furnish GEHF with a recommended set of formats with which to begin ADM testing. GEHF may propose alternate formats not currently available, cooperate with NADCHF to modify the provided formats as needed and evaluate the total package for completeness and compatibility. Time, accuracy and pilot opinion data will be gathered by using the static (slide projector) and dynamic cockpit simulators at NADC to evaluate these display formats. To adequately assess the effectiveness of VSTOL flight display formats on pilot performance, a dynamic simulator with sufficient motion cues to duplicate the VSTOL aspects of flight, is required, GEHF and NADCHF will jointly participate in the above display format evaluations.

After determing the AIDS control functions from the ASW/AEW task analysis, different allocations will be made between dedicated and multifunction switches. Also, various numbers of indenture levels, panel layouts, and cockpit locations will be proposed. An evaluation of these candidate configurations will be made to determine the optimum ICS as measured by time, accuracy, general operability and operator preference.

IV. HUMAN FACTORS SUPPORT CONTRACTOR

A contractor will be employed to provide direct support to NADCHF by designing and conducting human factors experiments and questionnaires to evaluate various display formats (including the use of color). Other areas in which the HFSC will provide assistance to NADCHF are information requirements analysis, display format generation and collection, and display psychophysical measurements. In order to accomplish these tasks the HFSC will need to conduct literature searches, interview potential users, and maintain continuous direct liaison with NADCHF.

V. AIR FORCE DAIS HUMAN FACTORS COOPERATION

As established by the Memorandum of Agreement-Advanced Development of Aircraft Displays and Controls, dated 4 May 1977, AFHF will cooperate with NADCHF by exchanging information and participating in the development of joint human factors standards and guidelines. Specific areas in which AFHF will provide cooperation are: pilot information requirements, display format standardization, and ICS switching logic. AFHF and NADCHF will meet at least semiannually as members of the joint (AIDS/DAIS) pilot interface coordination team.

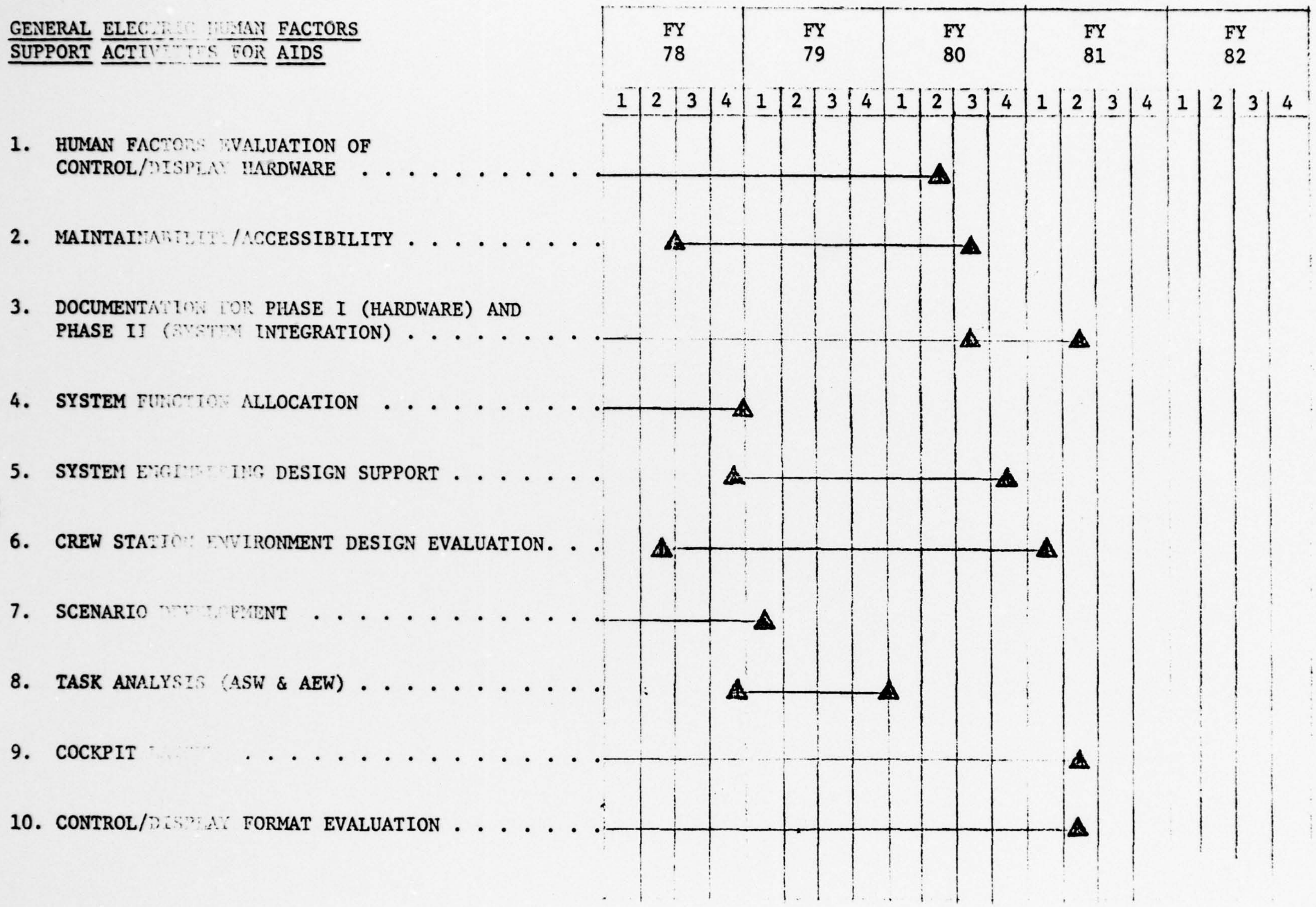

Figure 1. - NADCHF AIDS Program Schedule

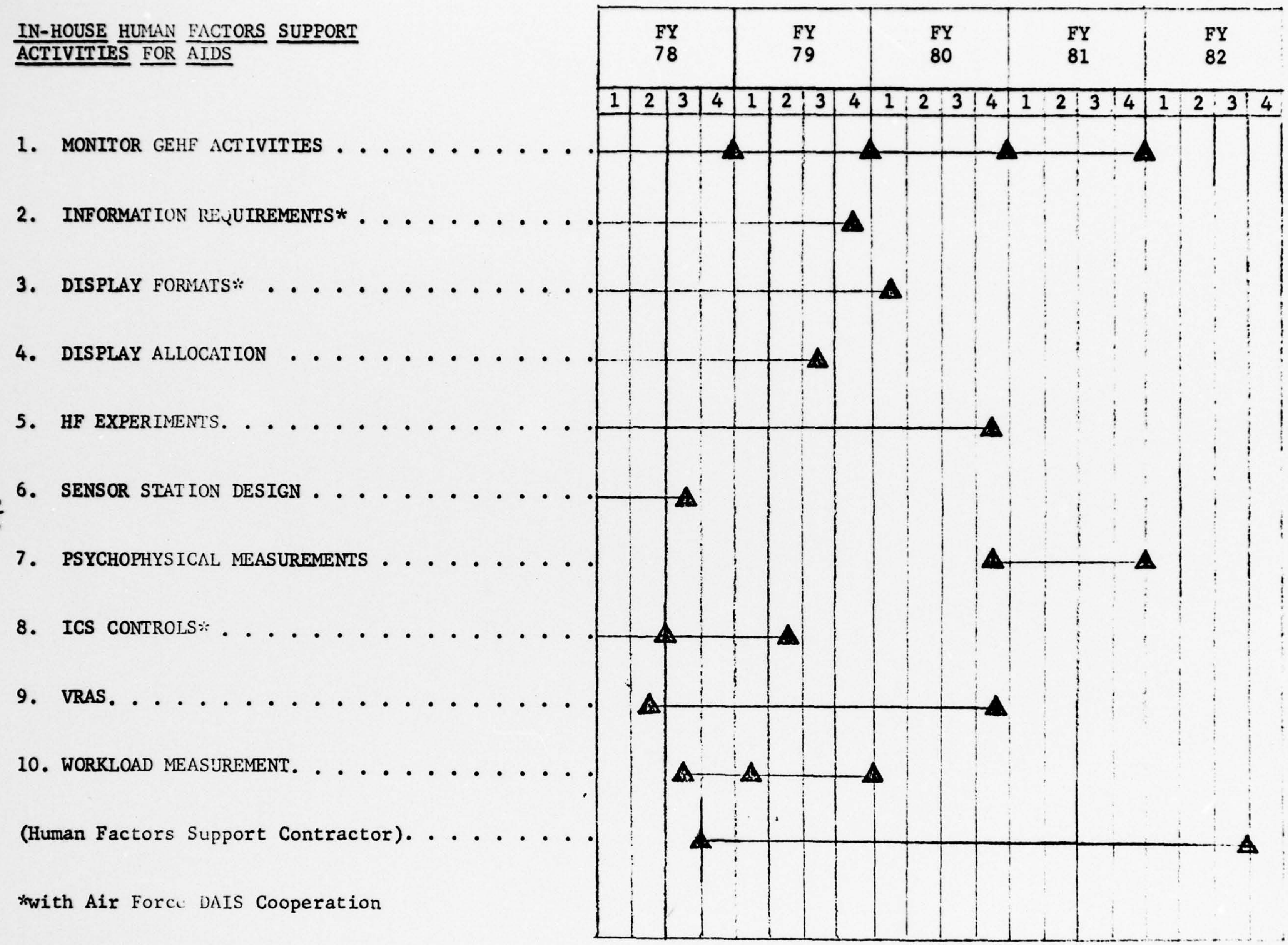

Figure 2. - GEHF AIDS Program Schedule

LIST OF ABBREVIATIONS

ADM --- Advanced Development Model
ADU --- Analogue Display Unit
AEW --- Airborne Early Warning
AFCS --- Automatic Flight Control System
AIDS --- Advanced Integrated Display System
AIMIS --- Advanced Integrated Modular Instrumentation System
APC --- Approach Power Control
AOA --- Angle of Attack
ASW --- Anti-Submarine Warfare
BIED --- Briefing Information Entry Device
CRT --- Cathode Ray Tube
CTOL --- Conventional Take-Off and Landing
ECM --- Electronic Counter Measures
EDM --- Engineering Development Model
FOV --- Field Of View
GPMS --- General Purpose Multiplex System
HMD --- Helmet Mounted Display
HSD --- Horizontal Situation Display
HUD --- Head Up Display
ICDP,
ICP,
ICS --- Integrated Display Control Panel/Set
IMC --- Instrument Meteorological Conditions
IMS --- Inertial Measurement Set
IOC --- Initial Operational Capability
MAD --- Magnetic Anomoly Detection
MIDER --- Modular Integrated Display Electronics Rock
MPD --- Multi-Purpose Display
NADC --- Naval Air Development Center
NWDC --- Navigation/Weapons Delivery Computer
NWDS --- Navigation/Weapons Delivery System
PMDS --- Projected Map Display System
RFQ/I --- Request For Quote/Information
SAD --- Situation Advisory Display
SCD --- Signal Data Converter
SDP --- Signal Data Processor
SENSO --- Sensor Operator
SOFM --- Safety Of Flight Monitor
SSIU --- System Signal Interface Unit
TACCO --- Tactical Coordinator
VMC --- Visual Meteorological Conditions
VSD --- Vertical Situation Display
V/STOL --- Vertical/Short Take-Off and Landing

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