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ANALYSIS AND FLIGHT SIMULATOR EVALUATION OF AN ADVANCED FIGHTER COCKPIT CONFIGURATION

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The objective of this study contract was to apply the techniques developed during previous Integrated Information Presentation and Control System (IIPACS) programs to the systems in a present day tactical fighter and to perform a flight simulator evaluation of certain key elements of the proposed configuration.

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Work was begun with a review of the previous IIPACS studies and a state of the art survey relative to multifunction controls and multipurpose displays. This preliminary work led to a functional analysis of the A-7D systems constrained by the Close Air Support (CAS) mission requirements and weapon mix as provided by the Avionics Laboratory. As a result of the analysis and survey a generalized layout of a proposed cockpit was formulated and a detailed trade study was performed to configure the two multifunction control panels required. Hardware and software modifications were made to the simulator used in the IIPACS III evaluations to reflect the primary features of the proposed configuration.

Flight simulator evaluations of two combat mission segments (Air-to-Air and Air-to-Ground) and two types of landings (Day and Night) were flown by six operational fighter pilots and two consultant pilots. The pilots performed various tasks in the cockpit associated with the multifunction control panel and multipurpose displays. In addition, they flew the missions with either a fixed, cowl-mounted head up display or with a helmet-mounted sight display for one comparison. In another comparison they performed normal navigation system updates with a map presentation overlayed on sensor imagery on the electronic horizontal situation display or with the two sets of information separated on the same display. Objective performance data related to maintaining an optimum flight profile, delivering a weapon against a ground target and tracking a bogey was collected during the trials. Subjective opinions were derived from written questionnaires and interviews.

Modifications were made to the proposed configuration as a result of the evaluations. This final report summarizes the work and presents recommendations for configuring an advanced fighter cockpit utilizing integrated controls and displays.

FOREWORD

This report covers the work accomplished during the period June 1973 through December 1974 under Contract F33615-73-C-1201; Display Systems Concept Development. The work was sponsored by the United States Air Force Avionics Laboratory (AFAL), Wright-Patterson Air Force Base, Dayton, Ohio. The Technical Monitor was Mr. N. A. Korchick of AFAL.

The work was accomplished by the Research and Engineering Division of the Boeing Aerospace Company under the direction of Messrs. W. D. Smith and D. R. Zipoy who were Program Managers during the program. Special acknowledgement is given to the following individuals for contributions to this project: Mr. W. Willich, who was Project Engineer, conducted the systems analysis, test planning and simulator evaluation/coordination. Dr. R. E. Edwards conducted the experimental test design and data analysis.

This technical report has been technically reviewed and is approved.

ROBERT N. SPANBAUER, Lt. Col., USAF
Chief, System Avionics Division
AF Avionics Laboratory

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SECTION I

INTRODUCTION

A series of studies have been performed under contract to the U.S. Air Force to formulate and test a concept representing an integrated control/ display system for an advanced tactical fighter. These studies were known as the IIPACS I, II and III (Integrated Information Presentation and Control System Study) series and resulted in a cockpit configuration which made extensive use of multipurpose electronic displays and multifunction switching controls. The simulator configuration that was evaluated during the IIPACS III contract period is shown in Figure 1 and documentation of this work is given in References 1 through 5.

The purpose of the present contract effort was to apply the concepts developed during the previous programs to a present day tactical fighter cockpit (A-7D) and to evaluate certain elements of the configuration in terms of system performance and pilot workload. An overview in sequence diagram format is presented in Figure 2 and shows the support relationship of this program (termed DAIS I - Digital Avionics Information System) to the larger DAIS II Advanced Development Program.

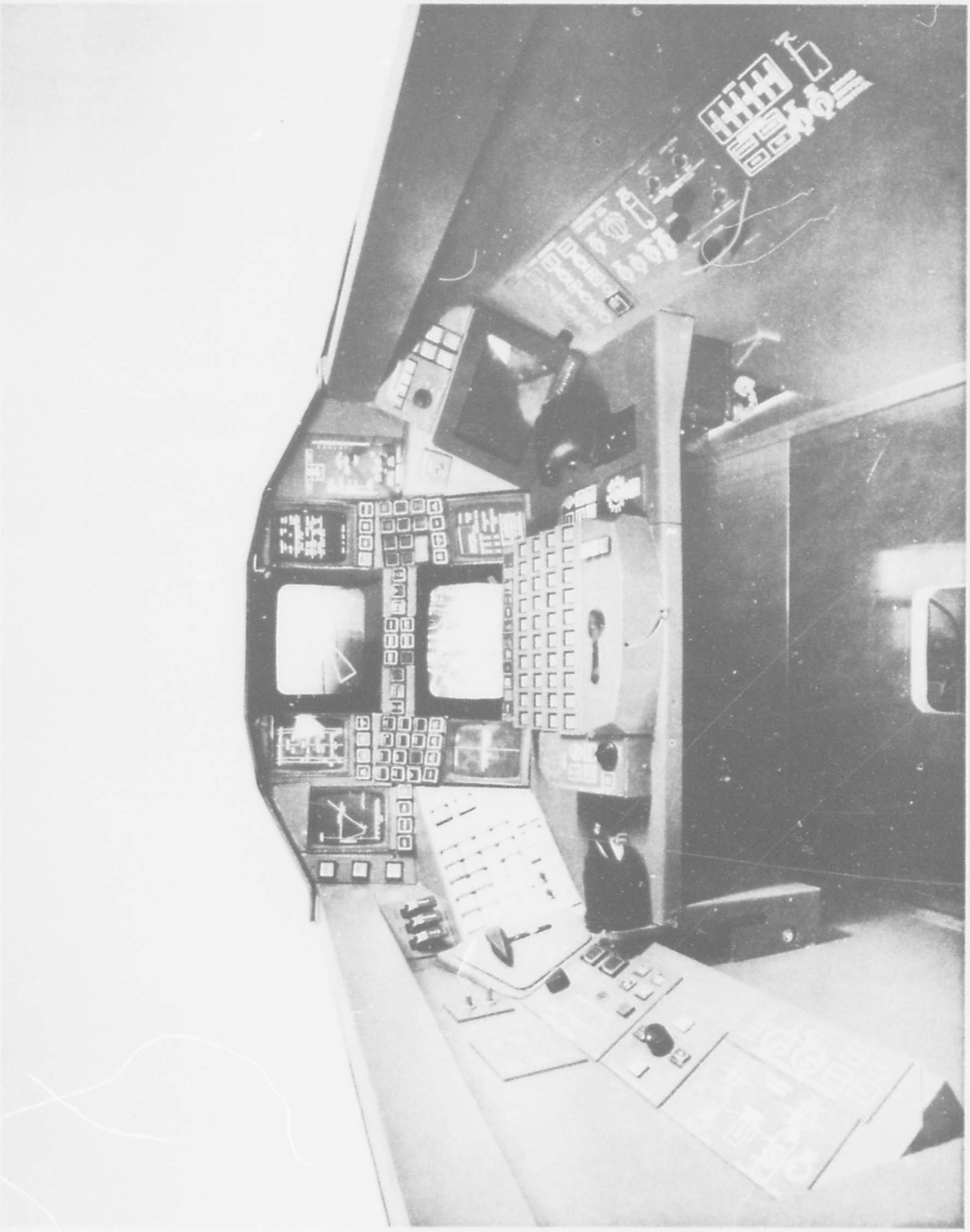

Figure 1. IIPACS III Cockpit Arrangement

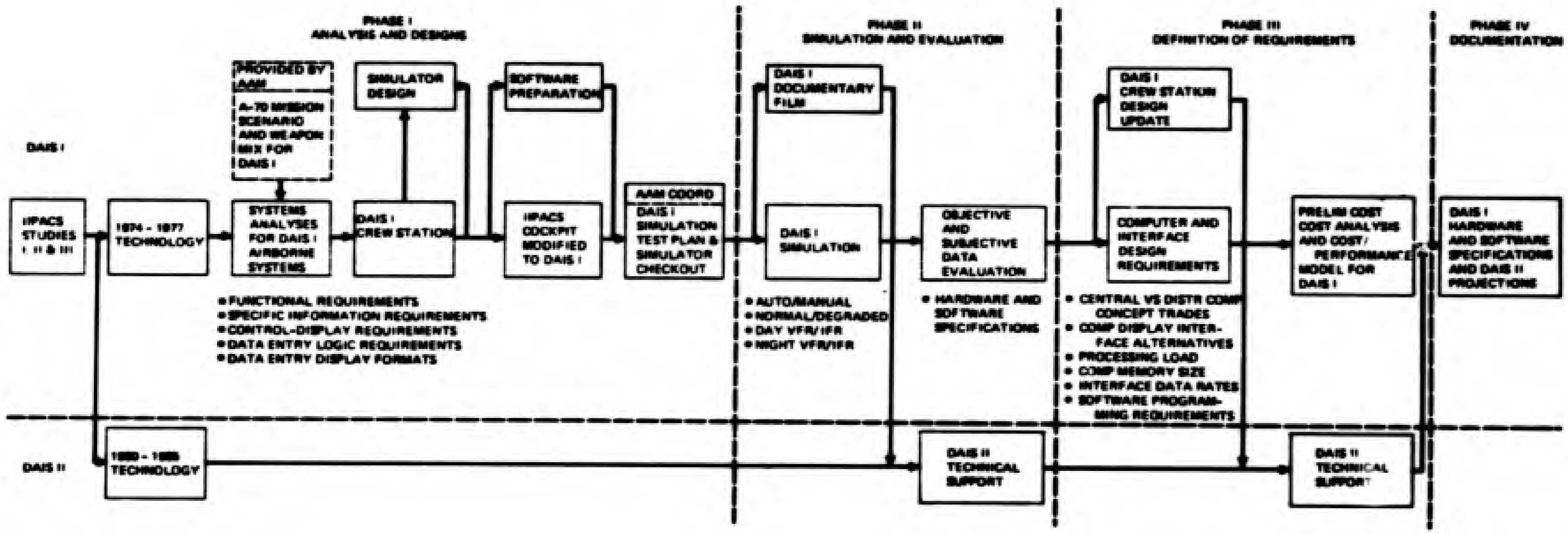

Figure 2. ***Program Overview***

SECTION II

SUMMARY

This report summarizes work done under contract to the U.S. Air Force Avionics Laboratory in the time period from June 1973 to December 1974. The objective of this study was to apply the techniques developed during previous studies to the systems in a present day tactical fighter and to perform a flight simulator evaluation of certain key elements of the proposed configuration.

Work was begun with a review of the previous IIPACS studies and a state of the art survey relative to multifunction controls and multipurpose displays. This preliminary work led to a functional analysis of the A-7D systems constrained by the close air support (CAS) mission requirements and weapon mix as provided by the Avionics Laboratory. As a result of the analysis and survey a generalized layout of a proposed cockpit was formulated and a detailed trade study was performed to configure the two multifunction control panels required. Hardware and software modifications were made to the simulator used in the IIPACS III evaluations to reflect the primary features of the proposed configuration.

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Modifications were made to the proposed configuration as a result of the evaluations. This final report summarizes the work and presents recommendations for configuring an advanced fighter cockpit utilizing integrated controls and displays.

SECTION III

RESULTS AND DISCUSSION

III.1 CONTROLS/DISPLAYS FUNCTIONAL ANALYSIS

A first step in the analysis procedure involved identifying the control/display functions in the A-7D cockpit, along with the advanced sensor systems and displays given in earlier programs (Reference 6) and separating them into broad functional areas. Eight general areas were established and are given in Figure 3. This functional grouping formed the basis for writing detailed narrative descriptions for all control/display functions and organizing them in a sequential manner. This was done in anticipation of treating the data with computer analysis techniques. An example of the detailed narrative descriptions is given in Figure 4.

Controls/Displays Functional Areas	
1.0	Electronic Displays
2.0	Flight Instruments
3.0	Flight Controls
4.0	Communications
5.0	Navigation
6.0	Sensors
7.0	Stores Management
8.0	Aircraft

Figure 3. Controls/Displays Functional Areas

1.0 ELECTRONIC DISPLAYS

1.1 HEAD UP DISPLAY

CONTROL FUNCTION	DISPLAY FUNCTION
1.1.1 SELECT IN RANGE SYMBOL WHEN AIRCRAFT WITHIN PRESELECTED RANGE TO TARGET	AIRCRAFT IS WITHIN PRESELECTED RANGE TO TARGET
1.1.2 HUD PANEL LIGHTS -ON/OFF-	INDICATION OF HUD PANEL LIGHTS -ON/OFF-
1.1.3 ADJUSTMENT OF STANDBY RETICLE BRIGHTNESS INCREASE/DECREASE/OFF	INDICATE INCREASING/DECREASING STANDBY RETICLE BRIGHTNESS AND-OFF-
1.1.4 ADJUSTMENT OF THE STANDBY RETICLE DEPRESSION ANGLE	PROVIDE THREE DIGIT INDICATION OF STANDBY RETICLE DEPRESSION ANGLE IN MILLIRADIANS
1.1.5 INITIATE HUD SELF TEST/OFF	INDICATE SELECTION OF HUD SELF TEST/OFF
1.1.6 SELECT-BAROMETRIC/RADAR-ALTITUDE DATA FOR PRESENTATION ON ALTITUDE SCALE. AUTO SELECT RADAR WHEN AIRCRAFT BELOW 5000 FEET.	DISPLAY SELECTED ALTITUDE DATA (BAROMETRIC/RADAR) ON ALTITUDE SCALE AND IDENTIFY WHICH DATA IS DISPLAYED

Figure 4. Basic Format Functional Requirements

III.1.1 Control/Display Allocation Summary

Following a procedure developed in a cockpit switching study (Reference 7) the functional requirements listing was translated into a control summary listing. As shown in Figure 5, the next step in the analysis procedure required allocating the control functions into multifunction/dedicated candidates along the guidelines given in Figure 6. An example of the resulting listing is given in Figure 7 with the following explanation of terms:

- Control allocation - control functions are assigned to three possible areas, multifunction manual, dedicated manual or dedicated automatic.

- Control allocation coding - appears in the computer listings preceding each control function

H	top level of indenture
MM	multifunction manual control candidate
M	second level of indenture
CF	control function - third level of indenture
DA	dedicated automatic control candidate
CFF	control function - fourth level of indenture
DM	dedicated manual control candidate

- Level of indenture/logical level - terms used interchangeably to describe a single step in a logical sequence associated with multifunction control.

- o Switch wafer level - it is assumed in this study that each multifunction switch has multiple legends and that this is accomplished through selective illumination of areas on a Mylar "wafer". Therefore, a 12 legend switch would contain a three column by four row wafer.

- o Wafer loading - number of switch legend locations used divided by the total number available. A multifunction panel with 24 switches having 12 legends each has 288 (24 x 12) legends available.

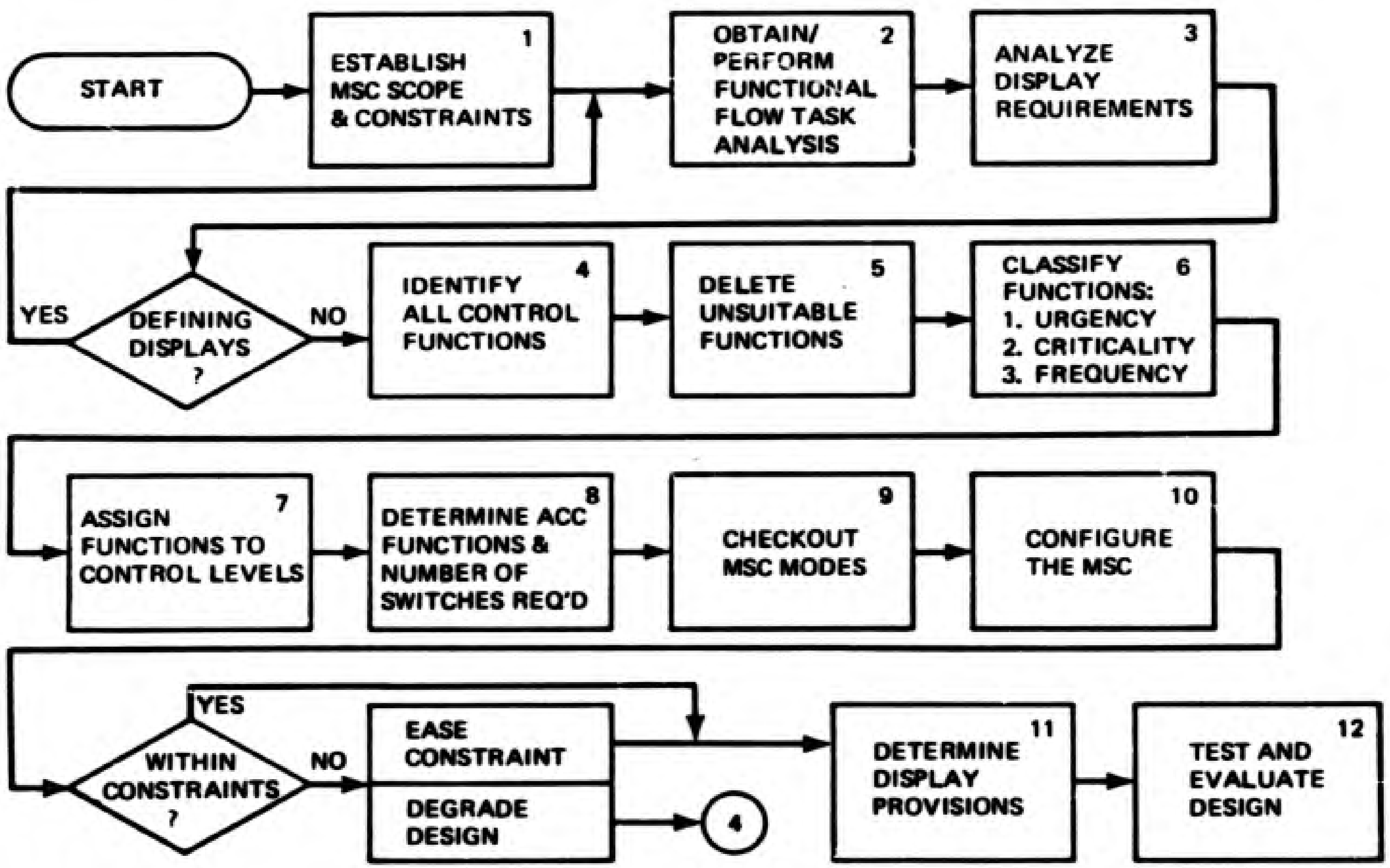


Figure 5. Multifunction Control Design Procedure

Unsuitable Control Functions

1. Emergency functions which must operate when the system is greatly degraded. Examples: emergency flaps, ram air turbine deployment.

2. Emergency functions which have a natural or traditional control locations. Examples: canopy, jettison, eject.

3. Functions naturally integrated with other controls. Gun/camera switch, microphone switch, trim "beeper."

4. Unusually sensitive functions. Special weapons enable switch. (Normally guarded and wired.)

5. Rarely used but potentially highly critical functions. Fuel master switch, master generator switch.

6. Normally non-critical functions which could endanger the system if erroneously activated. Emergency gear downlock, wingfold.

7. Naturally or appropriately mechanical functions. Air vent, harness release.

8. Critical annunciation and response functions, and acknowledgement functions normally associated with an indicator. Caution and acknowledge, data link message and acknowledge.

9. Analog functions. Suit vent-air temperature, radio volume, chart lights.

10. Setting functions associated with particular instruments. HSI heading set, Mach or airspeed limit set, altimeter baro pressure set. (Unless separate keyboard entry must be made anyway.)

11. Special purpose, one-time test functions. Anti-g valve test.

Figure 6. Multifunction Control Suitability Guidelines

```
H   MM1.0              ELEC       DISP
M   MM1.1              HUD
CF  DA1.1.1            IN RNG     SEL
CF  MM1.1.2            HUD        LGTS
CFFMM1.1.2.1           ON
CFFMM1.1.2.2           OFF
CF  DM1.1.3            SBY RET    BRT
CFFDM1.1.3.1           INCR/      DECR
CFFDM1.1.3.2           OFF
CF  DM1.1.4            SBY RET    DEP
CFFDM1.1.4.1           UP
CFFDM1.1.4.2           DN
CF  MM1.1.5            HUD        TEST
CFFMM1.1.5.1           TEST
CFFMM1.1.5.1           OFF
CF  MM1.1.6            BAR/RDR    SEL
CFFMM1.1.6.1           BAR
CFFMM1.1.6.2           RDR
CF  DM1.1.7            NITE       FILTER
CFFDM1.1.7.1           INSERT
CFFDM1.1.7.2           REMOVE
CF  MM1.1.8            ADD        SYMB
CFFMM1.1.8.1           ON
CFFMM1.1.8.2           OFF
CF  DM1.1.9            SYMB       BRT
CFFDM1.1.9.1           BRT        INC/DCR
CFFDM1.1.9.2           OFF
CF  DM1.1.10           COMB       GLASS
CFFDM1.1.10.1          FWD/AFT
CF  DA1.1.11           COMPTR
CFFDA1.1.11.1          MAG        HDG
CF  DA1.1.12           COMPTR
CFFDA1.1.12.1          HORIZON
CF  DA1.1.13           COMPTR
CFFDA1.1.13.1          BREAK      AWAY
CF  DA1.1.14           COMPTR
CFFDA1.1.14.1          VERT       VEL
CF  DA1.1.15           COMPTR
CFFDA1.1.15.1          FLT        DIR
CF  DA1.1.16           COMPTR
CFFDA1.1.16.1          FLT        PATH
CF  DA1.1.17           COMPTR
CFFDA1.1.17.1          WARNING
CF  DA1.1.18           COMPTR
CFFDA1.1.18.1          LNDG       DIR
CF  DA1.1.19           COMPTR
CFFDA1.1.19.1          A/S        SCALE
CF  DA1.1.20           COMPTR
CFFDA1.1.20.1          A-G-A      SYMB
CF  DA1.1.21           COMPTR
CFFDA1.1.21.1          PITCH      LADDER
CF  DA1.1.22           COMPTR
CFFDA1.1.22.1          ATTACK     BOX
CF  MM1.1.23           FORMAT     SEL
CFFMM1.1.23.1          A/A
CFFMM1.1.23.2          A/G
```

Figure 7. ***Listing – Switch Name and Allocation Codes***

III.2 MULTIFUNCTION CONTROL CONFIGURATION DEVELOPMENT

III.2.1 Modified Allocation Summary

An examination of the allocation summary previously discussed revealed two things: 1) it was unnecessary to require four levels of indenture to achieve all control functions and, 2) four of the broad functional areas consisted primarily of controls that were given the dedicated allocation. With this in mind, the allocation listing was reduced to three levels of indenture (except for the data entry keyboard which remained at the fourth level) and four of the functional areas were dropped from the multifunction candidate listing. The remaining areas deemed suitable for inclusion in the multifunction panel include:

4.0 COMMUNICATIONS
5.0 NAVIGATION
6.0 SENSORS
8.0 AIRCRAFT SUBSYSTEMS

It should be noted, there remained certain controls in these broad areas that were dedicated and provision was made for these controls in the overall configuration layout. An example of the modified computer listing is given in Figure 8.

III.2.2 Multifunction Switch Panel Configuration

Completion of the function allocation coding allowed computer analysis techniques to be used to define a multifunction switch panel configuration. A sample output of this program is given in Figures 9 through 12 with Figures 9, 10, 11, and 12 respectively showing a typical logical sequence beginning with depression of COMM at Level 1, depression of UHF at Level 2 and depression of CHAN SEL at Level 3 which calls up the data entry keyboard at Level 4.

The program also had the capability for showing how the panel would appear if various layers were selectively illuminated as shown in Figure 13. This

```
M   MM4.0       COMM
M   MM4.1       UHF
CF  MM4.1.1     PRESET     CHAN
CF  MM4.1.2     MAN
CF  MM4.1.3     GO         XMIT
CF  MM4.1.4     CHAN       SEL
CF  UM4.1.5     OFF/       VOL
CF  MM4.1.6     SQLCH
CF  MM4.1.7     T/R
CF  MM4.1.8     T/R+G
CF  MM4.1.9     ADF
CF  MM4.1.10    FREQ       SEL
CF  UM4.1.11    CHAN/      FREQ
M   MM4.2       VHF-FM
CF  UM4.2.1     FREQ
CF  MM4.2.2     FREQ       SEL
CF  MM4.2.3     T/R
CF  MM4.2.4     RETRAN
CF  MM4.2.5     HOME
CF  UM4.2.6     OFF/       VOL
CF  MM4.2.7     SQLCH
CF  MM4.2.8     CARR
CF  MM4.2.9     TONE
M   MM4.3       ADF        AUX UHF
CF  MM4.3.1     ADF
CF  MM4.3.2     CMD
CF  MM4.3.3     GND
CF  MM4.3.4     CHAN       SEL
CF  UM4.3.5     SENS
CF  UM4.3.6     OFF/       VOL
CF  MM4.3.7     GUARD
CF  MM4.3.8     NORM
M   UM4.4       INTER      COMM
CF  UM4.4.1     MIC
CF  UM4.4.2     VOL
CF  UM4.4.3     HOT        MIC
CF  UM4.4.4     TAC MON    OFF/VOL
CF  UM4.4.5     INT MON    OFF/VOL
CF  UM4.4.6     UHF MON    OFF/VOL
CF  UM4.4.7     MIS MON    OFF/VOL
CF  UM4.4.8     VHF MON    OFF/VOL
CF  UM4.4.9     IFF MON    OFF/VOL
CF  UM4.4.10    AUX MON    OFF/VOL
CF  UM4.4.11    ILS MON    OFF/VOL
CF  UM4.4.12    CALL       OFF/VOL
CF  UM4.4.13    INT/       UHF/VHF
M   MM4.5       IFF
CF  MM4.5.1     MASTER
CF  MM4.5.2     STBY
CF  MM4.5.3     LOW
CF  MM4.5.4     NORM
CF  MM4.5.5     EMER
CF  UM4.5.6     RAD/       TEST
CF  MM4.5.7     MON
M   MM4.6       IFF MODE   SEL
CF  MM4.6.1     MODE 1
```

Figure 8. Listing – Compressed Four Sub-functions

```
                               SWITCH PANEL CONFIGURATION


                                                  LOGICAL LEVEL=        1

          COLUMN
               1            2            3            4
     ROW 1------------1------------1------------1------------1
         1 4.0        1 5.0        1 6.0        1 8.3.       1
         1 COMM       1 NAV        1 SENSORS    1 AIRCRAFT   1
       1 1            1            1            1            1
         1------------1------------1------------1------------1
         1            1            1            1            1
         1            1            1            1            1
       2 1            1            1            1            1
         1------------1------------1------------1------------1
         1            1            1            1            1
         1            1            1            1            1
       3 1            1            1            1            1
         1------------1------------1------------1------------1
         1            1            1            1            1
         1            1            1            1            1
       4 1            1            1            1            1
         1------------1------------1------------1------------1
         1            1            1            1            1
         1            1            1            1            1
       5 1            1            1            1            1
         1------------1------------1------------1------------1
         1            1            1            1            1
         1            1            1            1            1
       6 1            1            1            1            1
         1------------1------------1------------1------------1
```

Figure 9. Logical Level 1 - Four Sub-functions

```
                                SWITCH FANEL CONFIGURATION
                                         4.

                                                         LOGICAL LEVEL=        2

      COLUMN
             1              2              3              4
ROW 1-------------1-------------1-------------1-------------1
    1 4.1         1 4.2         1 4.3         1 4.5         1
    1 UHF         1 VHF-FM      1 ADF         1 IFF         1
  1 1             1             1 AUX UHF     1             1
    1-------------1-------------1-------------1-------------1
    1 4.6         1 4.7         1 4.8         1             1
    1 IFF MODE    1 IFF MKII    1 VOCODER     1             1
  2 1 SEL         1 CODE        1             1             1
    1-------------1-------------1-------------1-------------1
    1             1             1             1             1
    1             1             1             1             1
  3 1             1             1             1             1
    1-------------1-------------1-------------1-------------1
    1             1             1             1             1
    1             1             1             1             1
  4 1             1             1             1             1
    1-------------1-------------1-------------1-------------1
    1             1             1             1             1
    1             1             1             1             1
  5 1             1             1             1             1
    1-------------1-------------1-------------1-------------1
    1             1             1             1             1
    1             1             1             1             1
  6 1             1             1             1             1
    1-------------1-------------1-------------1-------------1
```

Figure 10. Logical Level 2

```
                                        SWITCH PANEL CONFIGURATION

                                         4.
                                         4.1.

                                                       LOGICAL LEVEL=        3

           COLUMN
                 1             2             3             4
       ROW 1-------------1-------------1-------------1-------------1
           1 4.1.1       1 4.1.2       1 4.1.3       1 4.1.4       1
           1 PRESET      1 MAN         1 GD          1 CHAN        1
         1 1 CHAN        1             1 XMIT        1 SEL         1
           1-------------1-------------1-------------1-------------1
           1 4.1.6       1 4.1.7       1 4.1.8       1 4.1.9       1
           1 SQLCH       1 T/R         1 T/R+G       1 ADJ         1
         2 1             1             1             1             1
           1-------------1-------------1-------------1-------------1
           1 4.1.10      1             1             1             1
           1 FREQ        1             1             1             1
         3 1 SEL         1             1             1             1
           1-------------1-------------1-------------1-------------1
           1             1             1             1             1
           1             1             1             1             1
         4 1             1             1             1             1
           1-------------1-------------1-------------1-------------1
           1             1             1             1             1
           1             1             1             1             1
         5 1             1             1             1             1
           1-------------1-------------1-------------1-------------1
           1             1             1             1             1
           1             1             1             1             1
         6 1             1             1             1             1
           1-------------1-------------1-------------1-------------1
```

Figure 11. Logical Level 3

SWITCH PANEL CONFIGURATION

4.1.
4.1.10.
LOGICAL LEVEL = 4

ROW \ COLUMN	1	2	3	4
1				
2				
3				
4	4.1.10.1 1	4.1.10.2 M 2	4.1.10.3 N 3	4.1.10.4 4
5	4.1.10.5 + 5	4.1.10.6 S 6	4.1.10.7 Σ 7	4.1.10.8 - 8
6	4.1.10.9 CLEAR	4.1.10.10 9	4.1.10.11 0	4.1.10.12 ENTER

Figure 12 Logical Level 4 – Data Entry Keyboard

SWITCH PANEL CONFIGURATION

```
                                                        WAFER LEVEL=        1
        COLUMN
             1            2            3            4
   ROW 1------------1------------1------------1------------1
       1 4.0        1 5.0        1 6.0        1 8.0        1
       1 COMM       1 NAV        1 SENSOR     1 AIR-CRAFT  1
     1 1            1            1            1            1
       1------------1------------1------------1------------1
       1 4.6        1 4.7        1 4.         1 4.9        1
       1 IFF MODE   1 IFF MKII   1 VOCODE     1 HF         1
     2 1 SEL        1 CODE       1            1            1
       1------------1------------1------------1------------1
       1 6.12       1 5.13       1 6.14       1 4.6.14     1
       1 E-O STEER  1 E-O STEER  1 E-O        1 LIGHT      1
     3 1 (FLIR)     1 (LLTV)     1 VIDEO      1            1
       1------------1------------1------------1------------1
       1 4.1.4.1    1 4.1.4.2    1 4.1.4.3    1 4.1.4.4    1
       1            1  W         1    N       1            1
     4 1   1        1   2        1   3        1   4        1
       1------------1------------1------------1------------1
       1 4.1.4.5    1 4.1.4.6    1 4.1.4.7    1 4.1.4.8    1
       1   +        1  S         1    E       1   -        1
     5 1   5        1   6        1   7        1   8        1
       1------------1------------1------------1------------1
       1 4.1.4.9    1 4.1.4.10   1 4.1.4.11   1 4.1.4.12   1
       1 CLEAR      1            1            1 ENTER      1
     6 1            1   9        1   0        1            1
       1------------1------------1------------1------------1
```

Figure 13. Wafer Level 1 - Four Sub-functions

format proved useful during flight simulator system checks. In addition, a format showing the required legend configuration for each switch was available and an example for a twelve legend switch is shown in Figure 14.

III.2.3 Multifunction Switch Trade Studies

Using the computer program as described, a series of trade studies were performed to arrive at a suitable multifunction control panel configuration. As shown in Figure 15, Study I assumed four levels of indenture, included all eight functional areas, and utilized a separate data input device. Figure 16 shows that a 32 switch matrix 12 levels deep was required with 94% of the legends utilized. Using switches with capabilities for displaying 24 legends reduced the loading to 49%. As discussed earlier, the decision was made at this point to reduce the study to four functional areas.

Study II assumed three levels of indenture, four functional areas and a dedicated data input device. Figure 16 shows a requirement for a 24 switch matrix 12 levels deep with a wafer loading of 64%. Assuming a 24 legend switch configuration reduced the loading to 20%.

A second decision was made at this juncture to incorporate the data entry device into the multifunction panel. It was reasoned, that since it is necessary to go to another level of indenture to access the data input device, providing a separate control does not effect any saving in terms of actuation time. The concept of pre-assigning common legends to the same switch (such as FREQ SEL) was also traded against the simpler continuous string arrangement in this study. The latter approach increases the wafer loading, however it results in a "cleaner" and possibly a more readable configuration. It should be noted that in the flight simulator evaluations performed later, one of the pilots suggested that having common legends appear in the same physical location on the multifunction panel could improve its workability. Study III culminated with the final configuration: a 24 switch array arranged in four columns and six rows, the data entry keyboard pre-assigned to the last three rows, 12 legend switches and a wafer loading of 80%. This configuration (with

SWITCH PANEL CONFIGURATION

SWITCH NUMBER= 1

```
     COLUMN
           1             2             3
ROW 1-------------1-------------1-------------1
    1 4.0         1 4.1         1 [illegible].1        1
    1 COMM        1 UHF         1 NAV         1
  1 1             1             1 NO          1
    1-------------1-------------1-------------1
    1 6.1         1 4.4         1 4.1.1       1
    1 RADAR       1 ENVIRON     1 PRESET      1
  2 1 NAV         1 MENT        1 CHAN        1
    1-------------1-------------1-------------1
    1 4.2.2       1 4.3.1       1 4.5.1       1
    1 FREQ        1 ADF         1 MASTER      1
  3 1 SEL         1             1             1
    1-------------1-------------1-------------1
    1 4.6.1       1 4.7.1       1 4.[illegible].1       1
    1 MODE 1      1 ZERO        1 CLASS       1
  4 1             1             1             1
    1-------------1-------------1-------------1
```

Figure 14. Switch Number 1 – Wafer Configuration

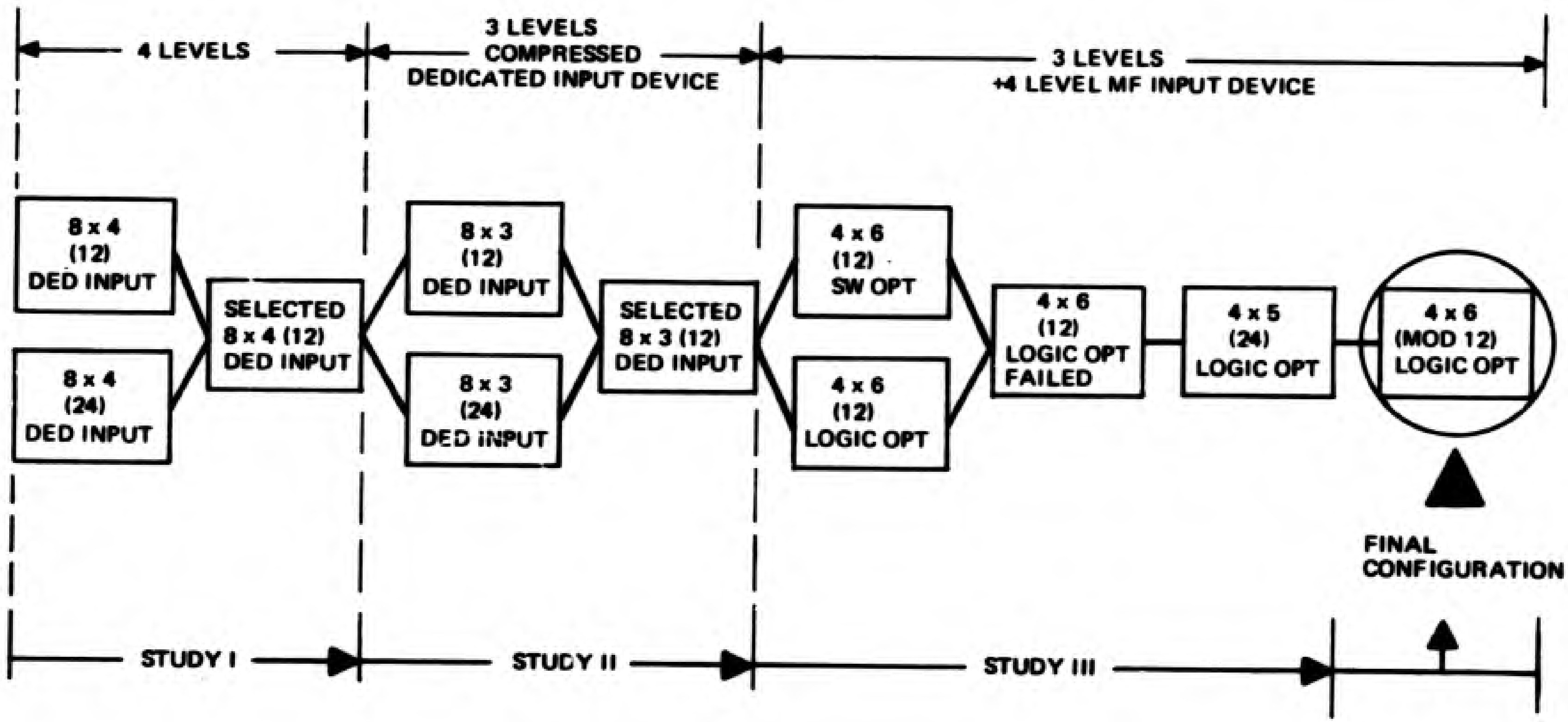


Figure 15. Trade Study Summary

	Dedicated input device				Multifunction input device			
	4 Level switch 12 8 x 4	4 Level switch 24 8 x 4	3 Level switch 12 8 x 3	3 Level switch 24 8 x 3	3 Level +KB switch 12 4 x 6	3 Level +KB switch 12 4 x 6	3 Level +KB switch 24 4 x 5	3 Level +KB switch 12 4 x 6
No. switches available	32	32	24	24	24	24	20	24
No. switches used	31	19	24	14	24	28*	20	24
Wafer loading %	94%	49%	64%	20%	72%	83%	52%	80%
Optimum logic yes - no	No	No	No	No	No	Yes	Yes	Yes
Optimum switch yes - no	Yes	Yes	Yes	Yes	Yes	No	No	No

* 8.6 and 8.8 strings do not fit

Figure 16. Trade Study Data

a pre-entry read out device added) was used for all subsequent cockpit configuration development. A detailed logical sequence report showing all combinations in this final configuration is given in Appendix A.

III.3 ELECTRONIC DISPLAY CONFIGURATION DEVELOPMENT

III.3.1 Display Requirements

Display systems and formats developed during previous IIPACS programs were used as a baseline for the proposed configuration. MPD (multipurpose display) requirements as derived from IIPACS III testing are summarized in Figure 17. It can be seen from this summary that by deleting some formats and substituting dedicated instruments for other formats, the MPD requirements can be met with two instead of five units. Figure 18 shows how the MPD's in the proposed configuration are formatted basically by flight phase and have four additional modes that override the basic format at the pilots' option. Examples of representative MPD formats taken from the IIPACS III work are given in Figure 19 through 27. The formats that were evaluated in the flight simulation and the resulting modified configuration is detailed in subsequent sections of this report. Recommended formats for display of primary sensor information were also evolved during previous IIPACS work. Figures 28 and 29 present the type of formats recommended for the Vertical and Horizontal Situation Displays (VSD and HSD). Combining these recommendations with the addition of a Head Up Display (HUD) resulted in the proposed format combinations given in Figure 30 below:

Primary electronic display	T/O	Climb	Cruise	TF	A/A	A/G	Descent	Approach
HUD	• Graphic symb	• Graphic symb	• Graphic symb	• Graphic symb • Flir or Flr	• Graphic symb	• Graphic symb • LST	• Graphic symb	• Graphic symb
VSD	• Graphic symb	• Graphic symb	• Graphic symb	• Graphic symb • TF radar processed	• Graphic symb • LST	• Graphic symb • LST	• Graphic symb	• Radar • Flir or TV • VSD overlay
HSD	• Graphic map	• Graphic map	• Radar map • Graphic map	• Graphic map	• Flir • LST	• Radar map • Graphic map	• Graphic map	• Radar map • Graphic map

Figure 30. Primary Sensor Display Modes

IIPACS III MPD'S	T/O	⊙ Climb	Cruise	⊙ TF	A/A	A/G	⊙ Desc	Approach
MPD-1	⊗ Air data		⊗ Alt range		V-N	V-N		⊗ Air data
MPD-2	Nav	Nav	Nav	Nav	~~Nav~~	~~Nav~~		⊗ Thrust
MPD-3	Comm		Store sel	Comm	Store sel	Store sel	Comm	Comm
MPD-4	~~GP~~	GP	⊗ Batt sit APN-26		⊗ Batt sit	⊗ Bat sit	GP	GP
MPD-5	⊗ Thrust		⊗ Thrust		~~Comm~~	~~Comm~~		⊗ Land

⊙ New flt phases/modes

—— Deleted

⊗ Replaced by dedicated status instruments

Figure 17. MPD Requirements

Primary electronic display modes

Master mode / MPD	T/O	Climb	Cruise	TF	A/A	A/G	DESC.	Approach
MPD-1	Comm	Gen pur	Comm	Comm	Stor stat	Stor stat	Comm	Gen pur
MPD-2	Nav	Nav	Nav	Nav	V_{-N}	V_{-N}	Nav	Nav

Available alternatives

MPD-1	Nav	Batt sit	Stor sel	Sensor	(1) Fail monitor
MPD-2	Comm	Gen pur	Air data	Stor stat	(1) Fail monitor

(1) Automatic status share MPD 2 & caution advisory
MFK interrogate failure

Figure 18. Primary Display Modes and Alternatives

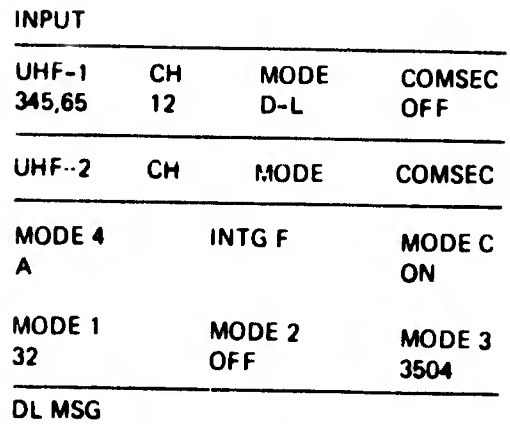


Figure 19. Communications MPD Format

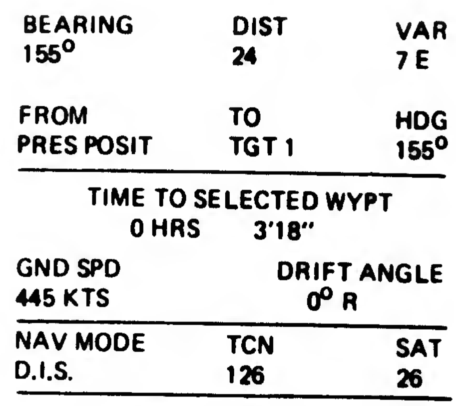


Figure 20. Navigation MPD Format

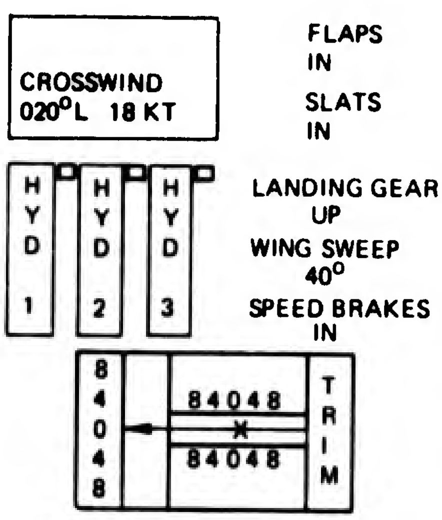


Figure 21. General Purpose MPD Format

Figure 22. Stores Status MPD Format

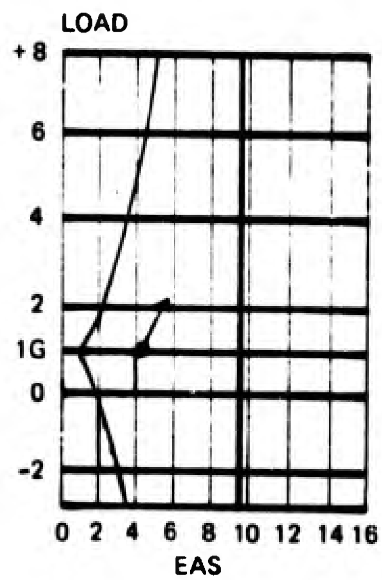


Figure 23. *Velocity-Load MPD Format*

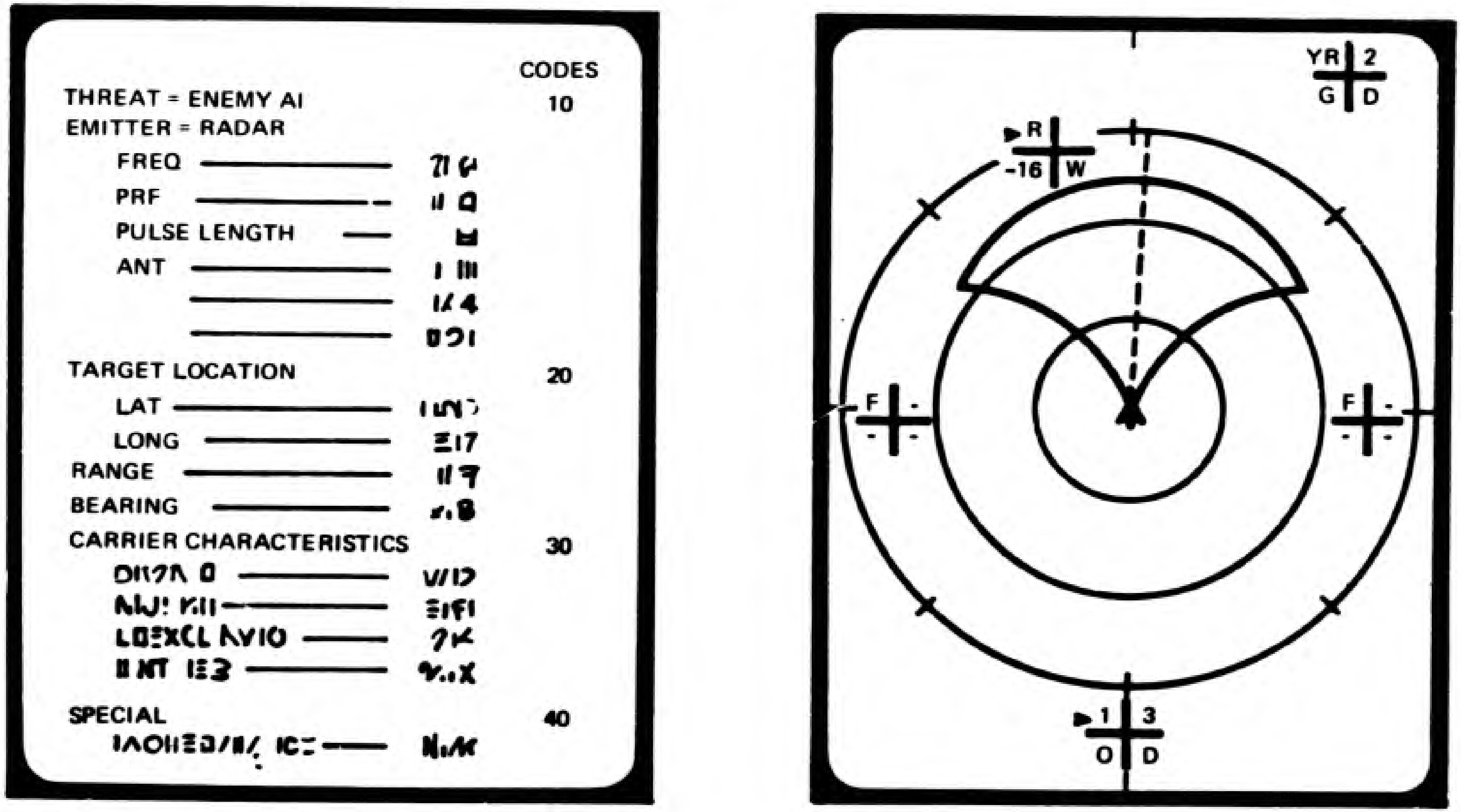


Figure 24. ***Battle Situation MPD Formats***

	DEL METHOD		SEQUENCE
1	RADAR	1	SINGLE
2	IR	2	RIPPLE
3	RHAW	3	SALVO
4	LASER	4	MAN STEP
5	TV	5	JETTISON
6	RDI		
7	VISUAL		
8	AUTO		
9	MANUAL		
	SPACING		**FUZE AND CONTROL**
		1	NOSE
		2	TAIL
	––– FT	3	BOTH
		4	SAFE
		5	BAL
		6	GUIDED
		7	RETARDED

Figure 25. Stores Select MPD Format

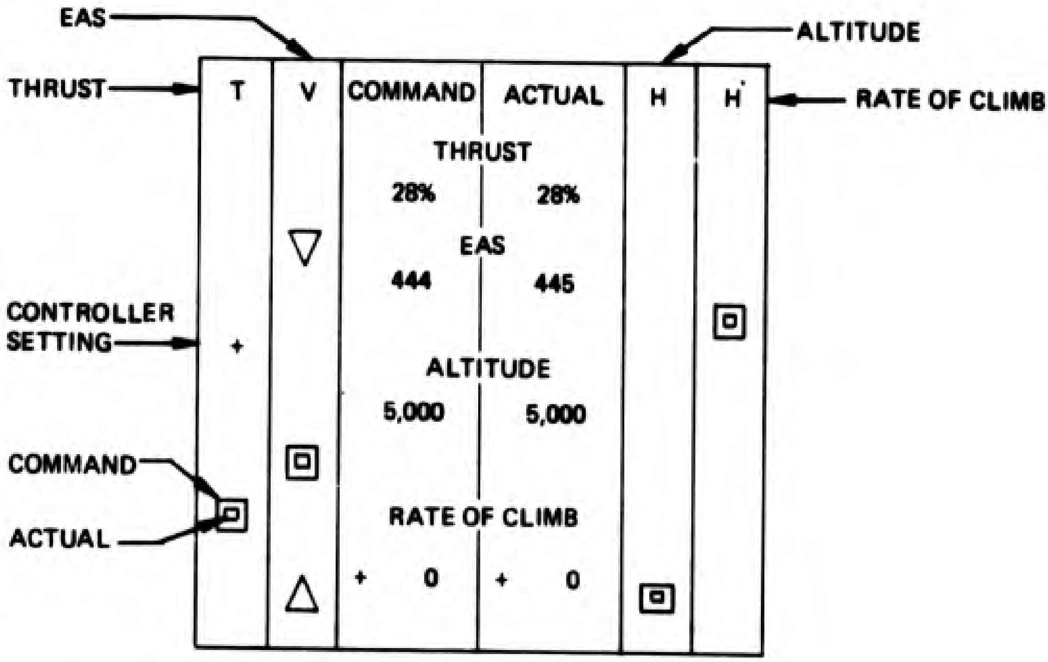


Figure 26. Air Data MPD Format

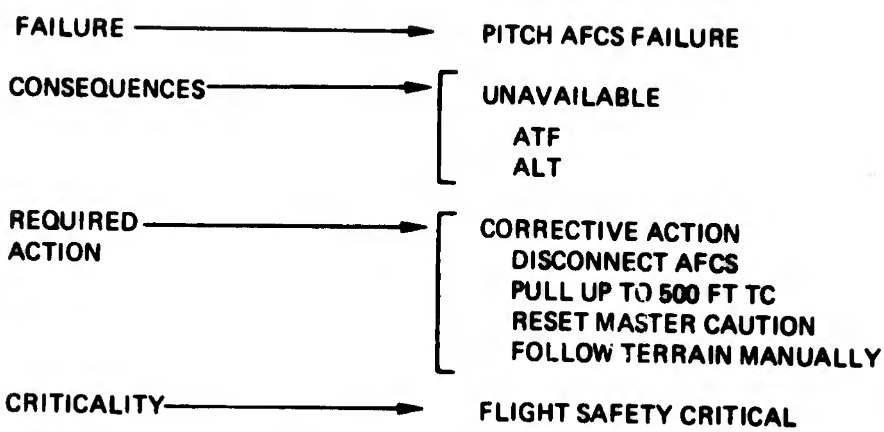


Figure 27. Failure Monitor MPD Format

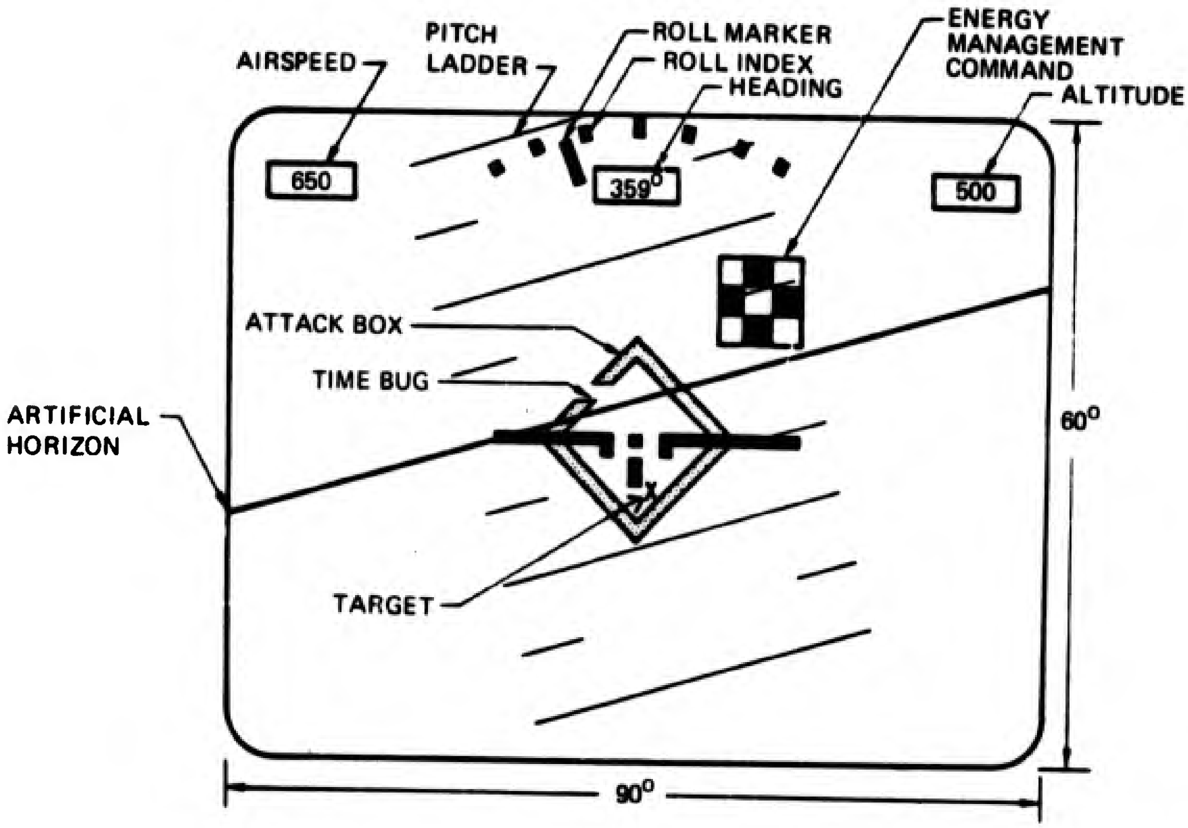


Figure 28. VSD Display Format

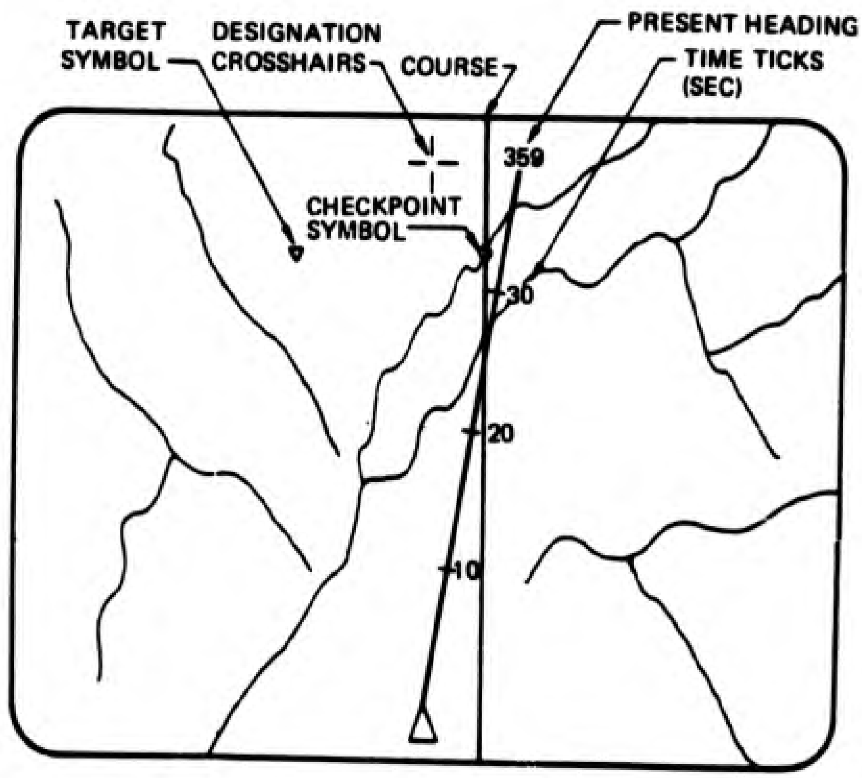


Figure 29. *HSD Display Format*

III.3.2 Display Configuration

As a result of the previously stated requirements the proposed configuration has the following display combination:

Head Up Display	- basic symbology overlayed on selected sensor formats
Vertical Situation Display	- same as HUD
Horizontal Situation Display	- same as HUD, VSD
Two Multipurpose Displays	- basic formats presented by flight phase in addition to optional formats
Dedicated basic flight instruments	- Mach-airspeed, altitude, vertical speed, etc. Standby attitude indicator
Dedicated engine instruments	- RPM, turbine outlet pressure, turbine outlet temperature
Miscellaneous dedicated displays	- trim indicators, subsystem status indicators, warning indicators and displays not accounted for in the electronic display formats

III.4 PROPOSED BASELINE CONFIGURATION

III.4.1 Controls/Displays General Arrangement

A comparison of Figures 31 and 32 shows the modifications made to the A-7D cockpit arrangement to accommodate the advanced controls and displays established in the analysis. Primary differences include: Replacement of some dedicated displays with electronic displays, transfer of many dedicated control functions into two multifunction control panels, grouping of dedicated controls into "zones" i.e. STORES MANAGEMENT, SENSOR MANAGEMENT, AFCS, etc., and grouping of aircraft subsystems into "zones" i.e. FUEL, HYDRAULIC, ELECTRICAL, etc. A description of the proposed configuration control and display elements is given in Figures 33a, b and c. Those items labelled GFE are assumed to be elements identical to the A-7D (-27 airplanes and later) as described in the -1 operations manual (Reference 8). Detailed panel layouts are presented in Figures 34a through 34g with flight phase and electronic display mode controls given in Figures 34a and 34b. A larger scale cockpit layout showing detail modifications is given in Figure 35.

III.4.2 System Operation

Basic formats for the electronic displays for the eight flight phases are selected by depressing the appropriate flight phase mode control located on the center panel adjacent to the HUD controls. Optional formats for the displays are selected by depressing the mode controls located at each display. Power to aircraft systems is applied through actuation of appropriate dedicated or multifunction controls with system checks performed in the same manner. Pre-takeoff and stores status checks are performed by selecting the appropriate optional displays for viewing. Stores management is accomplished by selecting the desired station(s) on the stores management panel and viewing the stores options available on the store select MPD format. The station select switches are the "depress and hold" type, therefore the station(s) must be deselected after programming. In addition, only those station/store combinations that have been selected can be released. The multifunction control panels are dual redundant and are positioned to be operated with either hand. Therefore, if either panel fails or if the pilot sustains an injury to either hand, the system is not degraded.

System failures are indicated by the master caution light and a condensed narrative appearing at the bottom of each MPD. A complete narrative describing the system failure and options available to the pilot for correction is obtained by interrogating the system in question on the multifunction keyboard or on the appropriate subsystem panel.

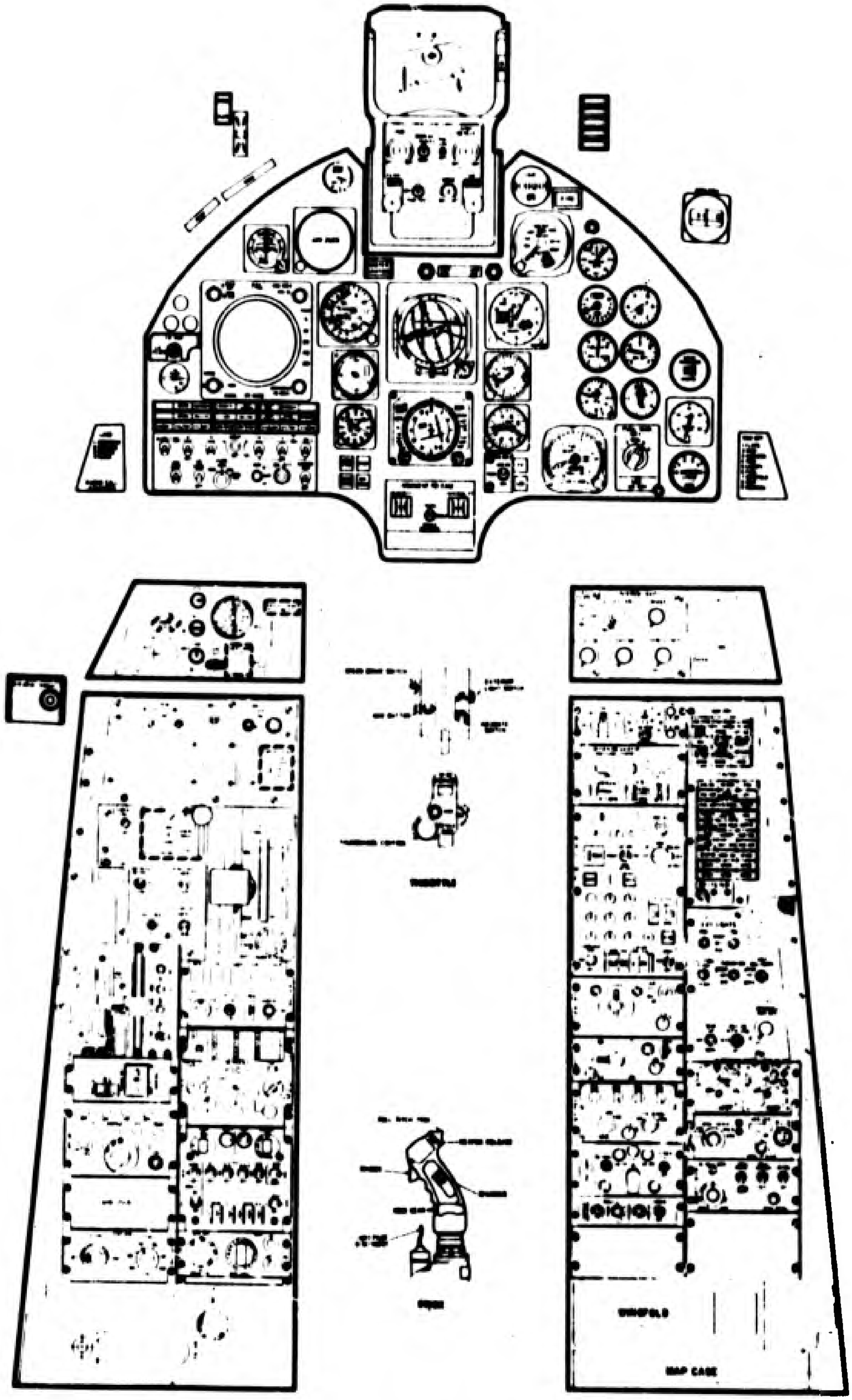


Figure 31. A-7D Cockpit Configuration

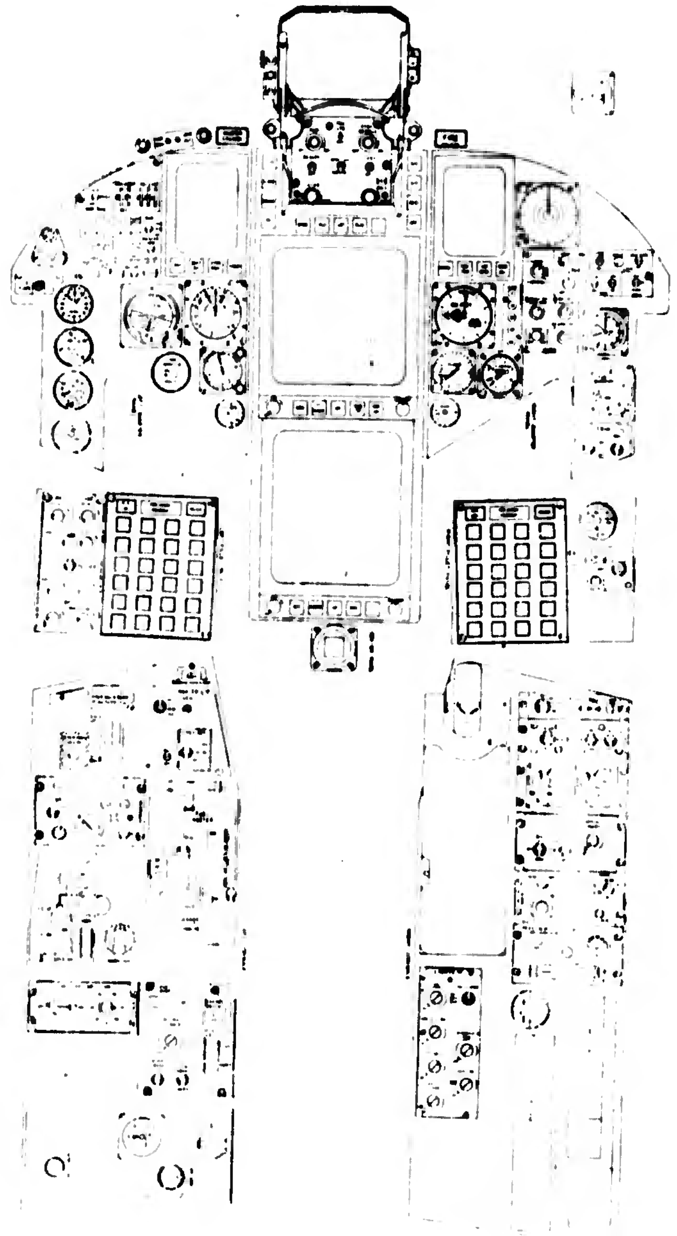


Figure 32. Proposed Cockpit Configuration

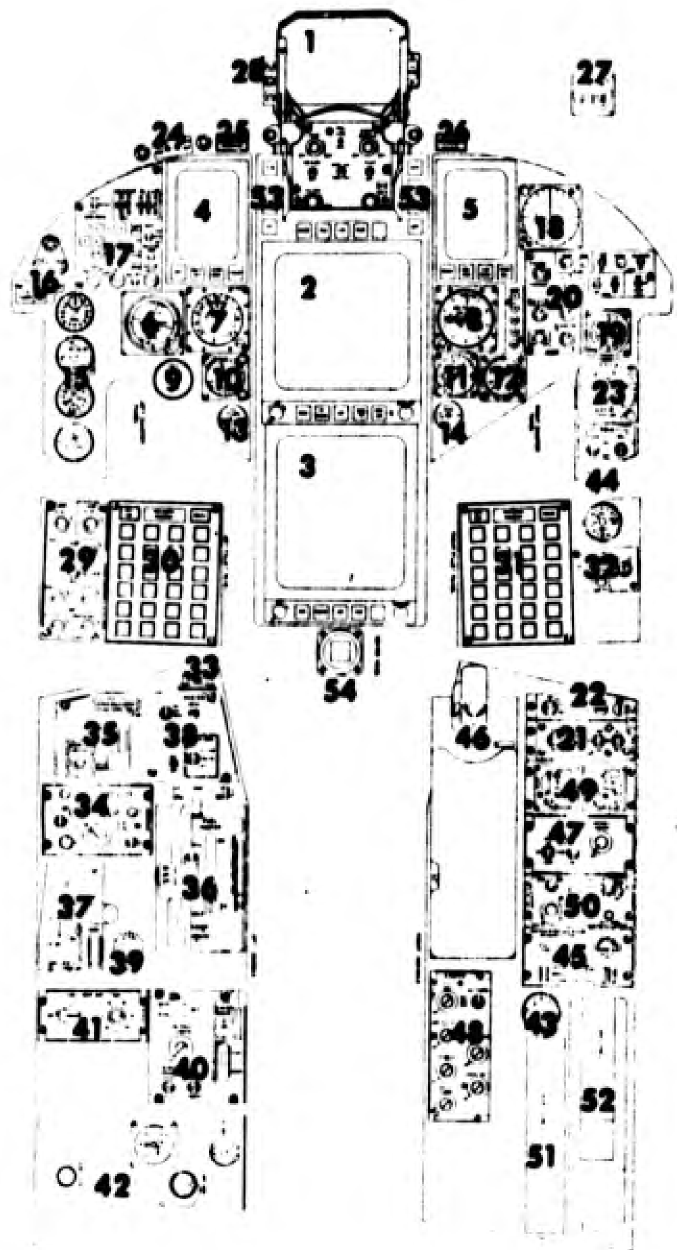


Figure 33a. Proposed Cockpit Configuration Detailed Listing

1. HUD – Head up display and associated controls – GFE
2. VSD – Vertical situation display, contrast/brightness controls and mode controls
3. HSD – Horizontal situation display, contrast/brightness controls and mode controls
4. MPD1 – Multipurpose display Number 1 and associated mode controls
5. MPD2 – Multipurpose display Number 2 and associated mode controls
6. Standby attitude indicator – GFE
7. Mach/airspeed indicator –GFE
8. Baro altimeter – GFE
9. True airspeed indicator – GFE
10. Angle-of-attack indicator – GFE
11. Vertical speed indicator – GFE
12. Accelerometer – GFE
13. Flap position indicator – GFE
14. Speed brake position indicator – GFE
15. Engine instrument cluster (RPM, TOP, TOT, fuel flow) – GFE
16. Gear and flap warning – GFE
17. Stores management panel
18. APR 25/26 threat analyzer – GFE
19. Clock – GFE
20. Sensor panel – dedicated controls not accounted for in the primary multifunction panel
21. AFCS panel
22. Trim indicators – GFE
23. Fuel quantity indicator –GFE
24. Low altitude – marker beacon indicator – GFE
25. Master caution indicator – GFE
26. Fire warning indicator – GFE
27. Wet compass – GFE
28. Approach indexer – GFE
29. Communication subfunction dedicated controls
30. Multifunction switch panel – left side

Figure 33b. Proposed Cockpit Configuration Detailed Listing

31. Multifunction switch panel – right side
32. Navigation subfunction dedicated controls
33. Emergency power handle – GFE
34. Intercom panel – GFE
35. Landing gear controls – GFE
36. Throttle control (including start abort and master fuel) – GFE
37. Flap control – GFE
38. Generator control panel – GFE
39. Rudder trim control – GFE
40. Fuel control panel – GFE
41. Vent air control panel – GFE
42. Anti–g valves and vent air – GFE
43. Oxygen quantity indicator – GFE
44. Pitch and roll trim system controls – GFE
45. Oxygen system control panel – GFE
46. Primary flight controller
47. Seat control, anti–ice and approach indicator intensity – GFE
48. Interior light control panel – GFE
49. ECM panel – GFE
50. Air Conditioning control panel – GFE
51. Map case – GFE
52. Wing fold control – GFE
53. Flight phase mode control
54. Designation control

Figure 33c. Proposed Cockpit Configuration Detailed Listing

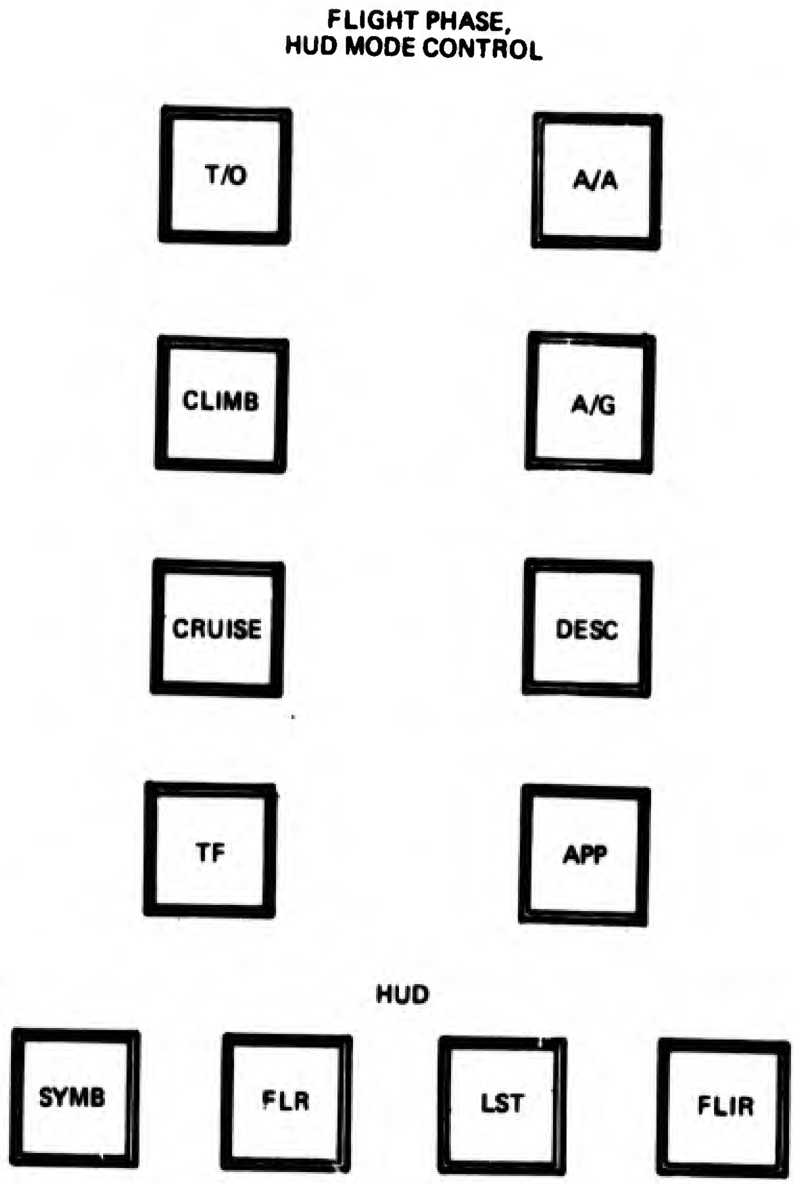


Figure 34a. Flight Phase, HUD Mode Control

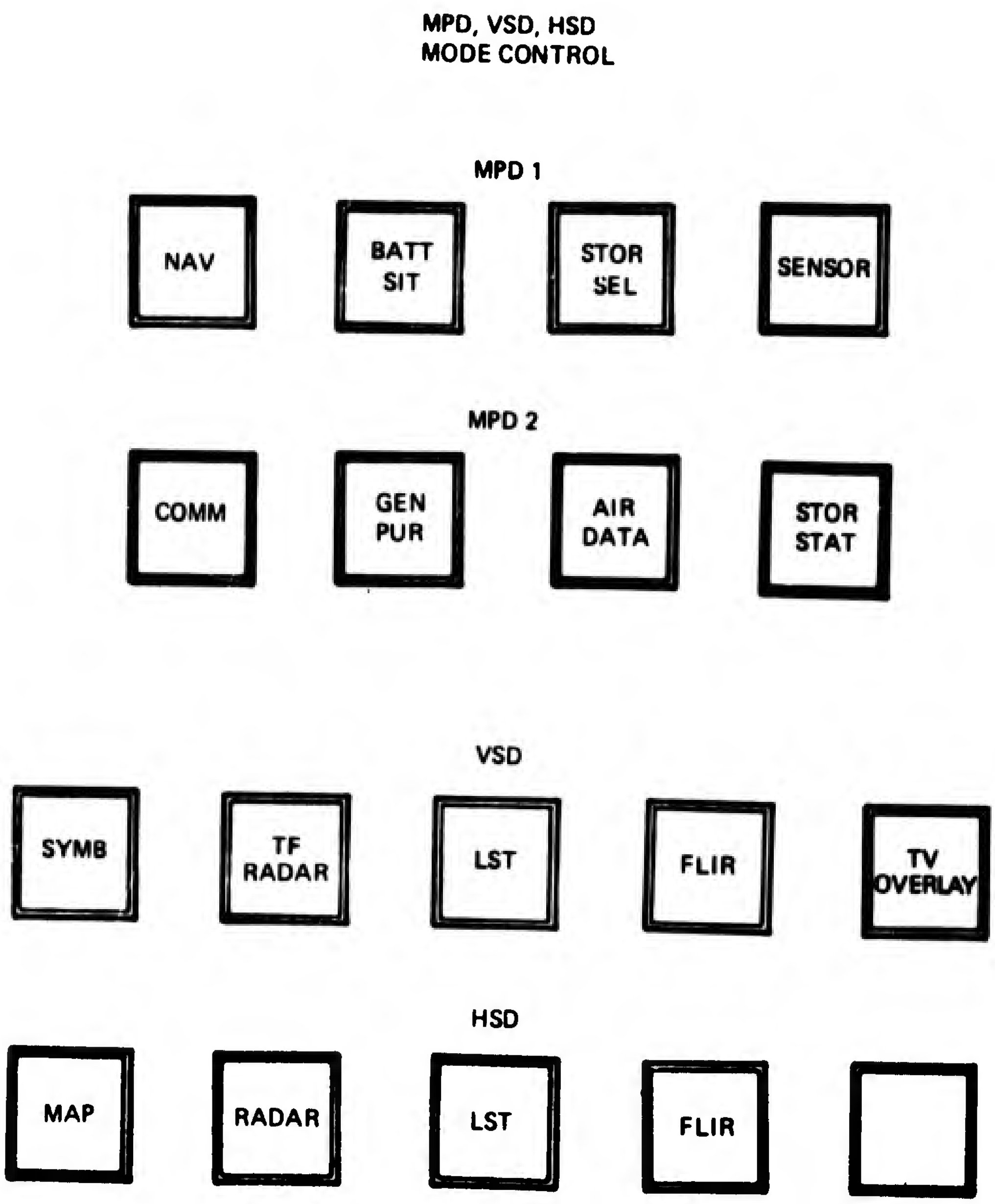


Figure 34b. MPD, VSD, HSD Mode Control

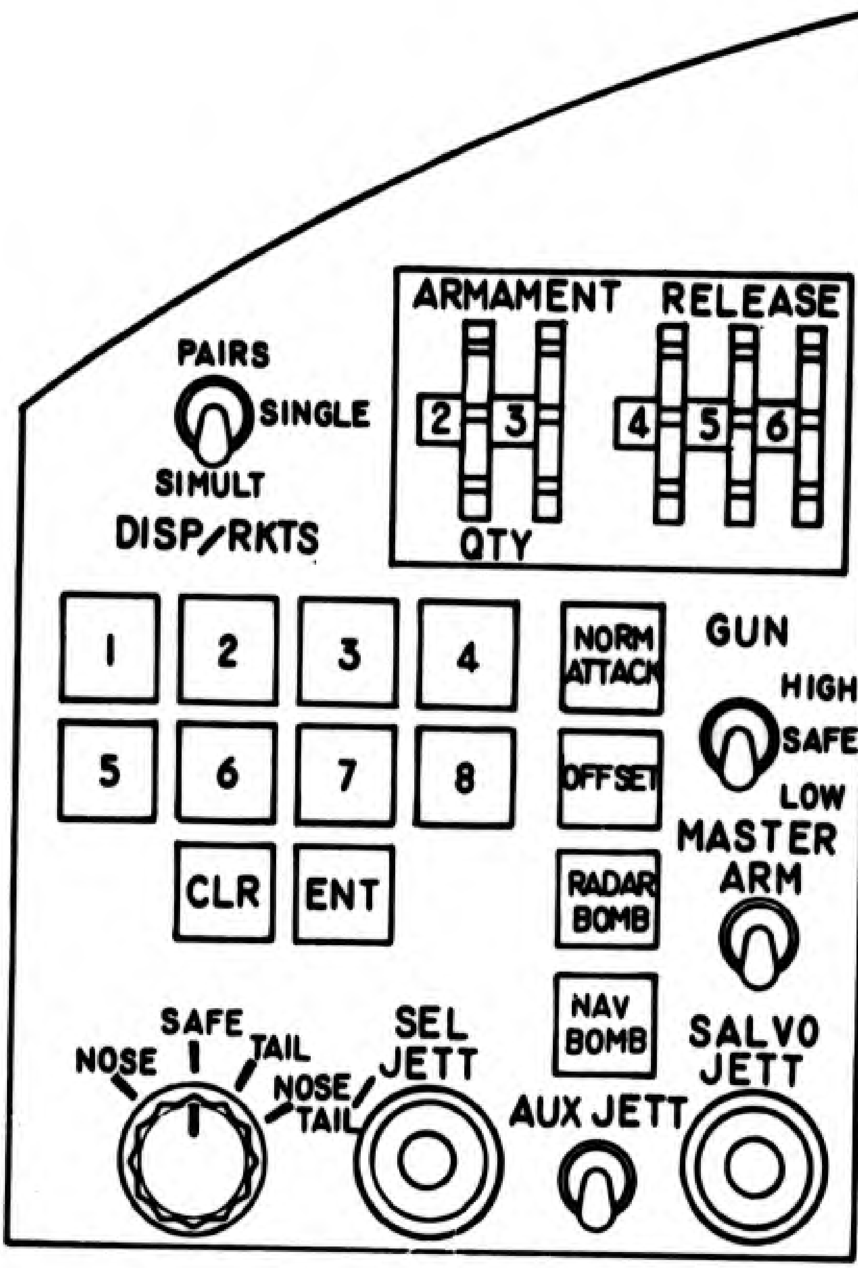


Figure 34c. Stores Management Panel

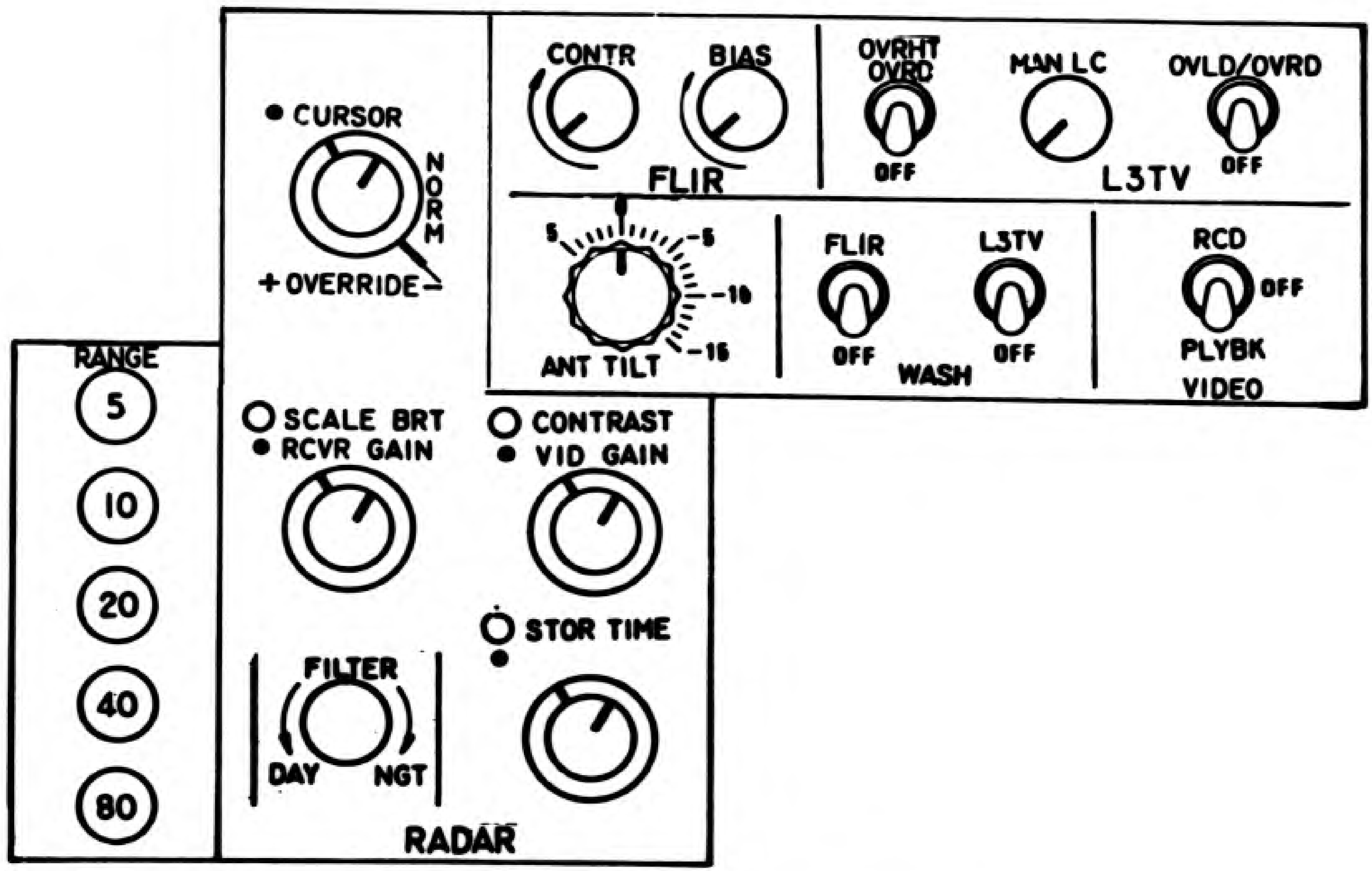


Figure 34d. Sensors Panel

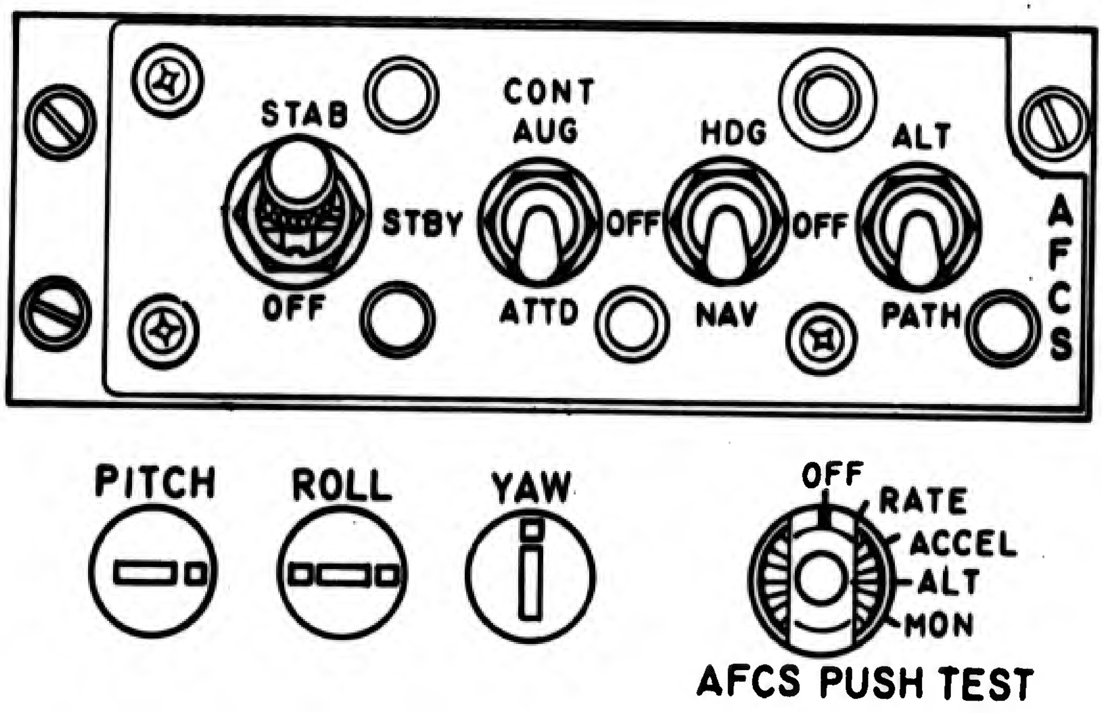


Figure 34e. AFCS Panel

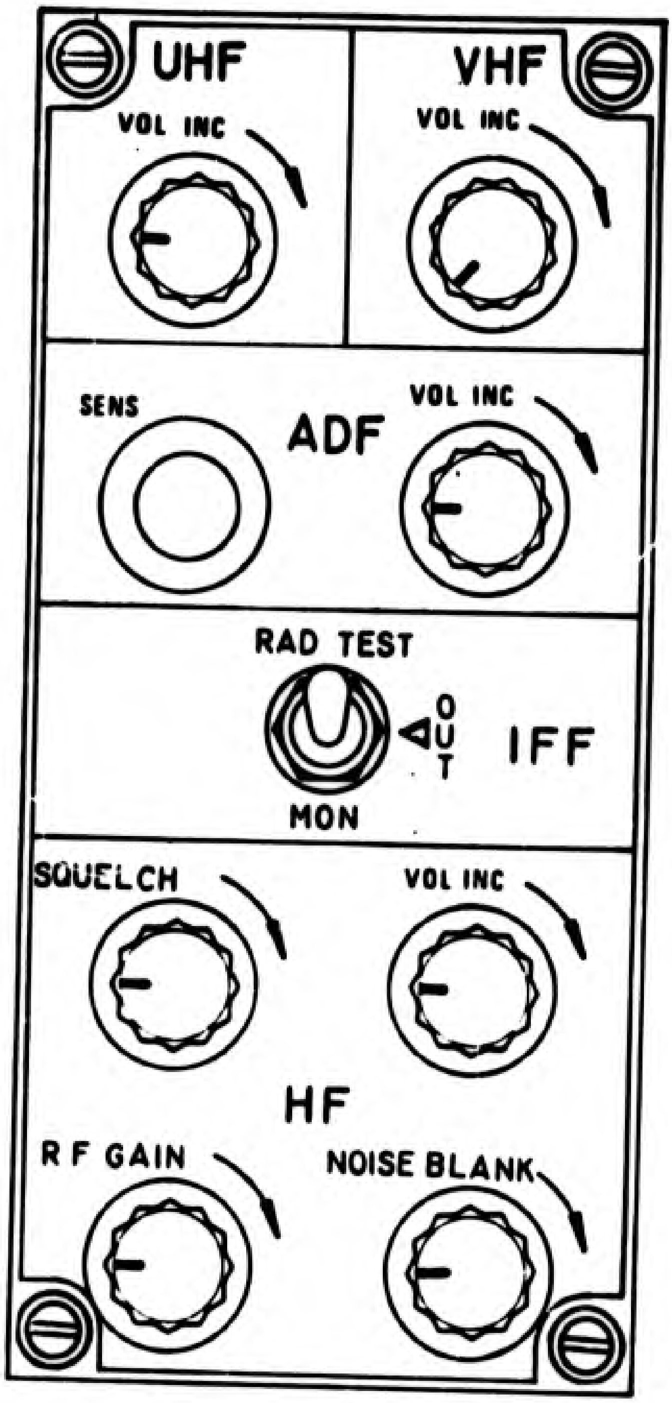


Figure 34f. Communications Panel

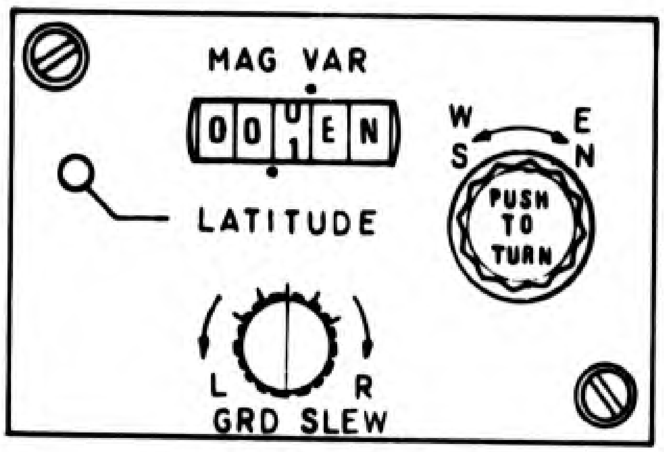
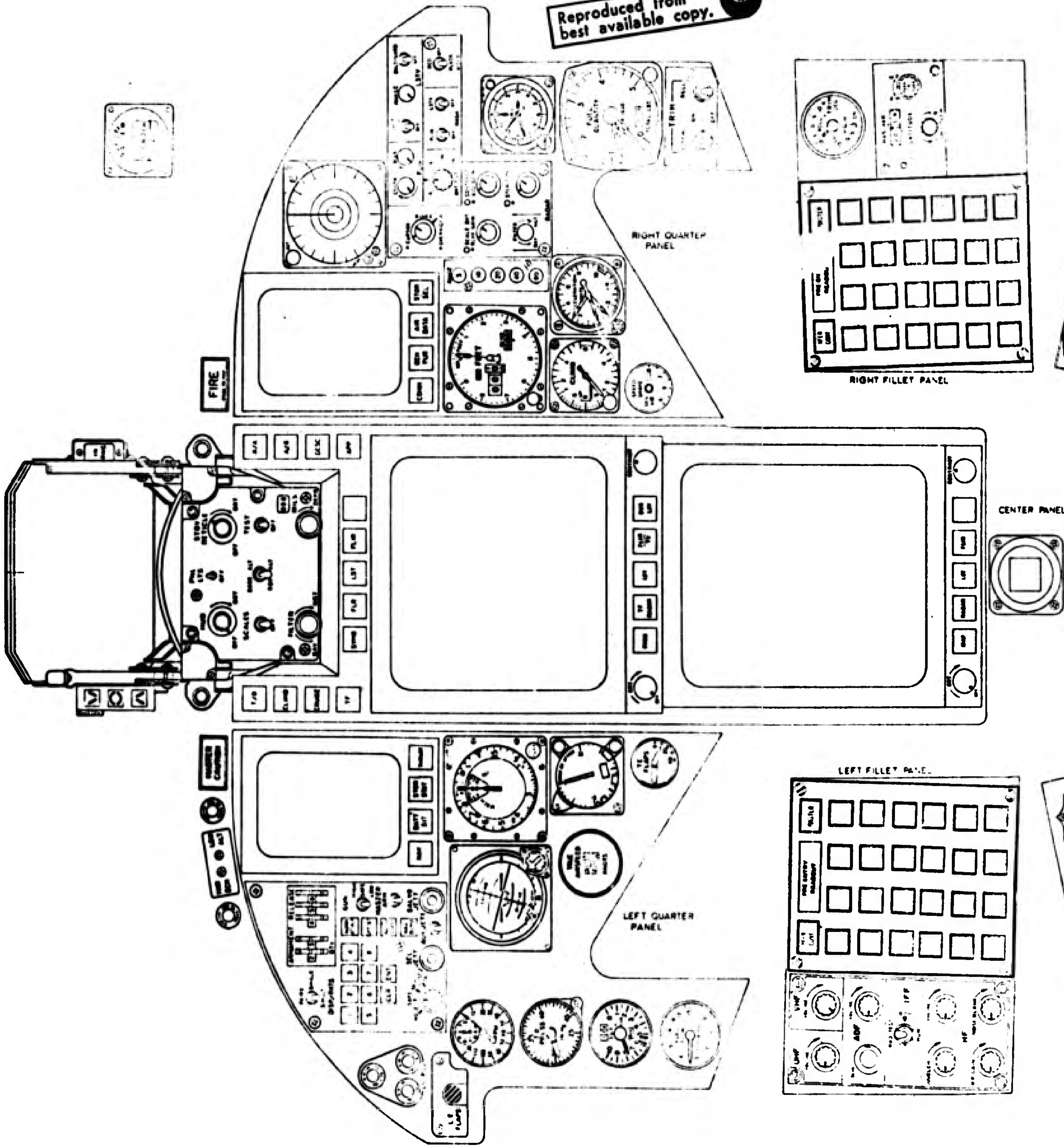


Figure 34g. Navigation Panel


RIGHT QUARTER PANEL
RIGHT FILLET PANEL
CENTER PANEL
LEFT FILLET PANEL
LEFT QUARTER PANEL
FIRE

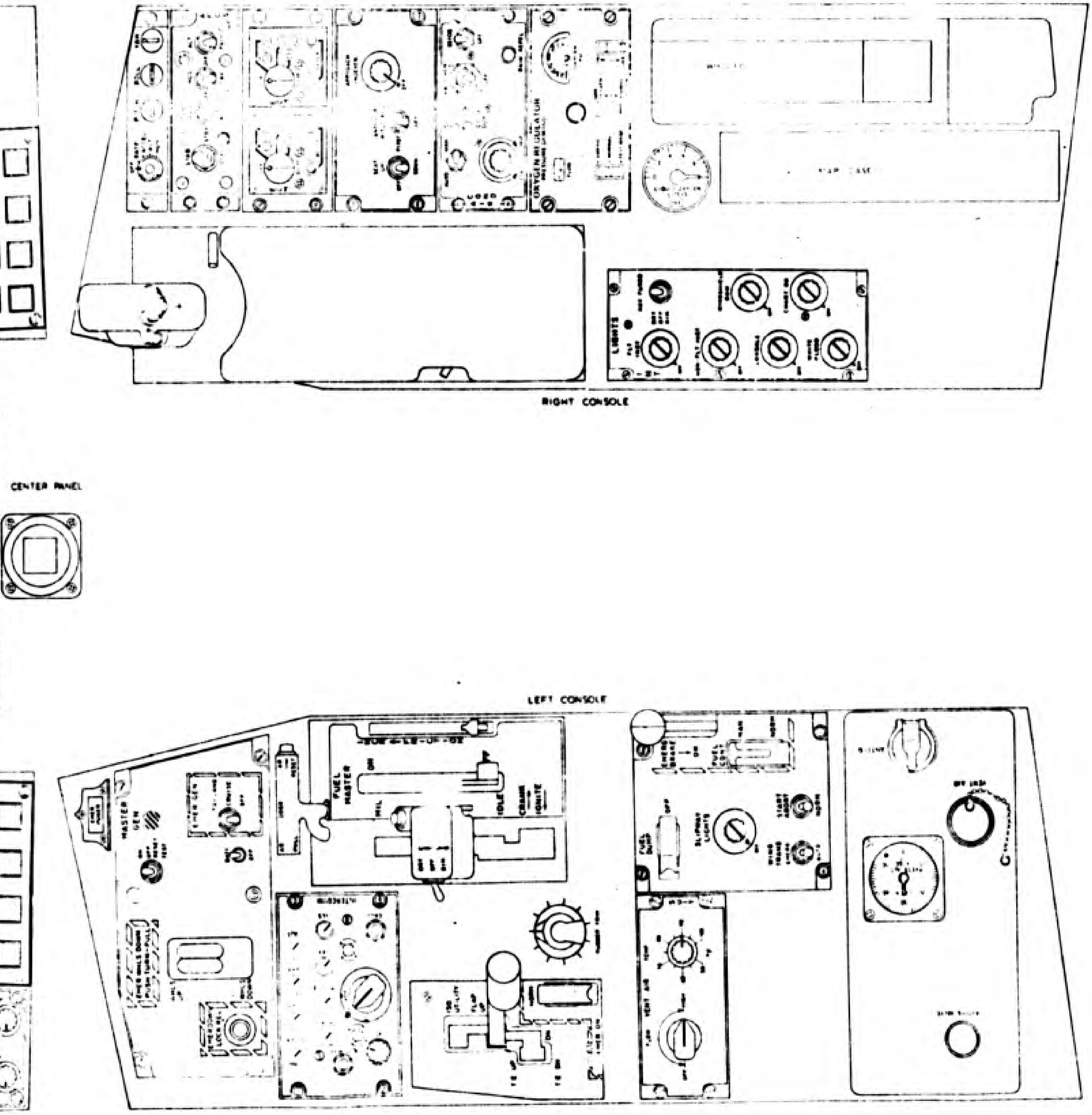


Figure 35. Proposed Cockpit Configuration

III.5 MULTIMISSION SIMULATOR DESCRIPTION

The IIPACS simulator was modified to evaluate the functional requirements and to test the hardware/software design characteristics for the primary and secondary controls and displays in a total crew station environment. The mission simulation was flown in manual modes under normal and contingency operations in visual and instrument flight conditions day and night. The following equipment was active during the pilot-in-the-loop simulation program:

- Modular vertical situation display
- Modular horizontal situation display
- Two modular multi-purpose displays
- Modular multifunction keyboard
- Cowl-mounted headup display
- Helmet-mounted headup display
- Side arm controllers
- Stores Management Panel
- 15 dedicated air data and engine instruments

The simulator consisted of five interconnected facilities as shown in Figure 36. Aircraft equations of motion, weapons delivery, and cockpit CRT display content information was calculated in the Hybrid Computer Laboratory (XDS 9300). The cockpit and pilot displays are part of the Multi-Mission Simulator (MMS). Many of the displays, including those used in the vertical situation display (VSD), Multi-Purpose Displays (MPD's) and Head-Up Displays (HUD) were generated in the Man-Machine Interface (MMI). Displays seen on the horizontal situation display (HSD), such as forward-looking infrared (FLIR) and moving map originate in the Sensor Display Simulator (SDS). Pilot controlled visual scenes of air-to-air engagement, landing, and surface target fly-over were produced in the Visual Flight Simulator (VFS).

In general, pilot responses such as control movements and switch positions were fed from the MMS through the MMI to the XDS 9300. Pilot stimuli such as HSD, VSD, and visual flight information was generated in the VFS, SDS, and MMI and transmitted to the MMS. Descriptions of each of the five facilities are presented in the following pages.

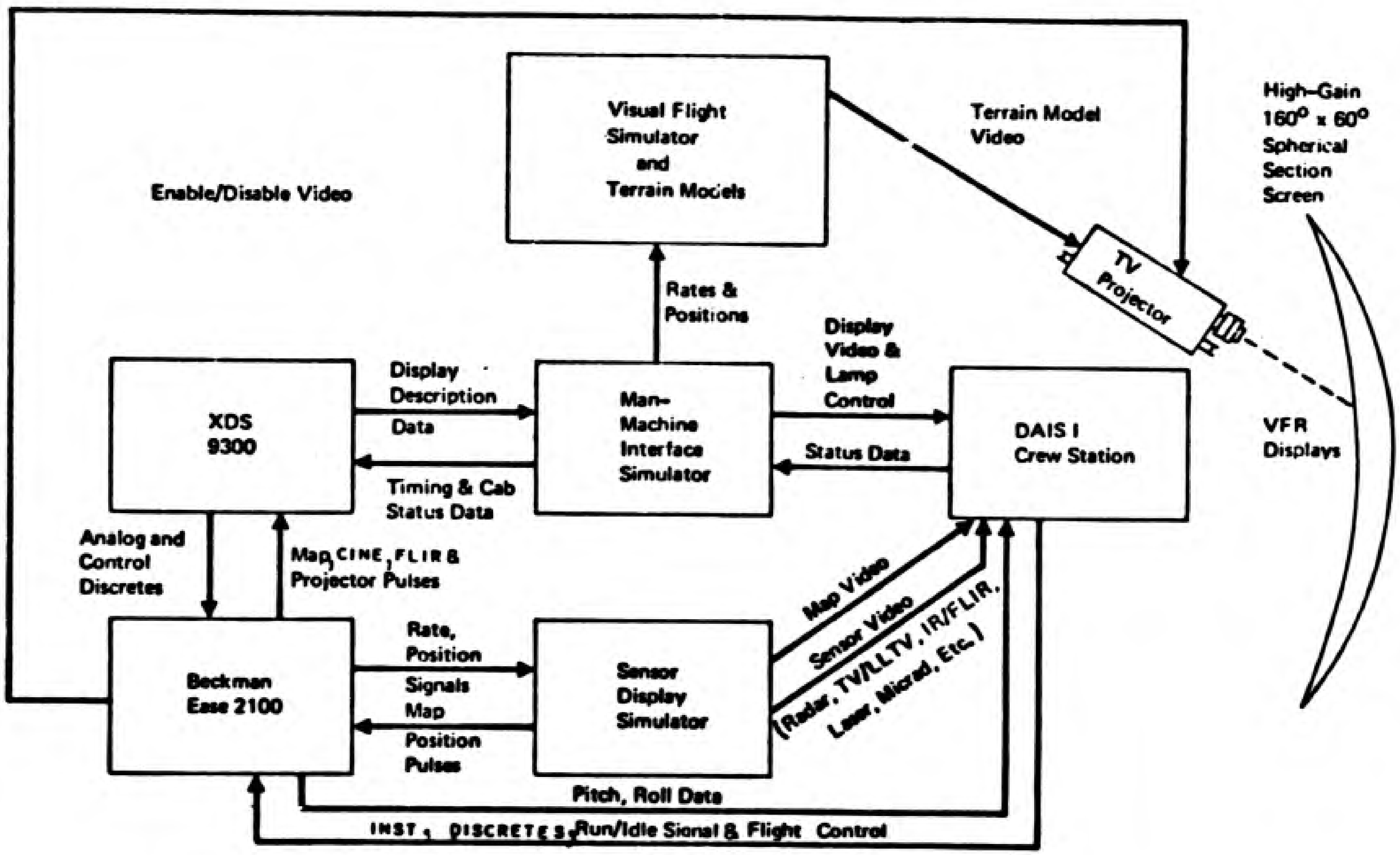


Figure 36. DAIS I Simulation Facilities

The facility that was used in the Hybrid Computer Laboratory is the Xerox Data Systems XDS 9300/Beckman EASE 2100 hybrid computer. The 9300 performed the calculations necessary to simulate aircraft flight, navigation, weapon delivery, and display contents. It transmits display descriptions to the MMI, so that the MMI can format them and transmit this data to the cab. The 9300 also transmits drive information for the VFS television servos to the MMI for relay to the VFS facility, and controls and monitors the equipments in the SDS facility.

The Multi-Mission Simulator (MMS) facility was modified for use in the simulation flights. A new multifunction control panel designed during the contract period, including a serial format digital control module (DCM) interface was installed. Signals were transferred from the control panel to the MMI, and response information was sent from the MMI to the DCM in the proper format.

The cockpit used for a previous IIPACS simulation was modified and used as the developmental cockpit. The existing eight-inch HSD, the color vertical situation display (VSD), and two of the three MPD's were retained. A third MPD was dedicated as a pre-entry read out for the data entry keyboard rather than procuring a special LED pre-entry read out display.

III.5.1 Simulator Cab Interface Description

The Multi-Mission Simulator described previously was used in an earlier IIPACS program and was modified for use in control display testing. A view of the modified cab is shown in Figure 37. This configuration was established as a result of the analysis described in previous sections of this report.

Key changes to the basic control display configuration consisted of reducing the number of multipurpose displays from five to two; replacement of air data and engine parameter MPD formats with dedicated instrumentation and replacing the integrated keyboard with a new design multifunction keyboard. For purposes of the developmental simulator, individual display format "demand" mode selection switching was not identical to those shown in the proposed configuration.

Figure 37. Modified Flight Simulator Cockpit

A Head-Up Display (Figure 38) was developed for use in the simulation testing. This device was designed to be positioned in front of the pilot to represent a structurally mounted HUD or be removed when testing the helmet mounted HUD configuration (Figure 39).

Basic MPD, VSD and HUD symbology used in this test demonstration was that developed for IIPACS III tests. MPD formats that were not used include those relating to air data and engine condition parameters. Basic formats that were provided on MPD-1 and MPD-2 during developmental testing are outlined in Figure 40. For purposes of these simulation tests, MPD-1 on demand called up NAV, STOR SEL, SENSORS and Failure Monitor. MPD-2 on demand called up COMM, STOR STAT or Failure Monitor.

Primary electronic display modes

	T/O	Climb	Cruise	TF	A/A	A/G	Dec.	Approach
MPD-1	Comm	Gen pur	Comm	Comm	Stor stat	Stor stat	Comm	Comm
MPD-2	Nav	Nav	Nav	Nav	Sensors	Sensors	Nav	Nav

Available alternatives

MPD-1	Nav	Batt alt	Stor sel	Sensors	Engine	Alt rng	Threat	V-N
MPD-2	Comm	Gen pur	Air data	Stor stat				

Figure 40. Primary MPD Display Modes

A new HSD map was developed to represent two methods of presenting the graphics map and sensor imagery. One was an overlay of map information on sensor imagery and the other was a separate display of the two types of information (Figure 41). Daytime lighting conditions were simulated by providing external cues on the vision screen outside the cockpit, while night time landing conditions were simulated with a runway lighting system.

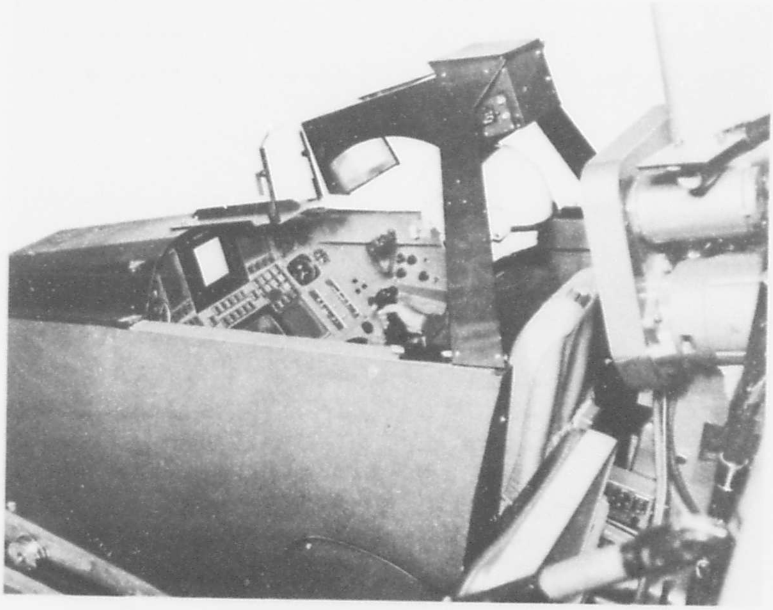


Figure 38. Cowl Mounted HUD

Figure 39. Helmet Mounted HUD

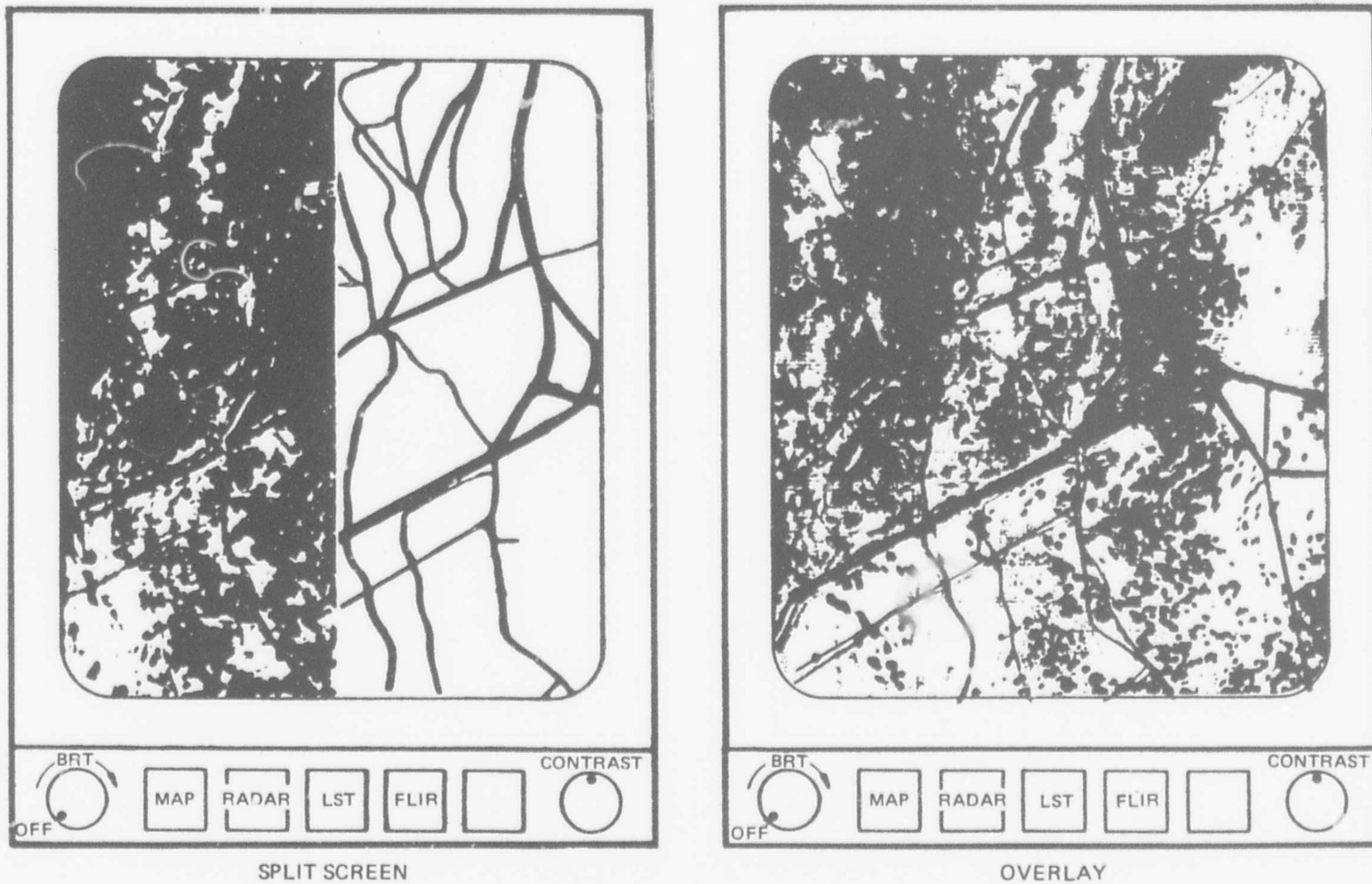


Figure 41. Moving Map Configurations

The development cockpit was positioned at the focal point of a curved screen. A black and white TV projector displayed images from the visual flight simulator model room for pilot controlled landings, air-to-ground and air-to-air target attacks.

Aircraft positions and attitudes were sent from the hybrid computer laboratory XDS 9300 to the MMI Varian 620i computer for transmission to another Varian computer in the visual flight simulator facility (VFS). Calculations are performed in the VFS Varian to transform aircraft attitude and position data to camera servo movement commands. These commands were transferred to one of the VFS XDS 9300 computers for output to the TV camera servos in the VFS model room. Servo mechanisms drove a TV camera over a three-dimensional terrain model to correspond with the aircraft motion in six degrees of freedom. The TV images generated were then piped to the TV projector in the MMS to complete a closed loop visual system. This allows pilot-controlled visual flight during landing, and surface target fly-over (Figure 42). Air-to-air combat is simulated with the same system except that the bogey flight is stored on a memory disc and a horizon and bogey shape are projected on the forward screen (Figure 43).

The composite mission developed for IIPACS III tests was maintained as the basic total mission flight capability. This is illustrated in Figure 44. Basic modifications included allowing midmission starts in order to simulate as closely as possible elements of the DAIS mission shown in Figure 45. The mini-test missions were started a) during cruise and in the search mode for an air-to-air target engagement. This segment allowed IFR acquisition and transition to a VFR tail chase gunnery engagement, b) low level inbound for a bomb drop. The bomb drop phase was modified to allow a three-minute run in for IFR navigation updates before entering the target area, and c) ILS capture through touchdown using night or day simulation of a CAT II airfield. A more detailed description of each minimission and related test conditions follow:

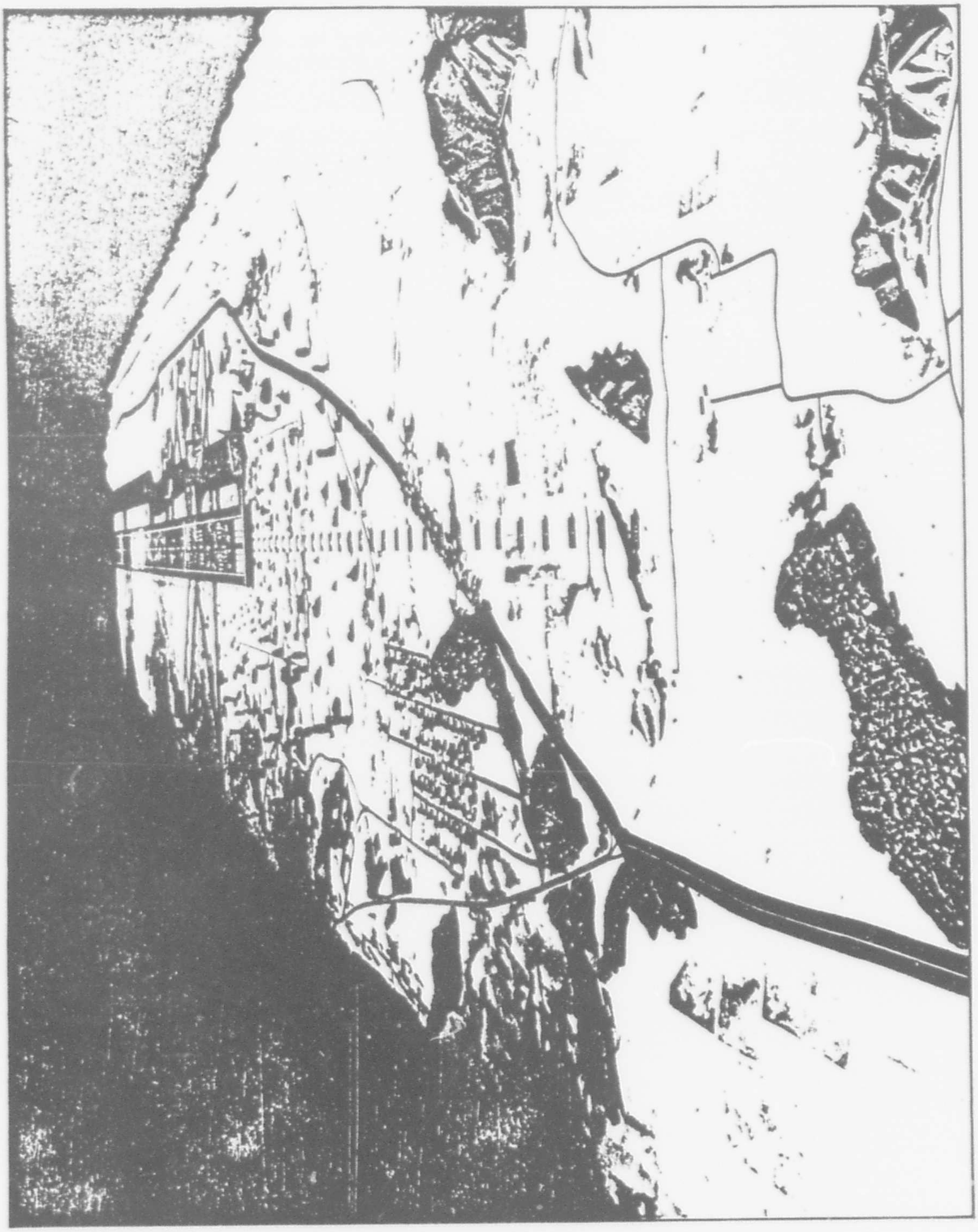


Figure 42. Visual Landing Model

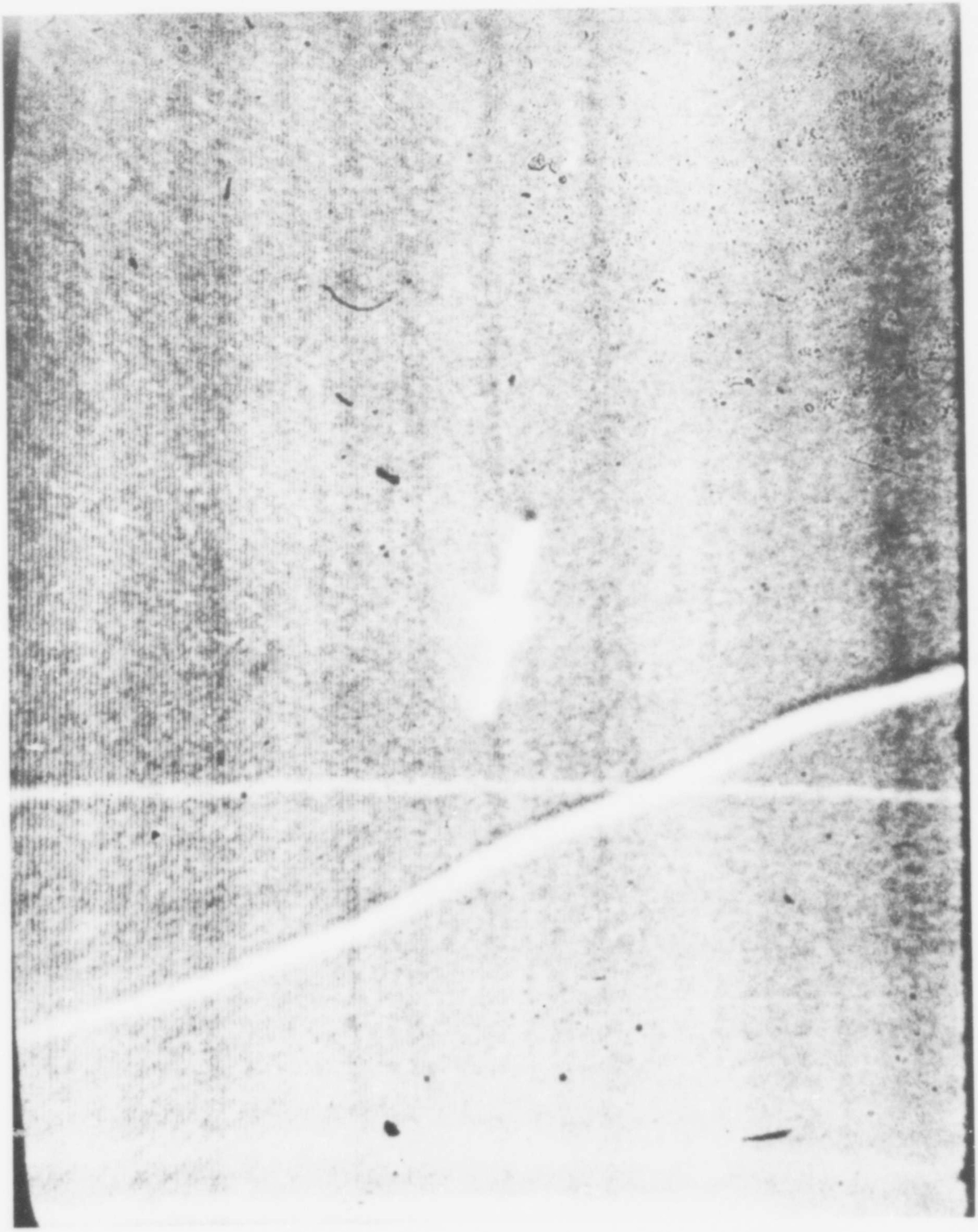
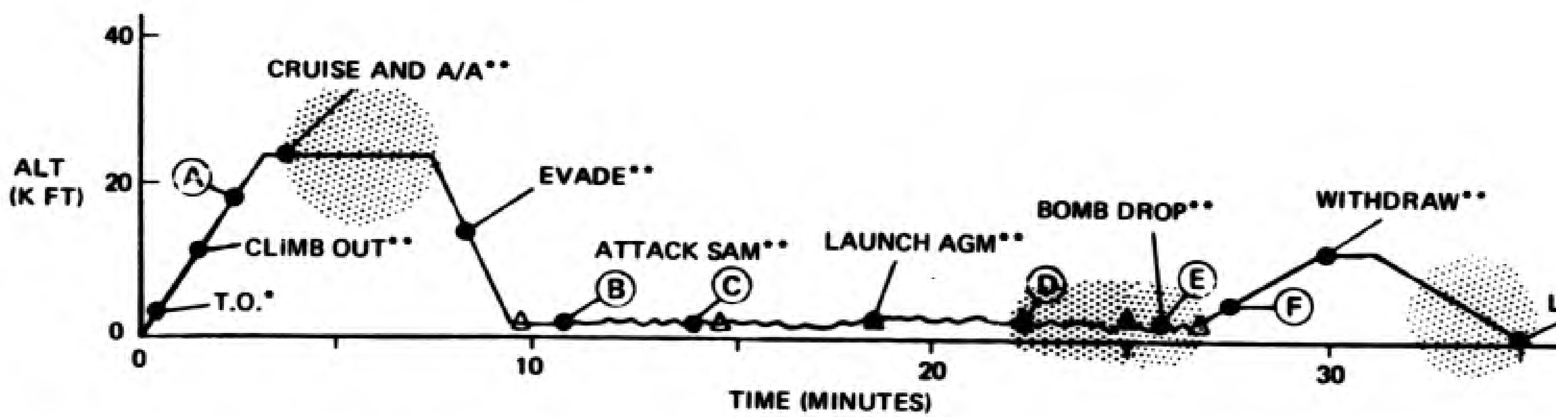


Figure 43. Computer Generated Bogey



* VISUAL FLIGHT CONDITIONS

** INSTRUMENT FLIGHT CONDITIONS

Δ CHECKPOINT

DEGARDED MODE EVENTS

A FAIL ALL AUTOMATIC WEAPON RELEASE
B FAIL AUTOMATIC TERRAIN FOLLOWING
C RESTORE AUTOMATIC TERRAIN FOLLOWING
D FAIL VSD
E FAIL AUTOPILOT
F FAIL SIDEARM FLIGHT CONTROLLER

Figure 44. IPACSS III Mission

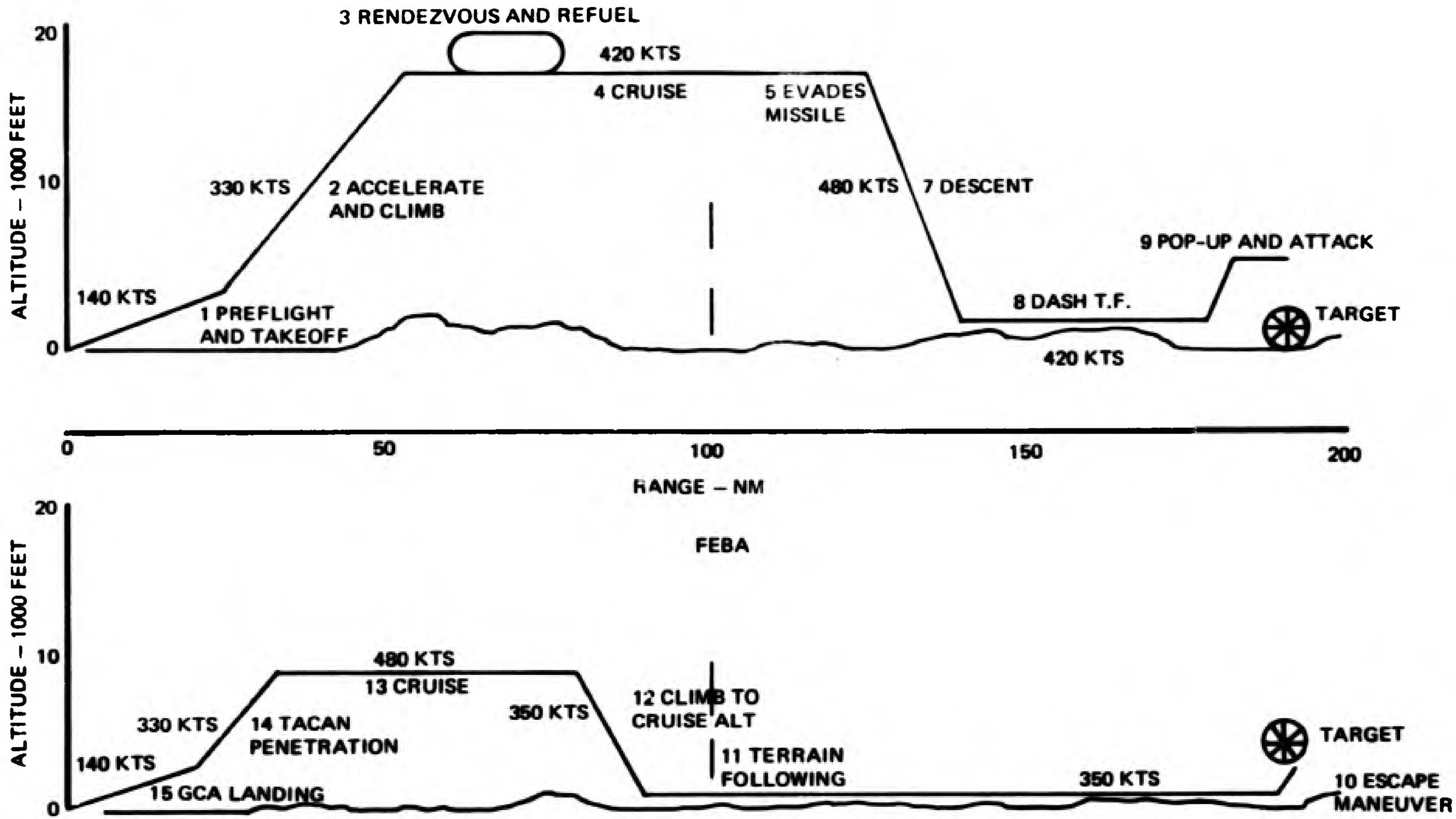


Figure 45. DAIS Interdiction Mission

III.5.2.1 Air-to-Ground Combat Minimission

The test situation starts with Alpha Red, the test aircraft on autopilot, holding altitude and heading, proceeding inbound to a pre-assigned target area. Battle area control calls and advises Alpha Red to contact FAC Pine Tree (Failure A)[1]. Alpha Red is given a target briefing and proceeds IFR on autopilot to a radar NAV update waypoint. (Failure B). After updating his navigation system, he proceeds on flight plan for a penetration to VFR for target acquisition and bomb delivery. As soon as the penetration breaks to VFR, Alpha Red disengages the autopilot and manually flies the remainder of the mission. He proceeds to the target area, acquires the target, lays his bombs on the first pass and initiates a penetration outbound to his next waypoint.

III.5.2.2 Air-to-Air Combat Minimission

This test situation was initiated with Alpha Red proceeding IFR to a pre-assigned loiter area. Battle Area Control requests Alpha Red Squawk on a specific IFF frequency (Failure C). Alpha Red complies and gets a lockon on an intruding aircraft. Alpha Red selects guns and laser track missiles for intercept combat with the enemy aircraft. An attempted missile delivery results in a hang up and the automatic pilot maneuvers into a tail chase position. The bogie and Alpha Red break out VFR: Alpha Red disengages the autopilot and performs a tail chase pursuit and cannon firing for final kill. The bogie goes into a cloud bank and Alpha Red takes up a heading toward his next way point. He calls Battle Control on his last UHF channel and is advised to change to a new channel for further instruction (Failure D).

III.5.2.3 Instrument Landing Minimission

This test situation was initiated with Alpha Red inbound from the final approach fix on a 45° intercept to the localizer for an ILS approach to

[1] See failure descriptions in Paragraph III.5.2.4

McChord AFB. Approach control calls and asks him to squawk a specific code. (Failure E). After contact with approach control he is cleared for an immediate approach and advised to change to TACAN channel 24 because of terminal area navigation aid problems. (Failure F). Alpha Red deselects the autopilot and makes a manual approach and landing.

III.5.2.4 Degraded Mode Test Situations

The following conditions were inserted in the test situation at the pre-selected times in the mission scenario:

(A) Error in UHF input frequency
- Pilot enters the frequency and the pre-entry read out shows a one digit error in UHF frequency. As pilot is requested to change UHF frequencies he notes an error in input on the COMM MPD. He re-enters correct frequency.

(B) Radar cursor slew function of designation control failure
- Radar cursor fails to respond to designation control input
As pilot attempts a RADAR position update he notes the cursor fails to respond to designation control input. He elects to go to the FLYOVER position update mode and uses the designation controller to slew the map.

(C) COMM MPD format failure
- COMM format is garbled and unreadable
As pilot inserts new IFF frequency, it is displayed on the pre-entry read out, however, the automatic override of the COMM format over the STOR STAT format on MPD 1 displays an unreadable message. The pilot selects the alternate COMM format on MPD 2 and verifies the change in IFF frequency. He returns the displays to the basic formats by depressing the A/A master mode control.

(D) Keyboard entry failure - UHF
- One digit in data entry keyboard fails to illuminate
- MASTER CAUTION light on
- MPD 1 displays "DATA ENTRY FAILURE"

As pilot selects CHAN SEL on the MFK in order to change UHF chanrels, he notices one of the digits has failed to illuminate. In addition, the MASTER CAUTION light illuminates and a display of the failure appears on MPD 1. The pilot returns the MFK to the top level of indenture by depressing MASTER, extinquishes the MASTER CAUTION light, which also removes failure message from MPD, and resorts to manual control of channel select on the side console. He verifies proper channel selection by voice communication with Battle Area Control.

(E) Error in IFF input channel

- Pilot enters a one digit error in IFF channel

As pilot is requested to change IFF mode 3/A channel he notes a one digit error in input on the COMM MPD. He re-enters correct channel.

(F) Keyboard entry failure - TACAN

- One digit in data entry keyboard fails to illuminate
- MASTER CAUTION light on

MPD 2 displays "DATA ENTRY FAILURE"

As pilot selects CHAN SEL on the MFK in order to change TACAN channels, he notices one of the digits has failed to illuminate. In addition, the MASTER CAUTION light illuminates and a display of the failure appears on MPD 2. The pilot returns the MFK to the top level of indenture by depressing MASTER, extinguishes the MASTER CAUTION light, which also removes failure message from MPD, and resorts to manual control of channel select on the side console.

III.6 TEST METHOD/APPROACH

A detailed series of tests were performed to evaluate key elements of the display system concept that was analytically developed during the first phase of this contract. Basic concepts tested/compared in the integrated tests included:

a) Cowl Mounted Headup Display vs. Helmet Mounted Headup Display
b) Dedicated Sensor/Map Display concept vs. Overlay concept
c) Evaluation of the Multifunction Keyboard

A detailed description of the simulator including controls and displays, flight problems and performance data systems are described in other sections of this report. This section of the report will discuss the specific test conditions, test sequences, test schedules, pilot training and testing procedures, data collection, data analysis, and a summary of the conclusions.

III.6.1 Test Objectives

The primary purpose of this series of tests was to evaluate various concept differences in the baseline display system. To accomplish this, short mini-missions were programmed in the simulator. The minimissions were representative of (1) an air-to-air combat encounter with another fighter aircraft, (2) an air-to-ground attack on a stationary target, and (3) an instrument landing approach terminated by a visual landing. The test design provided for an analysis of several objective performance measures and allowed experienced pilots to compare and subjectively evaluate the different concepts.

The specific test objectives were:

1. Evaluate and compare, in terms of minimission suitability, the usefulness of a fixed aircraft-mounted headup display versus a helmet-mounted headup display when using essentially identical symbology and imagery on each. This was not an evaluation of the specific headup display (HUD) hardware

used in the simulator. Rather, it was an evaluation to determine the advantages and disadvantages of two different HUD implementations in accomplishing selected mission segments representative of attack fighter operations.

2. Evaluate the display of navigation map symbology overlayed on corresponding sensor imagery (map/imagery correlation on HSD) vs. a separate dedicated display of each kind of information (on HSD) in terms of suitability and usefulness in performing the air-to-ground minimissions.
3. Evaluate the utility of the multifunction keyboard in terms of matrix size, number of integrated functions, logic indenture levels, and operational suitability in accomplishing the minimission scenarios; as well as assess the impact of keyboard implementation on pilot workload. In addition, evaluate keyboard utility in terms of reaction time for reprogramming the control/display system in the event of system failures (e.g. CRT display malfunction, keyboard entry errors, etc.).
4. Determine the impact (if any) of day vs. night operations on the usefulness and suitability of the two HUDs.

III.6.2 Test Configuration

The basic design for the minimission testing is shown in Figure 46. As can be seen from this illustration, the test design contained three mission environments.

a. <u>Air-to-Air Combat</u>. The basic design for the air-to-air combat mission was a 2^2 factorial with repeated measures. Two independent variables were evaluated: type of Headup Display (aircraft-mounted and helmet-mounted) and Mode of Operation (normal and degraded). Thus, each of the eight pilot subjects was tested with the cowl-mounted HUD under normal and degraded modes and also with the helmet-mounted HUD under normal and degraded modes. All tests were conducted under daytime conditions. Six performance measures were used to evaluate the above conditions; mean range while the bogey was within the inner and outer boresight circles, mean percent of hits while the bogey was within the inner and outer boresight circles, total time that the bogey was within the inner and outer boresight

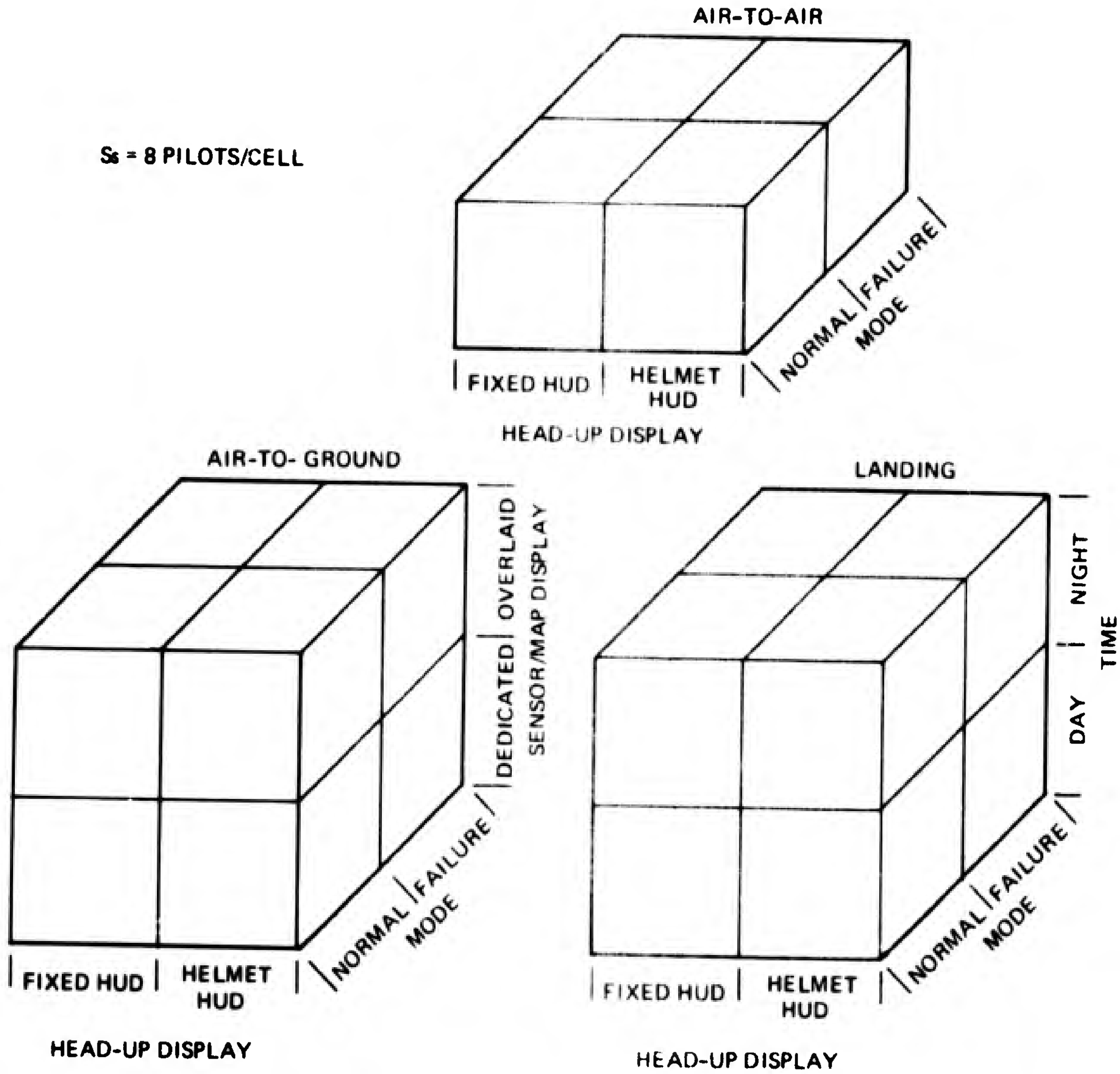


Figure 46. Experimental Design

circles, and the switch hit time to enter data into the multifunction keyboard.

b. Air-to-Ground Combat. The experimental design for the Air-to-Ground and combat mission was a 2^3 factorial with repeated measures. Three independent variables were evaluated: type of Headup Display (aircraft-mounted and helmet-mounted), type of Sensor/Map Display (dedicated and overlapping), and Mode of Operation (normal and degraded). Thus, each of the eight pilot subjects was tested in eight conditions formed by the factorial combination of the three independent variables. All tests were conducted under daytime conditions. Six performance measures were used to evaluate the above conditions: mean radial error, mean miss distance down range and cross range, lateral and vertical deviation from desired flight path, and switch hit time to enter data into the multifunction keyboard.

c. Instrument Approach Terminating in Visual Landing. The experimental design for the landing mission was a 2^3 factorial with repeated measures. Three independent variables were evaluated: type of Headup Display (aircraft-mounted and helmet-mounted), Time of Mission (day and night), and Mode of Operation (normal and degraded). Thus, each of the eight pilot subjects was tested in eight conditions formed by the factorial combination of the three independent variables. Seven performance measures were used to evaluate the above conditions: lateral and longitudinal touchdown error, sink rate and bank angle at touchdown, lateral and vertical deviation from desired flight path, and switch hit time to enter data into the multifunction keyboard.

In all of the above minimissions, the pilot did not know if a test run was normal or degraded. He was, however, trained to handle each type of failure presented. Other than for a short period of flight at the beginning of each minimission test, all flying was done manually. The basic test conditions are shown in Table 1. As can be seen, a total of twenty (20) different test conditions were evaluated.

Table 1. Test Configurations and Conditions

			Configuration									
Test Condition		A/A	A/G	LDG.	Fixed HUD	Helmet HUD	Ded. Sensor	O/L Sensor	Normal mode	Failure mode	Day	Night
1	→	X			X				X		X	
2	→	X			X					X	X	
3	→	X				X			X		X	
4	→	X				X				X	X	
5	→		X		X		X		X		X	
6	→		X		X		X			X	X	
7	→		X			X	X		X		X	
8	→		X			X	X			X	X	
9	→		X		X			X	X		X	
10	→		X		X			X		X	X	
11	→		X			X		X	X		X	
12	→		X			X		X		X	X	
13	→			X	X				X		X	
14	→			X	X					X	X	
15	→			X		X			X		X	
16	→			X		X				X	X	
17	→			X	X				X			X
18	→			X	X					X		X
19	→			X		X			X			X
20	→			X		X				X		X

20 TEST CONDITIONS

Key elements of the display and control system evaluation are described below. Two Headup Display methods were evaluated under the same flight conditions for each minimission. One configuration represented a structurally mounted HUD imaging glass. Another configuration involved the use of a helmet mounted HUD. Direct comparisons of performance differences and subjective critiques of good and bad features of the HUDs were elicited.

Sensor display concepts were comparatively evaluted in conjunction with compatible map display configurations. These concepts are described in detail in the controls and display sections of this plan. The basic comparison involved the use of dedicated dipslays for the sensor and map configurations as opposed to using a symbolic map overlay on the sensor presentation. Cockpit display presentations were different for each mini-test and are described in the Simulator control and di play description.

Configuration run time requirements are presented in Table 2.

Table 2. Test Configuration Run Time Requirements

	Air-to-ground				Landing				Air-to-air	
	Fixed HUD		Helmet HUD		Fixed HUD		Helmet HUD		Fixed HUD	Helmet HUD
	Overlay	Dedicated	Overlay	Dedicated	Day	Night	Day	Night	–	–
Test condition number	9, 10	5, 6	11, 12	7, 8	13, 14	17, 18	15, 16	19, 20	1, 2	3, 4
Run Time (minutes)	6	6	6	6	5	5	5	5	4	4
Set-up time (minutes)	5	5	5	5	5	5	5	5	5	5
Total time (minutes)	11	11	11	11	10	10	10	10	9	9

The test conditions were run in a specific sequence that minimized reconfiguration of the simulator and supporting facilities; i.e., SDS and visual flight simulator interface. The test sequences for each pilot subject are presented in Appendix B. Each subject was administered all of the test trials within a particular minimission before proceeding to the next minimission. The sequence of minimissions was counterbalanced across the eight pilot subjects. Within each minimission, the specific test conditions were independently randomized for each subject. A summary of simulator test time requirements as they affected simulator and support personnel activities is shown in Table 3.

III.6.3 Pilot Subjects and Test Procedure

Because of the constraints on testing time availability, the number of pilot subjects was quite small. All subjects were provided by the USAF contract monitor.

Six tactical fighter pilots from the Air Force and two ex-Air Force consultant pilots participated in the simulation program. The special qualifications of the pilots are listed in Table 4. The pilot subjects had an averabe age of 33 years and an average of 2,575 flying hours in several different aircraft. All of the pilots had had at least one combat tour of duty.

Names of participants were made available to the contractor approximately two weeks prior to the scheduled test dates. Each pilot subject received an abbreviated test plan to familiarize himself with the test objectives, conditions of test and simulation facility.

Four groups of two pilots each were tested. A pre-test training program was conducted for each group of pilot subjects at the beginning of the first twelve-hour working day. The pre-test training consisted of a description and walk through of the simulator facility, practice missions in the simulator, and familiarization with the testing procedures.

The test program was conducted over a period of four consecutive weeks. Two pilots per week were required for a period of two days to accomplish the

Table 3. Simulator Test Time Requirements

		Run time	Test time	Schedule time*
10 Conditions (normal) x 8 pilots		19.2 hrs	31.2 hrs	64 hrs
10 Conditions (degraded) x 8 pilots		19.2 hrs	31.2 hrs	64 hrs
	Total**	38.4 hrs	62.4 hrs	128 hrs
	Filming	1.6 hrs		
	Grand total	40.0 hrs		

* Schedule time includes two 12-hour test days for each group of pilots.

** Run time-to-schedule time ration = 1/3.33 hours

Table 4. Pilot Qualifications

	Mean	Range
Age:	33 yrs	27 - 42 yrs
Flying time:	2,575	900 - 5000 hrs.

Operational experience:

Pilot number	Type of Aircraft
1	A-7, T-37, T-38
2	A-7, F-4, T-37, T-38
3	A-7, F-4, F-100, T-33
4	A-7, F-100, T-33
5	A-7, F-105, T-37, T-38
6	A-7, F-4, T-37, T-38
7	B-57, F-4, F-100, F-111, T-33, T-37, T-38
8	F-86, F-89, RF-4C, T-33, T-37, T-38, T-39

training and test effort. The first half of day one was devoted to training and familiarization with the simulator cockpit control/display systems at the simulation facility. Actual testing began the second half of day one. Each test day was 12 hours long. The daily test schedule is presented in Table 5.

III.6.4 Test Data

Tables 6, 7, and 8 show the operational data that was recorded for each mini-mission environment. These performance measures were subjected to an analysis with inferential statistics.

Following the simulation, a Likert-type rating scale (Appendix C) was administered to elicit subjective evaluations of the headup displays, sensor/map displays, and the multifunction keyboard. The questionnaire responses were compiled and are presented in tabular form in the results section. Each pilot also completed a questionnaire concerning prior flight experience and anthropometric data. (Appendix D).

Each pilot was also asked to provide a verbal assessment of the overall suitability of the various IIPACS configurations. During the interview, emphasis was placed upon the identification of problem areas and on suggestions for improvement.

Table 5. Daily Test Schedule

	1st Test day
0730 – 0830	Prep and checkout, Pilot No. 1 on station at 0815
0830 – 1000	Pilot No. 1 familiarization training
1000 – 1130	Pilot No. 2 familiarization training
1130 – 1230	Lunch break
1230 – 1400	Pilot No. 1, practice trials
1400 – 1530	Pilot No. 2, practice trials
1530 – 1700	Pilot No. 1, 5 test conditions
1700 – 1800	Dinner break
1800 – 1930	Pilot No. 2, 5 test conditions
1930 – 2000	Post flight debriefing
	2nd Test day
0730 – 0830	Prep and checkout, Pilot No. 2 on station at 0815
0830 – 1000	Pilot No. 2, 5 test conditions
1000 – 1130	Pilot No. 1, 5 test conditions
1130 – 1230	Lunch break
1230 – 1400	Pilot No. 2, 5 test conditions
1400 – 1530	Pilot No. 1, 5 test conditions
1530 – 1700	Pilot No. 2, 5 test conditions
1700 – 1800	Dinner break
1800 – 1930	Pilot No. 1, 5 test conditions
1930 – 2030	Post flight debriefing and questionnaire

Table 6. Air-to-Air Test Performance Measures

Target Tracking		
AVRI	=	Average range while bogey within the inner circle
AVRO	=	Average range while bogey within the outer circle
PHI	=	Average percent of hits while bogey within the inner circle
PHO	=	Average percent of hits while bogey within the outer circle
TIC	=	Total time bogey within the inner circle
TOC	=	Total time bogey within the outer circle
Multi-function keyboard		
SHT	=	Switch hit time to enter data

Table 7. Air-to-Ground Test Performance Measures

Target tracking		
MRE	=	Mean radial error
MDCR	=	± Miss distance cross range
MDDR	=	± Miss distance down range
Flight path parameters		
ΔH	=	Vertical deviation from desired path (ft./sec)
ΔY	=	Lateral deviation from desired path (ft./sec)
Multi-function keyboard		
SHT	=	Switch hit time to enter data

Table 8. Landing Test Performance Measures

Touchdown parameters		
X	=	± Longitudinal touchdown error
Y	=	± Lateral touchdown error
HD	=	Sink rate at touchdown (ft./sec)
PHI	=	Bank angle at touchdown
Flight path parameters		
ΔH	=	Vertical deviation from desired path (ft./sec)
ΔY	=	Lateral deviation from desired path (ft./sec)
Multi-function keyboard		
SHT	=	Switch hit time to enter data

III.7 DATA ANALYSIS

This section contains a discussion of the simulation results. It is organized around the specific program objectives that were described in the preceding section. To briefly review, these objectives included a comparison of the operational effectiveness of the two HUDs and the two Sensor/Map Displays and an evaluation of the utility of the multifunction keyboard.

Table 9 provides an overall summary of the objective data with respect to the program objectives. In this table, a matrix of independent and dependent variables is shown for each minimission. All of the statistically reliable effects have been designated with a probability value in the appropriate matrix cells. Any cell that does not have a probability value indicates that there was not a significant difference between the two levels of a particular independent variable for a particular performance measure. As can be seen, only four of the comparisons reached commonly accepted standards of reliability. These results will be discussed in more detail in the following sections. For each program objective, there will be a discussion of the objective data, subjective data, limitations upon interpreting the data, and finally, a conclusion.

III.7.1 Head-Up Display Configuration

Objective Data. Reliable performance differences between the aircraft-mounted HUD and the helmet-mounted HUD were obtained for only one performance measure in the air-to-air mission. Figure 47 shows the mean time that the computer generated bogey was within the outer boresight circle as a function of HUD configuration for each pilot. The pilot numbers on the abscissa of this figure and on all subsequent figures have been randomized to preserve the anonymity of the subjects. As can be seen, the bogey was held within the outer boresight circle for a significantly longer period of time with the fixed HUD (51% of the mission time) than with the helmet HUD (31% of the mission time), $F(1,7) = 7.35$, $p < .05$. Fixed HUD performance also tended to be better for the mean time that the bogey was within the

Table 9. *Objective Data Summary*

Air-to-air

	Head-up display	Operational mode
Mean range/inner circle		
Percent hits/inner circle		
Total time/inner circle		
Mean range/outer circle		
Percent hits/outer circle		
Total time/outer circle	$P < .05$	
Switch hit time		

Air-to-ground

	Head-up display	Sensor/map display	Operational mode
Mean radial error			
Miss distance cross range			
Miss distance down range			
Vertical deviation from flt. path			
Lateral deviation from flt. path		$P < .025$	
Switch hit time			

Landing

	Head-up display	Time of mission	Operational mode
Longitudinal touchdown error			
Lateral touchdown error	(Interaction	$P < .01$)	
Sink rate at touchdown			
Bank angle at touchdown			
Vertical deviation from flt. path			
Lateral deviation from flt. path			
Switch hit time			$P < .001$

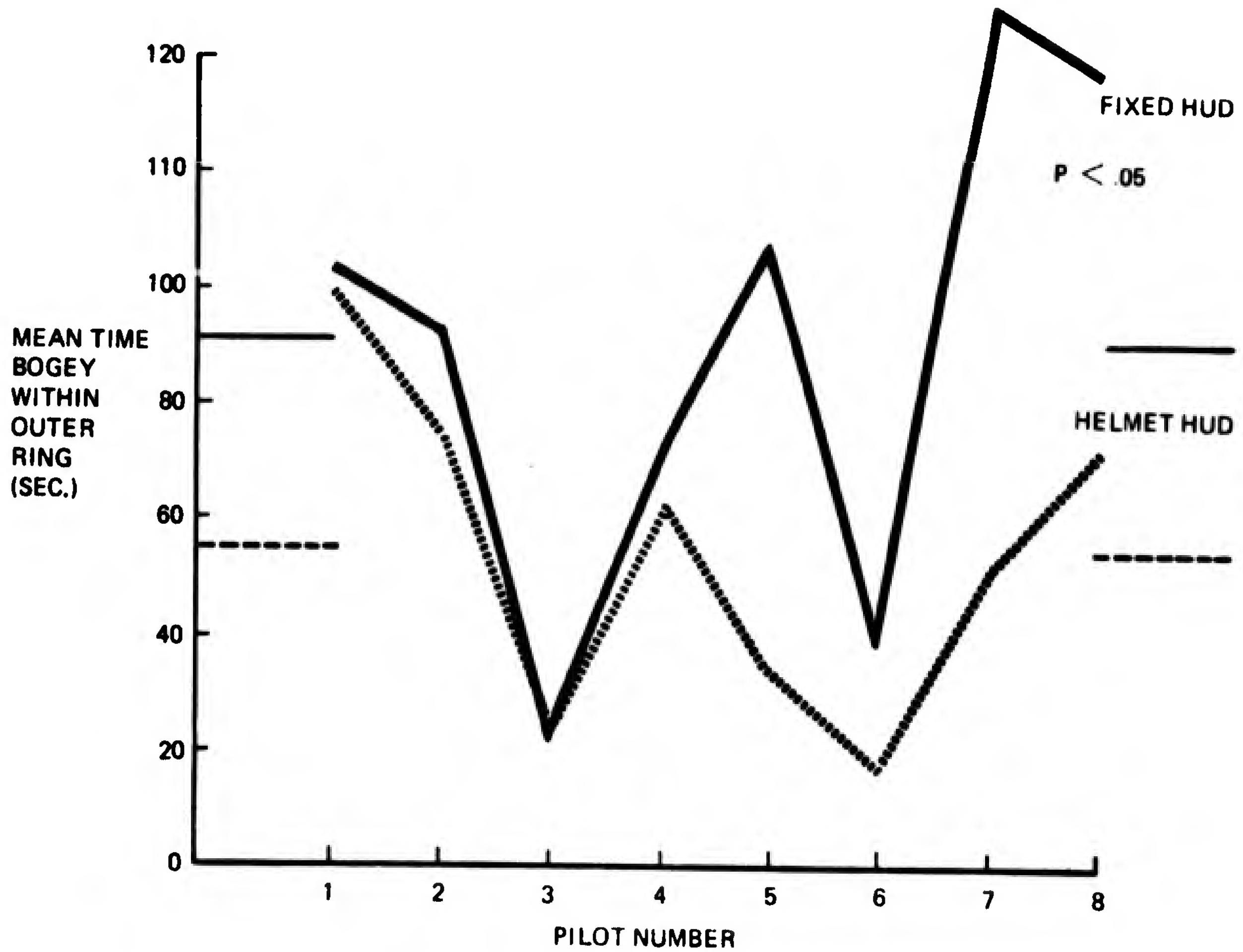


Figure 47. Air-to-Air Test Data

inner boresight circle, and the mean range while the bogey was within the inner and outer boresight circles, but these differences were not statistically significant.

In the landing mission, there was a significant Head-Up Display by Time of Mission interaction, ($F(1,7) = 12.83$, $\underline{P} < .01$ for the mean lateral touchdown error performance measure. The nature of this interaction was such that the mean lateral touchdown error was approximately equal for day and night operations with the helmet HUD while it was considerable less for the fixed HUD under day conditions than under night conditions. The interaction data are shown in Figure 48. The interaction may have been produced by different visual orientations that were maintained for the two types of HUD. An analysis of the objective data suggested that the subjects may have focused more attention outside of the cockpit when using the aircraft-mounted HUD. If this were true, one would expect that a reduction in the number of visual cues during night landings would affect performance more when pilots used the aircraft-mounted HUD.

No differences between the two HUD configurations were found for any performance measure of the Air-to-Ground mission.

Subjective Data. All subjects responded to eight questions concerning the two HUD configurations. Two categories of response were compared; profixed HUD statements and pro-helmet HUD statements. The percent of subjects responding to these two categories were tabulated and are presented in Figure 49. Any subject providing a neutral response to a question was not included in the percentages reported for that question. Thus, the total number of subjects shown in the fixed and helmet categories of each question may be less than 100% in some instances. As can be seen, all of the subjects rated the overall suitability of the fixed HUD more highly than the helmet HUD. The subjects were also unanimous in their opinion that the fixed HUD was superior for the Air-to-Ground mission. A majority of the subjects felt that the fixed HUD was superior for the Landing mission under both day and night conditions. It should be noted that this finding is in direct contradiction to the objective data shown previously. The subjects were apporximately evenly

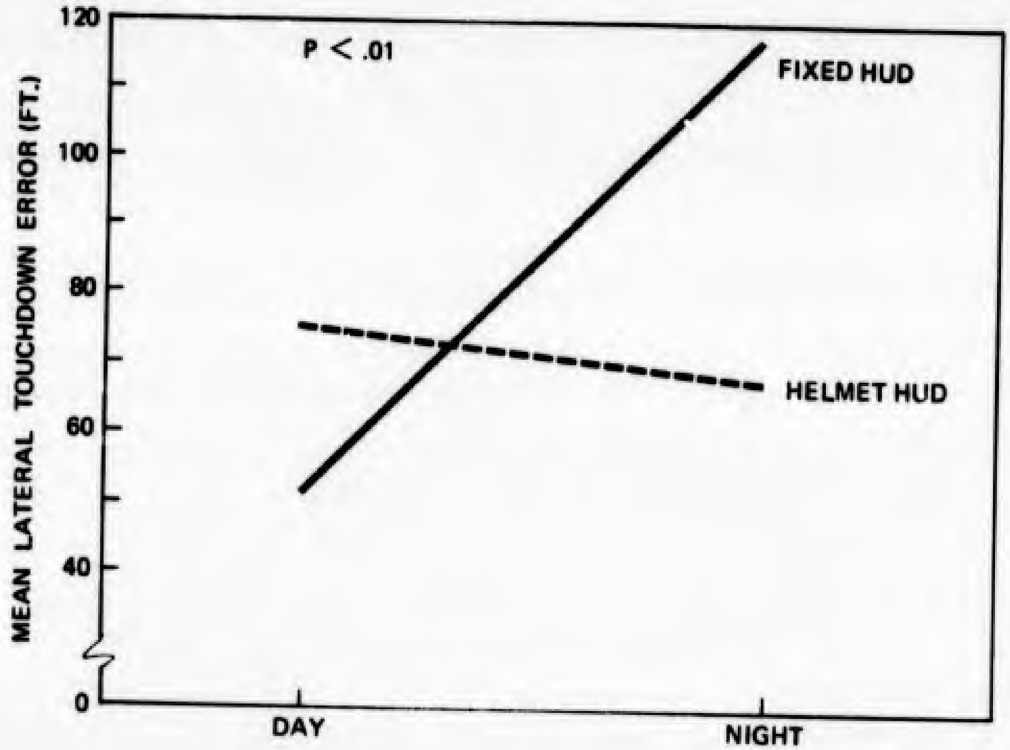


Figure 48. Landing Test Data

HELMET		FIXED
0.0%	OVERALL SUITABILITY	100%
0.0%	SUPERIOR FOR AIR-TO-GROUND	100%
12.5%	SUPERIOR FOR LANDING	87.5%
50.0%	RESTRICTED MOVEMENT MORE	37.5%
0.0%	SUPERIOR FOR DAY	75.0%
0.0%	SUPERIOR FOR NIGHT	87.5%
87.5%	MORE ACCOMMODATION PROBLEMS	12.5%

Figure 49. Questionnaire Responses: Head-up Display

divided in their opinions as to which HUD caused the greatest restriction of movement within the cockpit. The fixed HUD restricted movement by forcing the pilot to maintain a position directly in front of the HUD combining glass. The helmet HUD restricted movement by forcing the pilot to maintain a position so that the helmet was aligned with the IR helmet position sensor. In addition, several subjects questioned both the weight of the helmet HUD and the asymmetrical distribution of weight resulting from the monocular eyepiece. Finally, a greater number of accomodation problems were reported for the helmet-mounted HUD. The subjects seemed unable to "look through" the helmet HUD to view the symbology superimposed upon the bogey. Instead, they tended to switch their attention back and forth from the bogey to the symbology. The helmet HUD was also criticized for the following reasons: the symbology appeared to be too cluttered in the small eyepiece, the extended eyepiece blocked the pilots view of several instruments on the right hand side of the cockpit (i.e., Master Caution, Marker Beacon, etc.), and it tended to degrade the pilot's depth perception.

Limitations Upon Data Interpretation. A rigorous comparison of the two HUD configurations was not possible in the present simulation for two reasons. First, much of the information that was presented on the Head-Up Displays was also presented on the Vertical Situation Display. Second, some of the pilots avoided use of the helmet HUD by closing one eye or by decreasing the intensity of the symbology, and relying upon redundant information available elsewhere in the cockpit. Therefore, it is not clear whether the differences reported above reflect a comparison between two HUD configurations having the same symbology, between the fixed HUD and no HUD, or between the fixed HUD and several dedicated instruments and controls.

Two additional problems are involved in interpreting the data. One of these concerns the relative degree of prior experience with the two HUD configurations. It is possible that the subjects had a positive bias for the more familiar fixed HUD configuration. A second problem, which is more subtle, but equally important, concerns the goal of the HUD comparison. Ideally, the subjects should be comparing two Head-Up Display concepts rather than two specific pieces of hardware. This level of abstraction was not realized, however, and more often than not, the pilot's comments tended to be directed toward deficiencies in the particular equipment used in the simulator.

Conclusions. With the above limitations in mind, it was concluded that the aircraft-mounted HUD was superior to the helmet-mounted HUD for all three mission environments. This is not to say, however, that the helmet HUD concept is unworthy of further development. More advanced configurations have eliminated the problems associated with excess weight and asymmetrical balance of the helmet. The obstruction of cockpit instruments by the eyepiece has been avoided by projecting the symbology upon the helmet visor. There is still some question, however, whether a pilot can effectively operate a high performance fighter aircraft that has multiple degrees of freedom while simultaneously monitoring a display with multiple (head movement) degrees of freedom. Furthermore, the helmet HUD produces a serious accomodation problem which may limit its overall effectiveness (Reference 9).

III.7.2 Sensor/Map Display Configuration

Objective Data. As noted in the test design, the sensor/map display configurations were only evaluated in the Air-to-Ground minimission. Only one reliable difference between the two configurations was obtained. In that case, the mean lateral deviation from the desired flight path was significantly greater for the overlapping display, $F(1,7) = 9.37$, $P < .025$. Figure 50 shows the mean lateral deviation for each pilot as a function of the sensor/map display configuration. As can be seen in that figure, the mean lateral error was forty feet greater with the overlapping display. Though this difference was statistically reliable, it should be noted that it may not be a meaningful difference.

Subjective Data. All subjects responded to three questions concerning the two sensor/map display configurations. As can be seen in Figure 51, the subjects were unanimous in their opinion that the overlapping display was superior in all three areas; overall suitability, easier updates, and easier interpretation. In general, the pilots felt that the overlapping display enabled them to make more precise navigation updates and provided a greater amount of feedback concerning the accuracy of their updates.

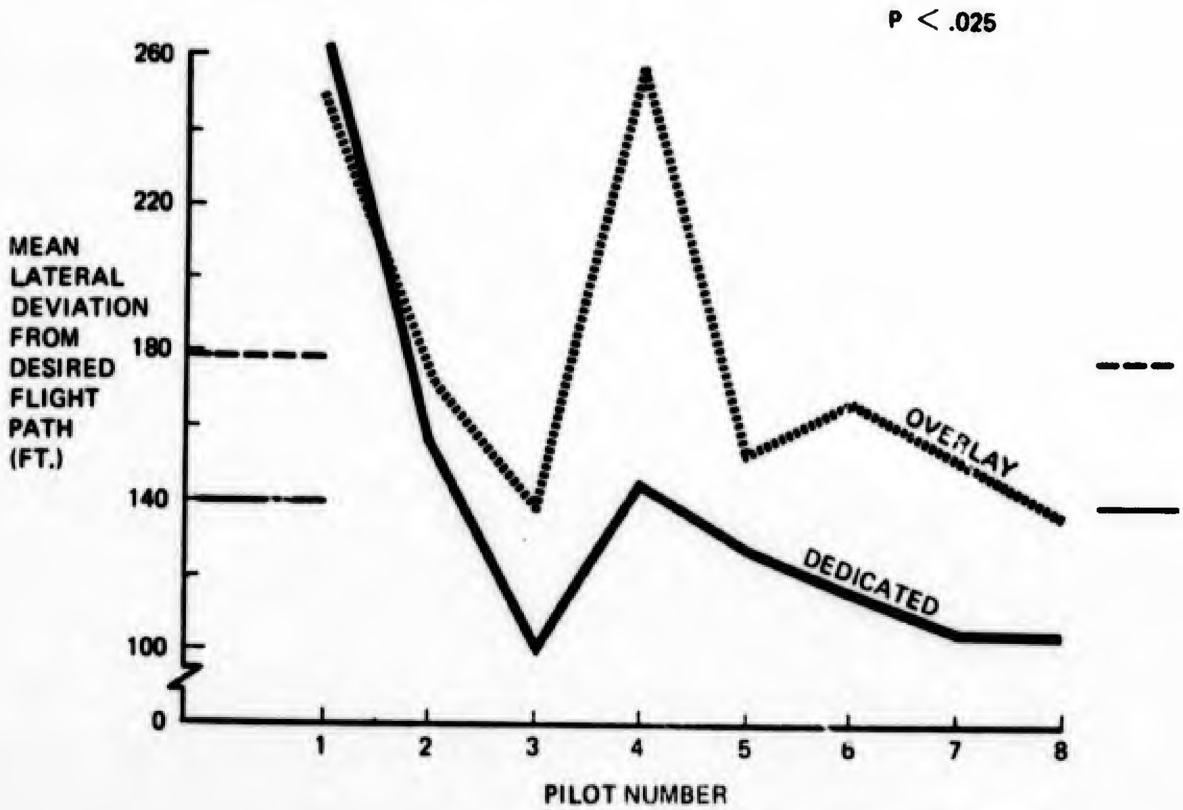


Figure 50. Air-to-Ground Test Data

DEDICATED		OVERLAID
0%	OVERALL SUITABILITY	100%
0%	EASIER MAP UPDATE	100%
0%	EASIER TO INTERPRET	100%

Figure 51. Questionnaire Responses: Sensor/Map Display

Limitations Upon Data Interpretation. The primary limitation of the sensor/map display data concerns the method by which two flight parameters (lateral deviation from desired flight path and drift between the IR sensor, and the map symbology) were measured and the relationship between those parameters. A description of these parameters and the method used to measure them can be found in the computer specification document, Reference 10. It should be noted that with the present measurement procedure, an attempted update in the cross range direction could actually produce a larger error in the lateral deviation variable than if no cross range update were attempted at all. Since more cross range updates were attempted with the overlapping display, a greater error in lateral deviation was obtained for that configuration.

Conclusions. It was concluded that the overlapping sensor/map display configuration was superior to the dedicated configuration. This conclusion was based entirely upon the subjective questionnaire data since the only reliable difference for the objective performance measures was an artifact of the data collection procedure.

III.7.3 Multifunction Keyboard

Objective Data. The objective data for the multifunction keyboard were obtained by comparing each performance measure under both normal and degraded operational modes. No reliable differences between the two modes were obtained for any performance measure in the Air-to-Air and the Air-to-Ground minimissions. The only reliable difference in the Landing minimission was obtained on the switch hit time variable. The mean time to enter a UHF channel change was significantly longer for the failure mode, $F(1,7) = 74.87$, $P < .001$. Figure 52 shows the mean time to enter a UHF channel change for each pilot as a function of the operational mode. As can be seen, approximately five seconds were required to perform this relatively simple operation on the multifunction keyboard.

Subjective Data. All subjects responded to eight questions concerning operation of the multifunction keyboard and its associated multipurpose displays. Figure 53 shows the percent of subjects who responded in a positive or

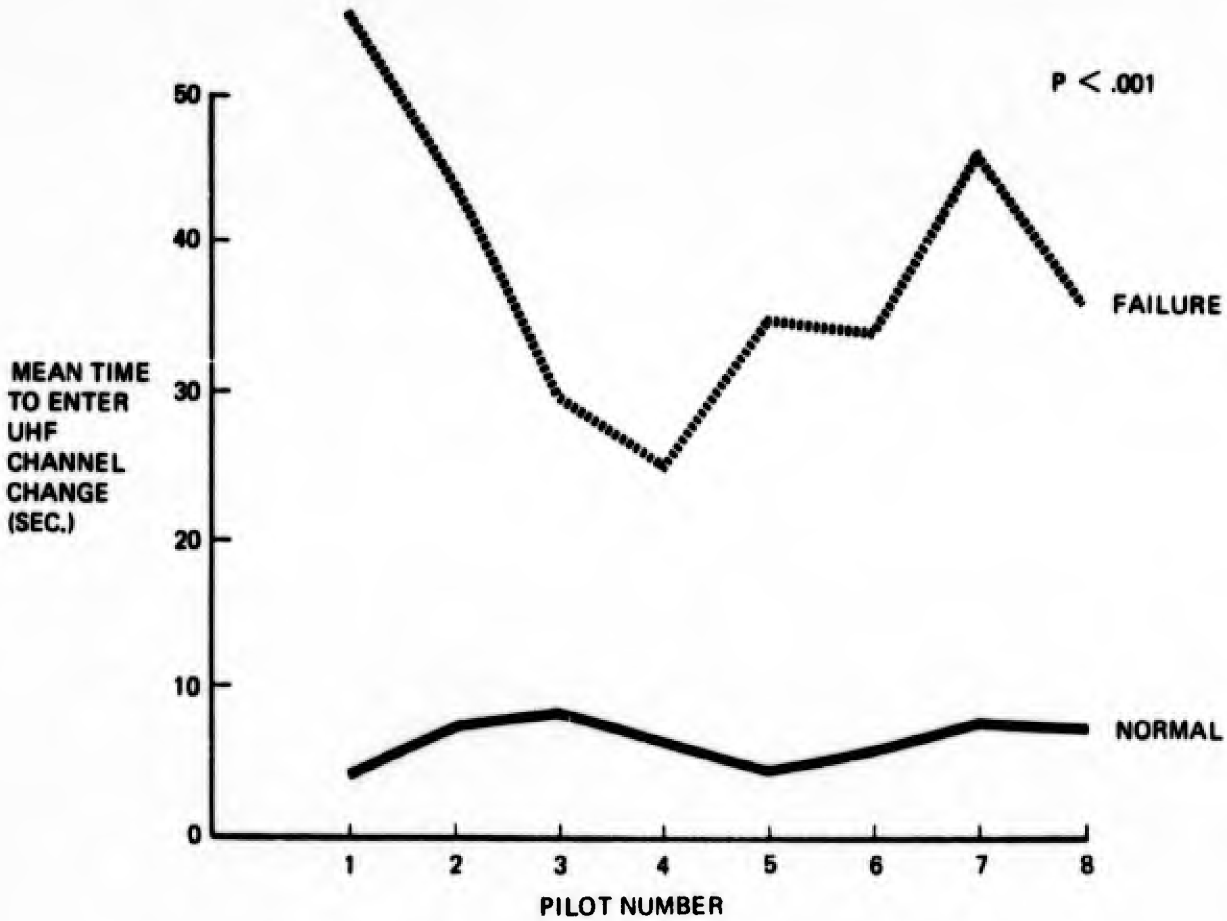


Figure 52. Landing Test Data

YES		NO
87.5%	EASY TO OPERATE	12.5%
50.0%	EFFICIENT	50.0%
75.0%	EASY TO CORRECT FAILURES	25.0%
50.0%	AIDED OTHER MISSION TASKS	12.5%
75.0%	EQUALLY SUITABLE FOR DAY-NIGHT USE	25.0%
75.0%	VALUE OF PRE-ENTRY READOUT	25.0%

Figure 53. Questionnaire Responses: Multi-function Control

negative manner toward six aspects of the keyboard. Eighty-seven percent of the subjects felt that the multifunction keyboard was easy to operate. Several subjects, however, complained about the inadequate size and brightness of the legends, the absence of tactile or auditory feedback, and the lag time between switch actuation and appearance of a legend on the pre-entry read out. The subjects were evenly divided concerning the efficiency of the multifunction keyboard. Those subjects who felt that the keyboard was efficient responded, primarily, to the compact appearance and easy operation of the keyboard. Those subjects who thought that the keyboard was inefficient, felt they could actuate a group of dedicated switches more rapidly than they could progress through four logic levels in a specific sequence. Seventy-five percent of the subjects thought it was easy to correct failures in the keyboard. The remaining twenty-five percent objected to the awkward position of the manual back-up for channel selections. They also felt that it was inefficient to return to a higher logic level to correct an error and to program a clear switch so that it only erased the last alphanumeric character instead of all characters at the data entry level. Seven of the eight subjects felt that the multifunction keyboard aided them in completing other mission tasks or, at least, did not interfere with the completion of other mission tasks. The multifunction keyboard was judged to be equally suitable for both day and night operations by six of the eight subjects. Of the remaining subjects, one felt that direct sunlight on the back-lighted keyboard would wash out the legends. The other subject felt that the multifunction keyboard would increase the workload under nighttime conditions. Seventy-five percent of the subjects thought that the pre-entry read out display was useful in detecting data input errors. Those subjects who criticized the pre-entry read out felt that data concerning logic levels should not appear on the pre-entry display and that the display should be located closer to the multifunction keyboard. Finally, the subjects were evenly divided with regard to the number of functions, keys, and logic levels that should be contained in the keyboard. Those subjects favoring a more complex keyboard seem to be concerned about placing as many instruments and controls as possible on the forward panels. Those subjects favoring a relatively simple keyboard seem to be more concerned with the increase in actuation time that may accompnay increases in keyboard complexity.

Limitations Upon Data Interpretation. The primary limitation on the multifunction keyboard data was that all keyboard failures occurred during the autopilot phase of each minimission. Thus, ample time was available for all subjects to correct the malfunctions and the subjects were not required to perform other tasks during the degraded period.

Conclusions. In general, the subjects were very responsive to the concept of an integrated multifunction control panel. Despite the relatively brief period of training, all subjects attained a high level of proficiency with the keyboard. The baseline data on switch hit times was encouraging, especially when considering the inadequate legend size, the absence of tactile or auditory feedback, the non-standard format of the data entry keyboard, and the spatial separation of the keyboard and the pre-entry read out display. Several modifications to the keyboard and the pre-entry display have been made in an effort to eliminate the above inadequacies from the final multifunction control panel configuration. With these modifications, the multifunction control concept is a potentially valuable innovation that is worthy of further development.

III.8 MODIFIED BASELINE CONFIGURATION

As a result of the simulator evaluations, several modifications were made to the proposed baseline configuration. Primarily, changes were made in the operation of the multifunction control panel and it's interaction with the multipurpose displays. Changes to the symbology presented on the HUD-VSD and HSD are also recommended and are described in the following sections.

III.8.1 Modified Multifunction Control Panel

Changes to the legends were made in the fourth level of indenture only. The proposed data entry keyboard was a nonstandard arrangement (Figure 54) and evoked negative response from the evaluation pilots. The keyboard was re-arranged, using the same last three rows of switches, to a more standard lay-out (Figure 55).

Interaction of the multifunction control panel and the multipurpose displays was also changed. In the proposed configuration and in the simulator, the pilot was forced to select alternate formats on the MPD's if the desired format was not basic for that flight phase. This resulted in many unnecessary control actions. The interaction of the controls and displays was modified and is best explained with an example:

1) Assuming the pilot would like to change a channel in his command radio set. He selects COMM on the multifunction control panel and he is presented with the COMM format on MPD 1 which has automatically replaced whatever format is basic for that flight phase. (Figure 56).
2) Another common complaint from the pilots was the amount of information presented on a single display. To solve this, when he selects a system within the COMM function (in this case the UHF set) he is presented with only information associated with that system. (Figure 57).
3) Since he wants to change channels, he selects CHAN SEL and is presented with the data entry keyboard (Figure 58). He performs the

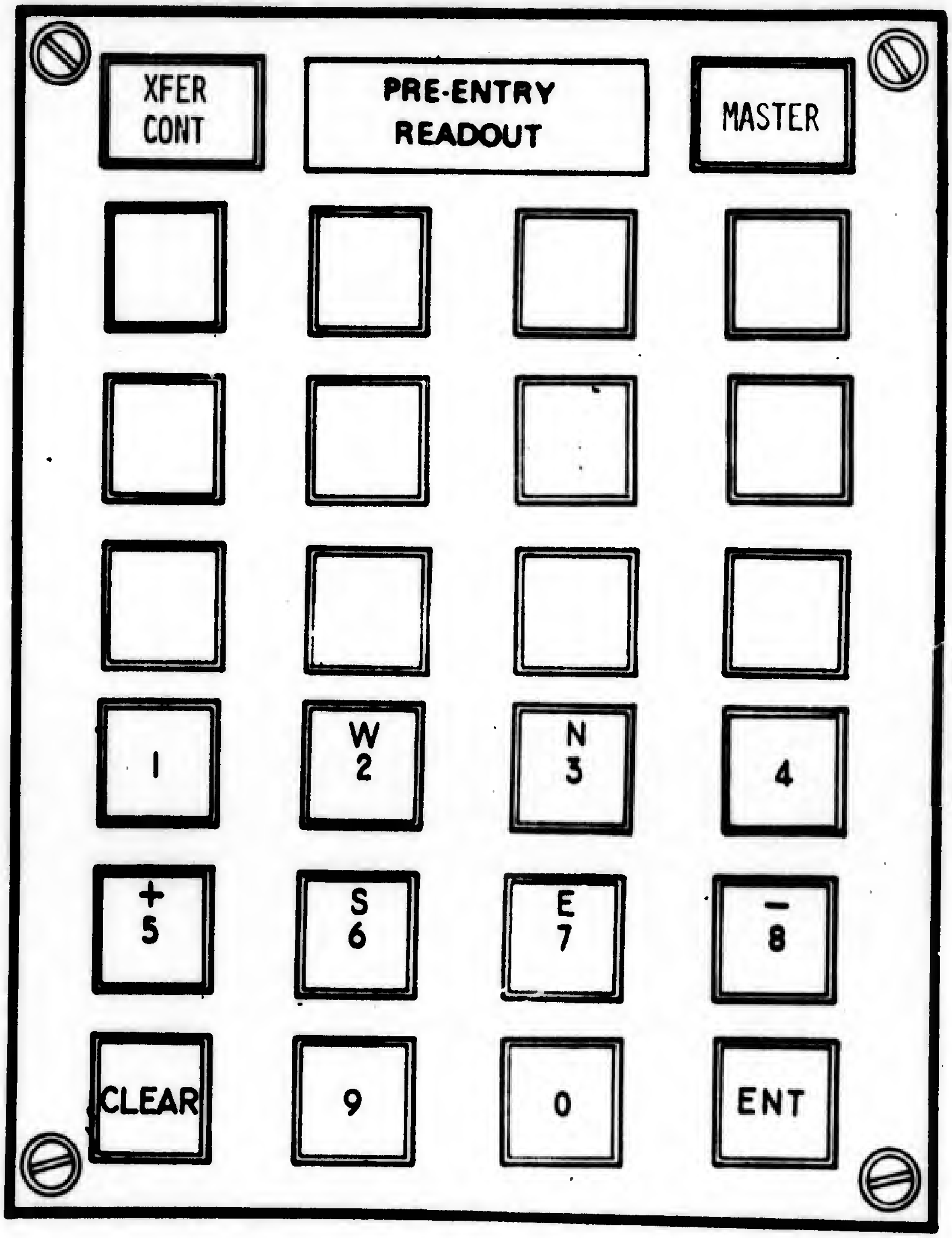


Figure 54. Non Standard Data Entry Keyboard

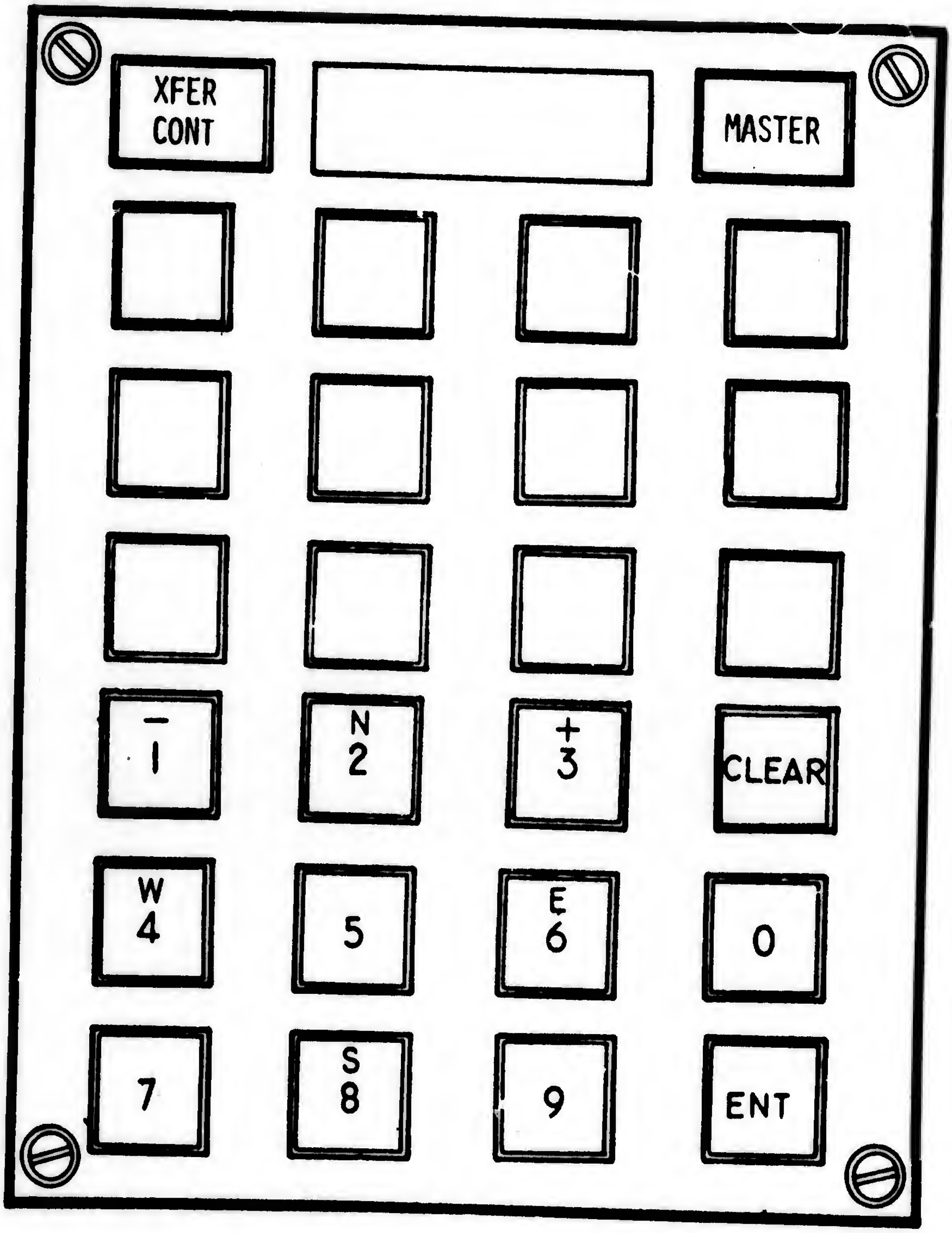


Figure 55. Modified Data Entry Keyboard

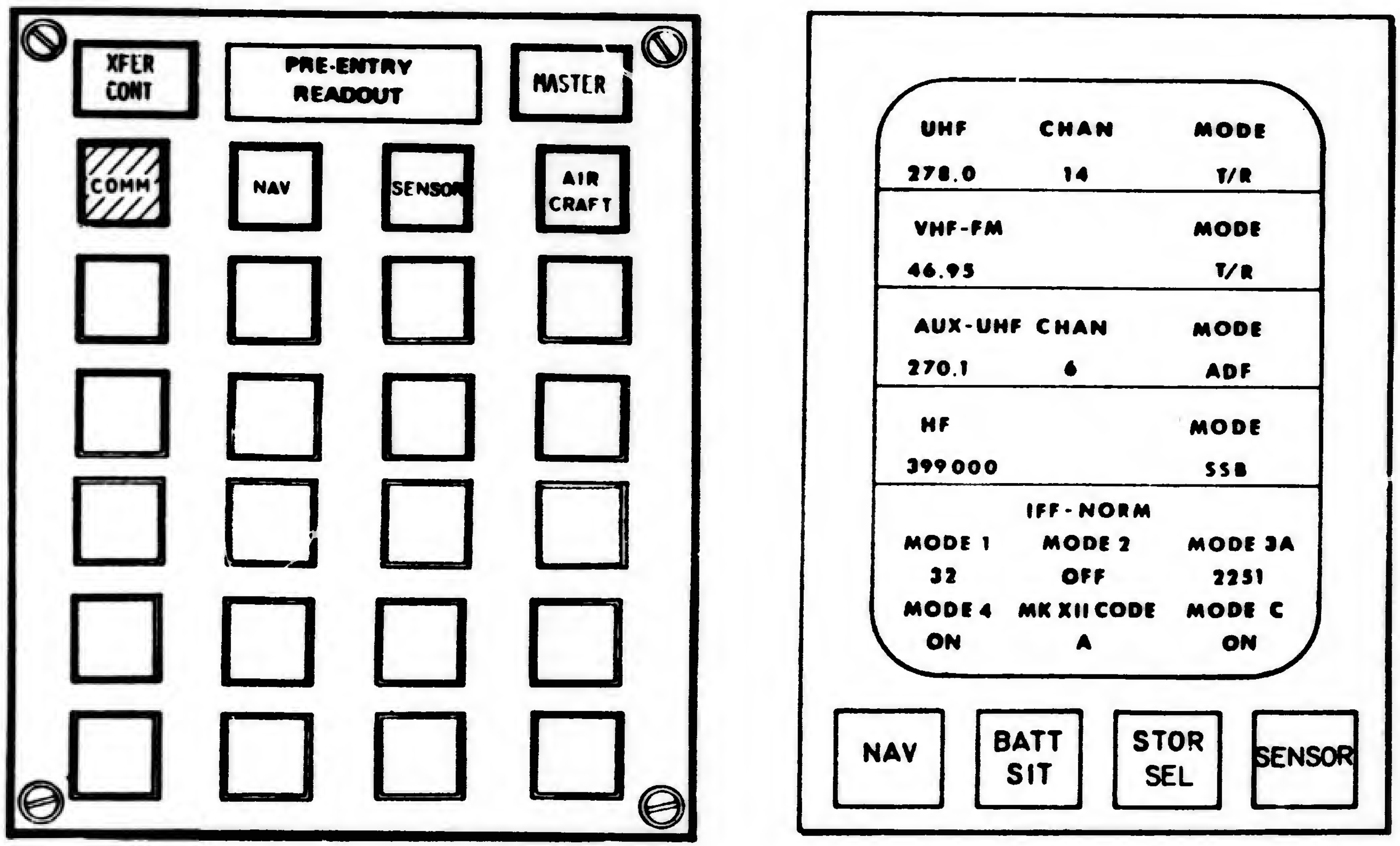


Figure 56. COMM Selected

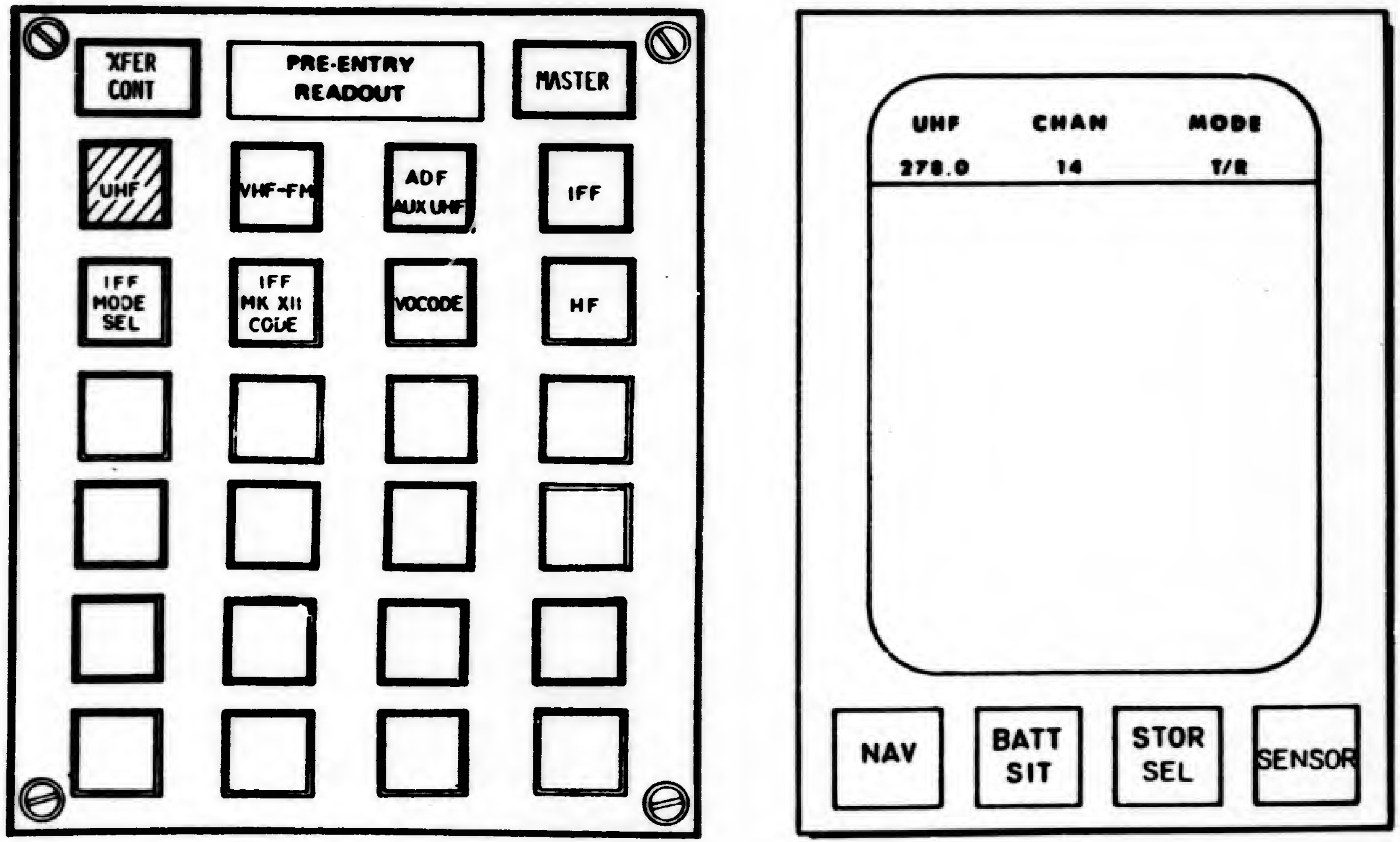


Figure 57. UHF Selected

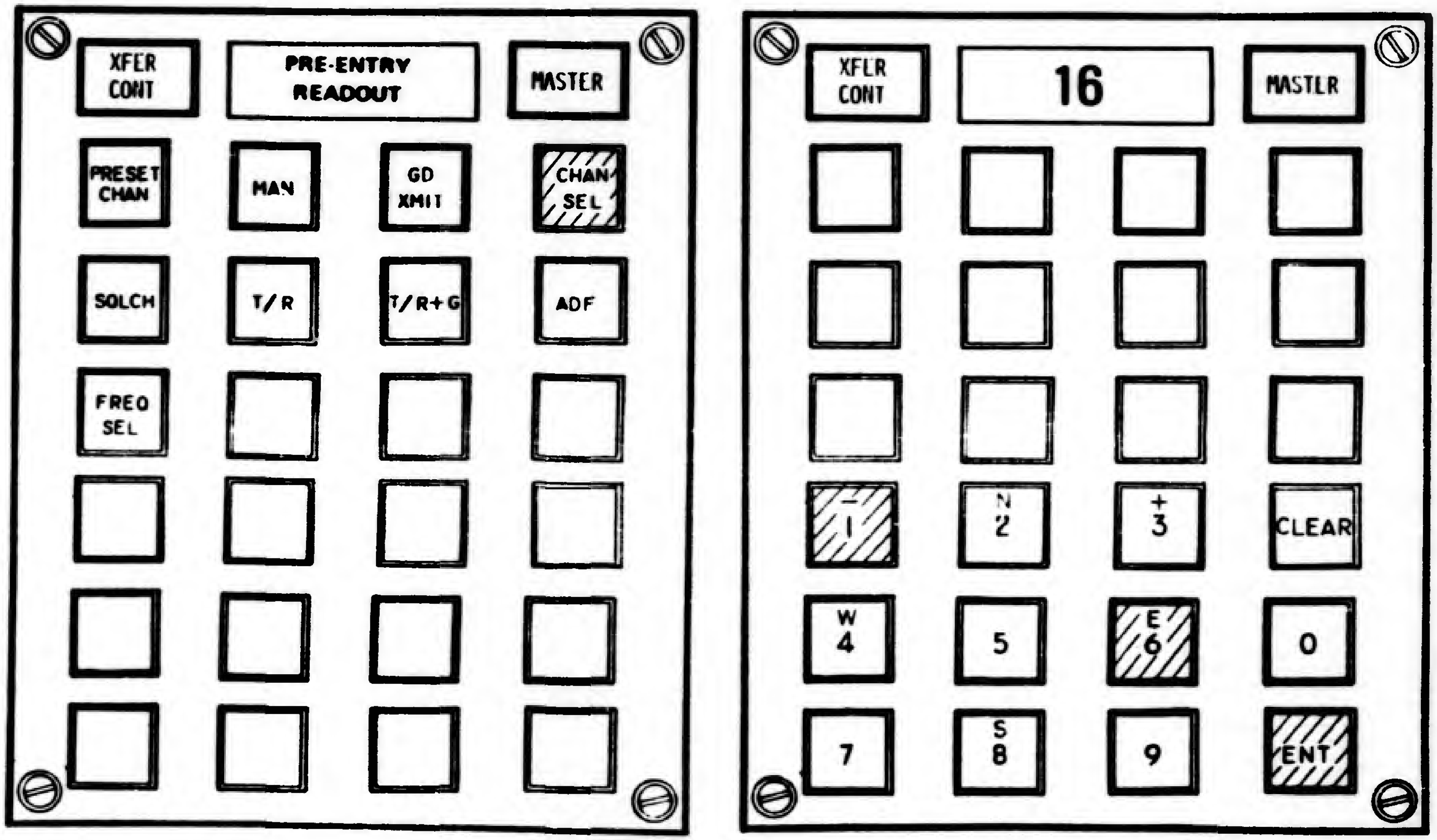


Figure 58. Chan Sel, 1, 6 and Enter Selected

numerical entry which appears in the pre-entry read out as it is selected and also appears on the COMM/UHF MPD format on entry. The display remains as is for three seconds for verification purposes and then returns to the basic format for that flight phase. At this point the multifunction control returns to the third or previous logical level ready for another entry. If this is not desired, the pilot can press MASTER which returns the control to the top logical level.

It should be noted the optional formats that can be selected using the controls at the bottom of each MPD are retained in order to achieve a degree of redundancy in the displays. It is expected that these would not be actuated in normal use.

III.8.2 Dedicated Controls Modifications

Numbering of the station select keys on the stores management panel was rearranged to allow easier selection of symmetrical stations. (Figure 59). A dedicated interrogation display was added to the IFF panel in addition to a dedicated IDENT control. (Figure 60). This change meets the requirement for easy access to this high frequency of use control.

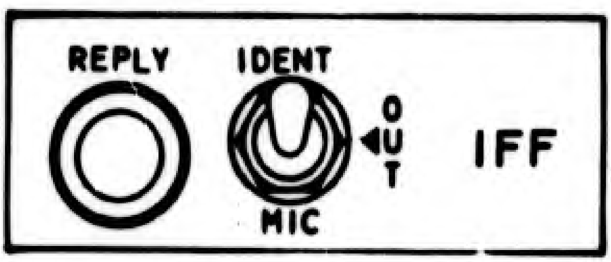


Figure 60. Modified IFF Panel

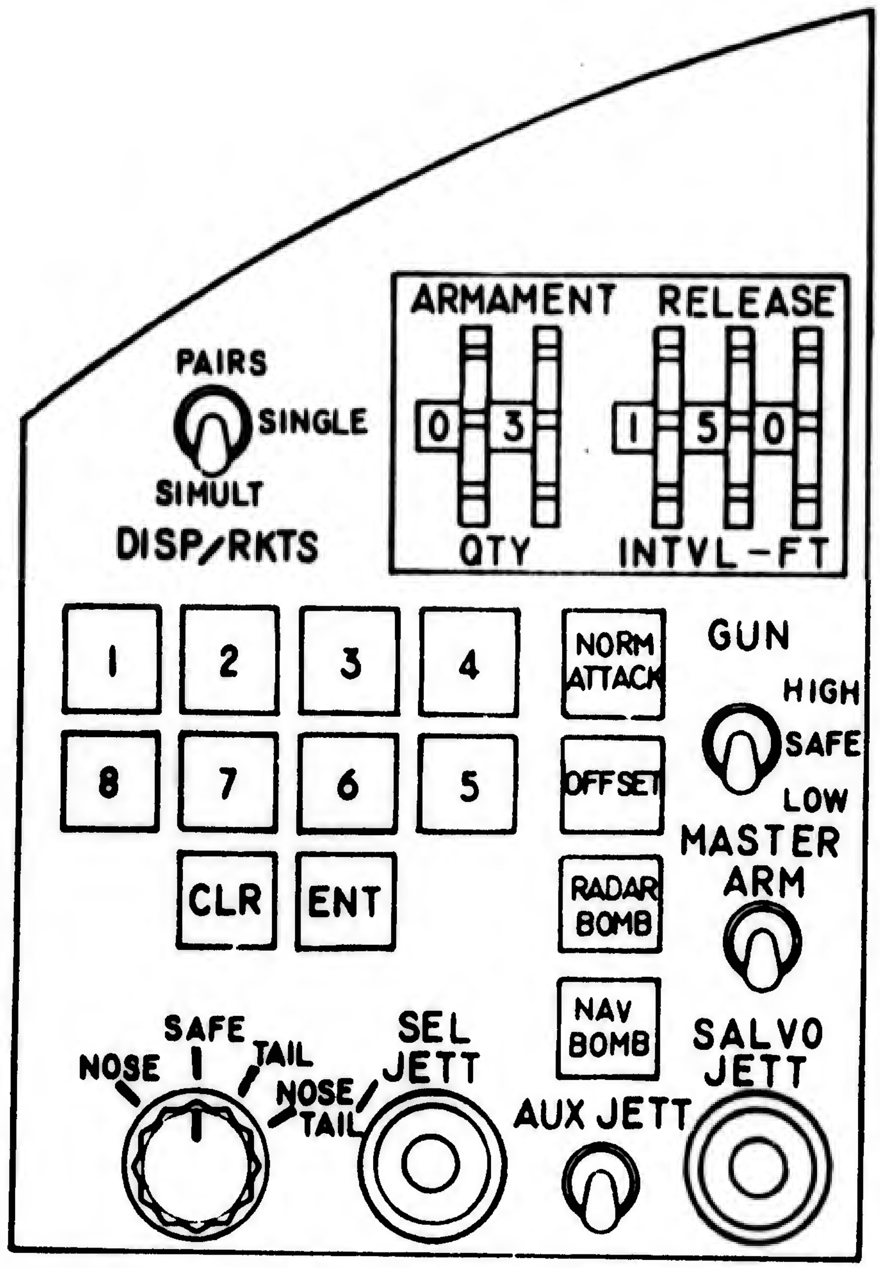


Figure 59. Modified Stores Management Panel

III.8.3 VSD, HSD Format Modifications

The symbology as presented to the pilots in the simulator did not receive good acceptance. Relative to the VSD presentation, complaints were voiced concerning the "coarseness" of the symbols (which was due to the limited resolution of the 525 line system) overall clutter of the presentation, the lack of trend information on the air data and heading presentations and lastly, the lack of flight path or velocity vector information. Considering these objections, it is suggested that a higher resolution system or a combination stroke/raster system be used for this display. A format that meets the objections mentioned above is presented in Figure 61. This display format and the recommended HSD formats to be discussed were developed in a DAIS related contract effort for the Avionics Laboratory.

Simulator evaluations of the HSD were limited to examining the concept of overlaying a map display on sensor imagery. Therefore, the presentation was obviously deficient in other areas. Two display formats that meet the requirements for an HSD presentation are given in Figures 62 and 63. Again, these displays are a result of the DAIS effort with certain threat warning symbols deleted from the moving map display.

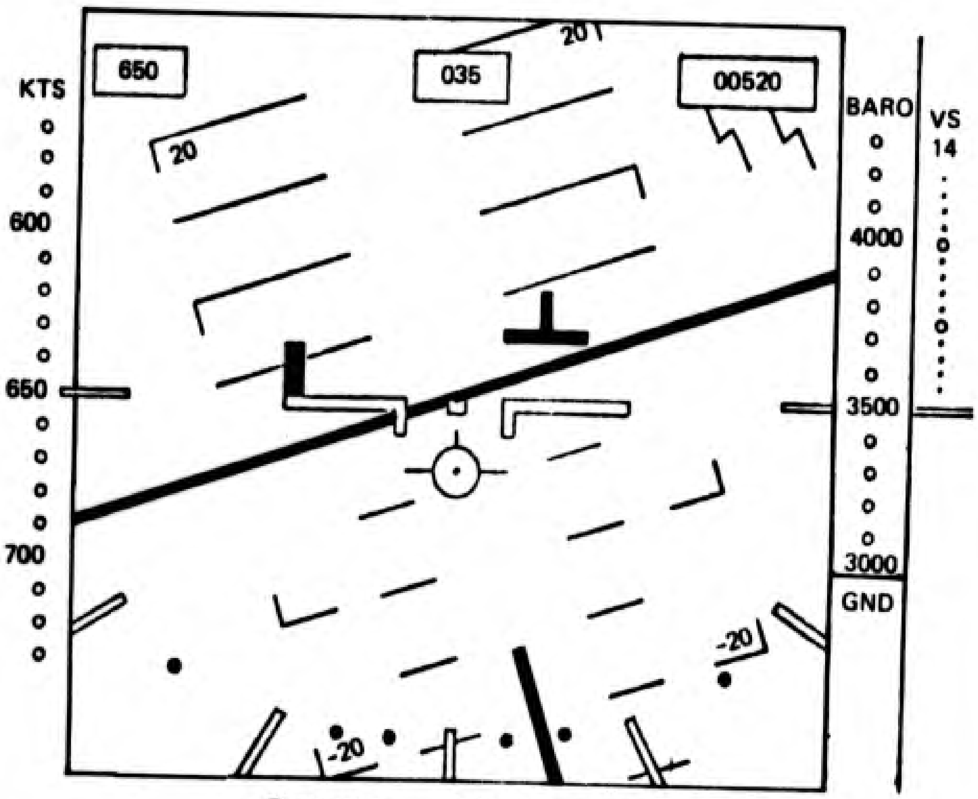


Figure 61. *VSD Symbology*

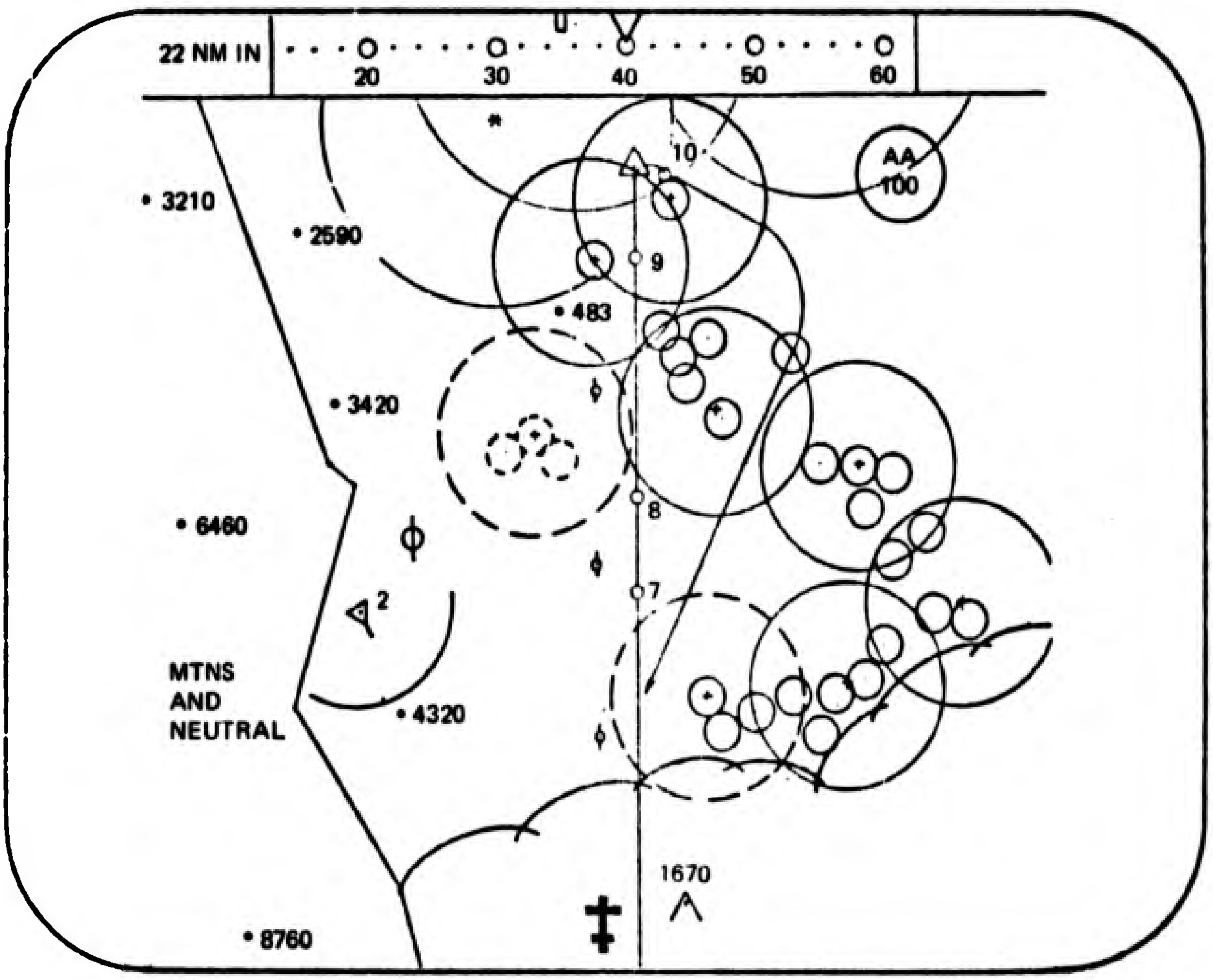


Figure 62. Moving Map Display

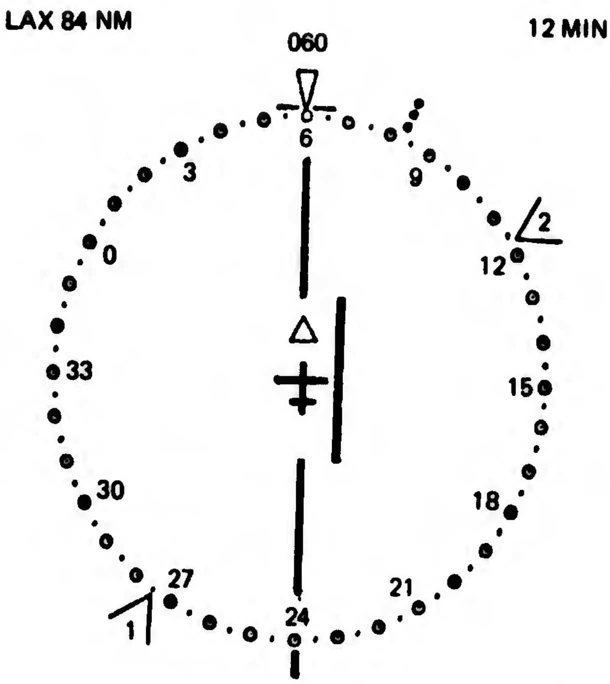


Figure 63. HSD (HSI Mode) Symbology

IV CONCLUSIONS AND RECOMMENDATIONS

Program objectives that were met during the contract period included the following:

1) An analysis of A-7D systems and advanced sensors and communications systems supplied by the Avionics Laboratory.
2) Integration of these systems into an advanced control/display concept utilizing multifunction controls and multipurpose electronic displays.
3) A flight simulator evaluation of certain elements of the advanced cockpit configuration.

It was concluded that the integrated digital systems approach to cockpit controls and displays could be applied effectively to a contemporary fighter and its associated systems. Additionally, and in detail, it was concluded that:

1) A fixed, cowl mounted head up display is superior in use to a helmet mounted sight display, however, further development may reduce this advantage and in some situations (Air-to-Air and Air-to-Ground target acquisition/designation) the helmet mounted display may be superior.
2) Overlaying computer generated map symbology on sensor imagery (IR or PPI radar) is an effective way of reducing the required amount of symbology presented on fewer displays.
3) Integration of many of the control functions into a multifunction control panel conveniently located in a more "forward" location is a significant improvement in the workability of the cockpit

Considering the above and the results of the flight simulator evaluations, it is recommended that:

1) Evaluations of more advanced helmet mounted sight display concepts be oriented around the basic objections raised during this study. A flight evaluation may indicate the usefulness of such a display is severely limited.

2) The overlay concept of map and sensor imagery be explored further considering digital map generation techniques and the possibility of multicolor displays.

3) The modular integrated control panel approach is basically sound, however, more investigative work needs to be done relative to the interaction of the controls and the displays to derive the benefits in terms of workload that exist now only potentially.

APPENDIX A

Logical Sequence Report

Major functional headings are located on the switch panel under logical level 1. These are:

4.0 COMM

5.0 NAV

6.0 SENSOR

8.0 AIRCRAFT

Actuation of any one of these controls places the panel at logical level 2 under that major functional area. Actuation of a control in this configuration places the panel at logical level 3 and presents options appropriate to that control. If actuation of a control at level 3 requires a data entry, the data entry keyboard appears at logical level 4 in the last three rows of the panel.

SWITCH PANEL CONFIGURATION

```
                                              LOGICAL LEVEL=      1
       COLUMN
             1            2            3            4
ROW  1------------1------------1------------1------------1
     1 4.0        1 5.0        1 6.0        1 8.0        1
     1 COMM       1 NAV        1 SENSOR     1 AIR-CRAFT  1
   1 1            1            1            1            1
     1------------1------------1------------1------------1
     1            1            1            1            1
     1            1            1            1            1
   2 1            1            1            1            1
     1------------1------------1------------1------------1
     1            1            1            1            1
     1            1            1            1            1
   3 1            1            1            1            1
     1------------1------------1------------1------------1
     1            1            1            1            1
     1            1            1            1            1
   4 1            1            1            1            1
     1------------1------------1------------1------------1
     1            1            1            1            1
     1            1            1            1            1
   5 1            1            1            1            1
     1------------1------------1------------1------------1
     1            1            1            1            1
     1            1            1            1            1
   6 1            1            1            1            1
     1------------1------------1------------1------------1
```

SWITCH PANEL CONFIGURATION

LOGICAL LEVEL=   2

```
        COLUMN
              1             2             3             4
ROW 1-------------1-------------1-------------1-------------1
    1 4.1         1 4.2         1 4.3         1 4.5         1
    1 UHF         1 VHF-FM      1 ADF         1 IFF         1
  1 1             1             1 AUX UHF     1             1
    1-------------1-------------1-------------1-------------1
    1 4.5         1 4.7         1 4.[illegible]         1 4.9         1
    1 IFF MODE    1 IFF MKII    1 VOCODE      1 HF          1
  2 1 SEL         1 CODE        1             1             1
    1-------------1-------------1-------------1-------------1
    1             1             1             1             1
    1             1             1             1             1
  3 1             1             1             1             1
    1-------------1-------------1-------------1-------------1
    1             1             1             1             1
    1             1             1             1             1
  4 1             1             1             1             1
    1-------------1-------------1-------------1-------------1
    1             1             1             1             1
    1             1             1             1             1
  5 1             1             1             1             1
    1-------------1-------------1-------------1-------------1
    1             1             1             1             1
    1             1             1             1             1
  6 1             1             1             1             1
    1-------------1-------------1-------------1-------------1
```

SWITCH PANEL CONFIGURATION

5.

LOGICAL LEVEL=   2

```
      COLUMN
           1             2             3             4
ROW 1-------------1-------------1-------------1-------------1
    1 5.1         1 5.2         1 5.3         1 5.4         1
    1 NAV         1 NAV AID     1 LORAN       1 DPLR        1
  1 1 WD          1 UPDATE      1             1             1
    1-------------1-------------1-------------1-------------1
    1 5.5         1 5.6         1 5.7         1             1
    1 IMS         1 TACAN       1 RADAR       1             1
  2 1             1             1 BCN         1             1
    1-------------1-------------1-------------1-------------1
    1             1             1             1             1
    1             1             1             1             1
  3 1             1             1             1             1
    1-------------1-------------1-------------1-------------1
    1             1             1             1             1
    1             1             1             1             1
  4 1             1             1             1             1
    1-------------1-------------1-------------1-------------1
    1             1             1             1             1
    1             1             1             1             1
  5 1             1             1             1             1
    1-------------1-------------1-------------1-------------1
    1             1             1             1             1
    1             1             1             1             1
  6 1             1             1             1             1
    1-------------1-------------1-------------1-------------1
```

SWITCH PANEL CONFIGURATION

5.

LOGICAL LEVEL= 2

```
CJLUMN
            1             2             3             4
ROW 1-------------1-------------1-------------1-------------1
    1 6.1         1 6.2         1 6.5         1 6.7         1
    1 RADAR       1 RADAR       1 RDR FLT     1 RHAW        1
  1 1 NAV         1 SENS/ANT    1 MODES       1             1
    1-------------1-------------1-------------1-------------1
    1 6.4         1 6.3         1 6.10        1 6.11        1
    1 ECM         1 LST         1 FLIR        1 L3TV        1
  2 1             1             1             1             1
    1-------------1-------------1-------------1-------------1
    1 6.12        1 6.13        1 6.14        1             1
    1 E-O STEER   1 E-O STEER   1 E-O         1             1
  3 1 (FLIR)      1 (L3TV)      1 VIDEO       1             1
    1-------------1-------------1-------------1-------------1
    1             1             1             1             1
    1             1             1             1             1
  4 1             1             1             1             1
    1-------------1-------------1-------------1-------------1
    1             1             1             1             1
    1             1             1             1             1
  5 1             1             1             1             1
    1-------------1-------------1-------------1-------------1
    1             1             1             1             1
    1             1             1             1             1
  6 1             1             1             1             1
    1-------------1-------------1-------------1-------------1
```

SWITCH PANEL CONFIGURATION

```
                                                        1.

                                                                      LOGICAL LEVEL=        2

     COLUMN
          1            2            3            4
ROW 1------------1------------1------------1------------1
    1 8.4        1 8.5        1 8.6        1 8.7        1
    1 ENVIRON    1 HYDRAULIC  1 FUEL       1 INTERNAL   1
  1 1 MENT       1            1            1 LIGHTING   1
    1------------1------------1------------1------------1
    1 8.8        1            1            1            1
    1 EXT LTS    1            1            1            1
  2 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  3 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  4 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  5 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  6 1            1            1            1            1
    1------------1------------1------------1------------1
```

SWITCH PANEL CONFIGURATION

-.1.

LOGICAL LEVEL= 3

ROW \ COLUMN	1	2	3	4
1	4.1.1 PRESET CHAN	4.1.2 MAN	4.1.3 GD XMIT	4.1.4 CHAN SEL
2	4.1.5 SQLCH	4.1.7 T/R	4.1.[illegible] T/R+G	4.1.3 ADF
3	4.1.10 FREQ SEL			
4				
5				
6				

```
                                          SWITCH PANEL CONFIGURATION

                                          4.2.

                                                          LOGICAL LEVEL=        3

          COLUMN
                   1            2            3            4
     ROW 1------------1------------1------------1------------1
         1 4.2.2      1 4.2.3      1 4.2.4      1 4.2.5      1
         1 FREQ       1 T/R        1 RETRAN     1 HOME       1
       1 1 SEL        1            1            1            1
         1------------1------------1------------1------------1
         1 4.2.7      1 4.2.[illegible]  1 4.2.[illegible]  1            1
         1 SQLCH      1 CARR       1 TONE       1            1
       2 1            1            1            1            1
         1------------1------------1------------1------------1
         1            1            1            1            1
         1            1            1            1            1
       3 1            1            1            1            1
         1------------1------------1------------1------------1
         1            1            1            1            1
         1            1            1            1            1
       4 1            1            1            1            1
         1------------1------------1------------1------------1
         1            1            1            1            1
         1            1            1            1            1
       5 1            1            1            1            1
         1------------1------------1------------1------------1
         1            1            1            1            1
         1            1            1            1            1
       6 1            1            1            1            1
         1------------1------------1------------1------------1
```

```
                                   SWITCH PANEL CONFIGURATION

                                   4.
                                   4.3.

                                               LOGICAL LEVEL=         3

            COLUMN
                  1            2            3            4
        ROW 1------------1------------1------------1------------1
            1 4.3.1      1 4.3.2      1 4.3.3      1 4.3.4      1
            1 ADF        1 CMD        1 GRD        1 CHAN       1
          1 1            1            1            1 SEL        1
            1------------1------------1------------1------------1
            1 4.3.7      1 4.3.6      1            1            1
            1 GUARD      1 NORM       1            1            1
          2 1            1            1            1            1
            1------------1------------1------------1------------1
            1            1            1            1            1
            1            1            1            1            1
          3 1            1            1            1            1
            1------------1------------1------------1------------1
            1            1            1            1            1
            1            1            1            1            1
          4 1            1            1            1            1
            1------------1------------1------------1------------1
            1            1            1            1            1
            1            1            1            1            1
          5 1            1            1            1            1
            1------------1------------1------------1------------1
            1            1            1            1            1
            1            1            1            1            1
          6 1            1            1            1            1
            1------------1------------1------------1------------1
```

```
                                 SWITCH PANEL CONFIGURATION

                                 4.
                                 4.5.

                                              LOGICAL LEVEL=        3

     COLUMN
          1            2            3            4
ROW 1------------1------------1------------1------------1
    1 4.5.1      1 4.5.2      1 4.5.3      1 4.5.4      1
    1 MASTER     1 STBY       1 LOW        1 NORM       1
  1 1            1            1            1            1
    1------------1------------1------------1------------1
    1 4.5.5      1 4.5.6      1 4.5.7      1            1
    1 EMERG      1 RAD/       1 MON        1            1
  2 1            1 TEST       1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  3 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  4 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  5 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  6 1            1            1            1            1
    1------------1------------1------------1------------1
```

SWITCH PANEL CONFIGURATION

4.

4.6.

LOGICAL LEVEL= 3

ROW \ COLUMN	1	2	3	4
1	4.6.1 MODE 1	4.6.2 MODE 1 TEST	4.6.3 MODE 2	4.6.4 MODE 2 TEST
2	4.6.5 MODE 3A	4.5.6 MODE 3A TEST	4.6.7 MODE C	4.6.8 MODE C TEST
3	4.6.9 MODE 4	4.6.10 MODE 4 TEST	4.6.13 AUDIO	4.6.14 LIGHT
4				
5				
6				

```
                                         SWITCH PANEL CONFIGURATION

                                         4.7.

                                                        LOGICAL LEVEL=        3

          COLUMN
                    1             2             3             4
      ROW 1-------------1-------------1-------------1-------------1
          1 4.7.1       1 4.7.2       1 4.7.3       1 4.7.4       1
          1 ZERO        1 B           1 A           1 HOLD        1
        1 1             1             1             1             1
          1-------------1-------------1-------------1-------------1
          1             1             1             1             1
          1             1             1             1             1
        2 1             1             1             1             1
          1-------------1-------------1-------------1-------------1
          1             1             1             1             1
          1             1             1             1             1
        3 1             1             1             1             1
          1-------------1-------------1-------------1-------------1
          1             1             1             1             1
          1             1             1             1             1
        4 1             1             1             1             1
          1-------------1-------------1-------------1-------------1
          1             1             1             1             1
          1             1             1             1             1
        5 1             1             1             1             1
          1-------------1-------------1-------------1-------------1
          1             1             1             1             1
          1             1             1             1             1
        6 1             1             1             1             1
          1-------------1-------------1-------------1-------------1
```

```
                         SWITCH PANEL CONFIGURATION

                           4.
                           4.5.
                                    LOGICAL LEVEL=      3

     COLUMN
            1            2            3            4
ROW 1------------1------------1------------1------------1
    1 4.5.1      1            1            1            1
    1 CLASS      1            1            1            1
  1 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  2 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  3 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  4 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  5 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  6 1            1            1            1            1
    1------------1------------1------------1------------1
```

SWITCH PANEL CONFIGURATION

```
                                        4.
                                        4.9.
                                                           LOGICAL LEVEL=       3
          COLUMN
                  1                2                3                4
     ROW 1---------------1----------------1----------------1----------------1
         1               1 4.3.1          1 4.3.2          1 4.9.4          1
         1               1 SS3            1 AME            1 FREQ SEL       1
       1 1               1                1                1                1
         1---------------1----------------1----------------1----------------1
         1               1                1                1                1
         1               1                1                1                1
       2 1               1                1                1                1
         1---------------1----------------1----------------1----------------1
         1               1                1                1                1
         1               1                1                1                1
       3 1               1                1                1                1
         1---------------1----------------1----------------1----------------1
         1               1                1                1                1
         1               1                1                1                1
       4 1               1                1                1                1
         1---------------1----------------1----------------1----------------1
         1               1                1                1                1
         1               1                1                1                1
       5 1               1                1                1                1
         1---------------1----------------1----------------1----------------1
         1               1                1                1                1
         1               1                1                1                1
       6 1               1                1                1                1
         1---------------1----------------1----------------1----------------1
```

SWITCH PANEL CONFIGURATION

5.
5.1.

LOGICAL LEVEL=   3

```
          COLUMN
               1              2              3              4
ROW   1--------------1--------------1--------------1--------------1
      1              1              1              1              1
      1              1              1              1              1
  1   1              1              1              1              1
      1--------------1--------------1--------------1--------------1
      1 5.1.1        1 5.1.2        1 5.1.3        1 5.1.4        1
      1 PRES         1 DEST         1 MARK         1 RNG/         1
  2   1 POS          1              1              1 BRG          1
      1--------------1--------------1--------------1--------------1
      1 5.1.5        1 5.1.6        1 5.1.7        1 5.1.8        1
      1 DELPNT       1 ALT          1 FLY TO       1 FLY TO       1
  3   1              1 MSL          1 UPDATE       1 DEST         1
      1--------------1--------------1--------------1--------------1
      1 5.1.9        1 5.1.10       1 5.1.11       1 5.1.12       1
      1 FLY TO       1 FLY TO       1 FLY OVR UP   1 PRS POS      1
  4   1 MARK         1 SELECT       1 DATE         1 LAT/LONG     1
      1--------------1--------------1--------------1--------------1
      1 5.1.13       1 5.1.14       1              1              1
      1 PRS POS      1 PRS POS      1              1              1
  5   1 UPDATE       1 WIND         1              1              1
      1--------------1--------------1--------------1--------------1
      1              1              1              1              1
      1              1              1              1              1
  6   1              1              1              1              1
      1--------------1--------------1--------------1--------------1
```

SWITCH PANEL CONFIGURATION

5.
5.2.

LOGICAL LEVEL= 3

```
      COLUMN
            1             2             3             4
ROW 1-------------1-------------1-------------1-------------1
    1             1             1             1             1
    1             1             1             1             1
  1 1             1             1             1             1
    1-------------1-------------1-------------1-------------1
    1 5.2.1       1 5.2.2       1 5.2.3       1 5.2.4       1
    1 HUD         1 RADAR       1 FLYOVER     1 LORAN       1
  2 1             1             1             1             1
    1-------------1-------------1-------------1-------------1
    1 5.2.5       1 5.2.6       1 5.2.7       1 5.2.8       1
    1 TAC LL      1 TAC MV      1 IMS HUD     1 SINS        1
  3 1             1             1             1 X-Y         1
    1-------------1-------------1-------------1-------------1
    1 5.2.9       1 5.2.10      1             1             1
    1 Z-DELTA     1 DATA        1             1             1
  4 1 HDG         1             1             1             1
    1-------------1-------------1-------------1-------------1
    1             1             1             1             1
    1             1             1             1             1
  5 1             1             1             1             1
    1-------------1-------------1-------------1-------------1
    1             1             1             1             1
    1             1             1             1             1
  6 1             1             1             1             1
    1-------------1-------------1-------------1-------------1
```

SWITCH PANEL CONFIGURATION

5.

5.3.

LOGICAL LEVEL= 3

COLUMN

ROW	1	2	3	4
1				
2	5.3.1 POWER	5.3.2 TEST	5.3.3 DATA PC	5.3.4 DATA LL
3	5.3.5 DATA I/S	5.3.6 DATA CD	5.3.7 STATION 1	5.3.8 STATION W
4	5.3.9 STATION X	5.3.10 STATION Y	5.3.11 STATION Z	5.3.12 CHAIN 1
5	5.3.13 CHAIN 2	5.3.14 CHAIN 3	5.3.15 TRIAD WX	5.3.16 TRIAD WY
6	5.3.17 TRIAD WZ	5.3.18 TRIAD XY	5.3.19 TRIAD XZ	5.3.20 TRIAD YZ

SWITCH PANEL CONFIGURATION

5.
5.4.

LOGICAL LEVEL= 3

ROW \ COLUMN	1	2	3	4
1				
2		5.4.1 POWER	5.4.2 STBY	5.4.3 DRIFT LEFT
3	5.4.4 DRIFT RIGHT	5.4.5 EST G/S		
4				
5				
6				

SWITCH PANEL CONFIGURATION

5.
5.5.

LOGICAL LEVEL= 3

```
     COLUMN
           1            2            3            4
ROW 1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  1 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1 5.5.1      1 5.5.2      1
    1            1            1 POWER      1 END        1
  2 1            1            1            1 ALIGN      1
    1------------1------------1------------1------------1
    1 5.5.3      1 5.5.4      1 5.5.5      1 5.5.6      1
    1 NORM       1 INERTL     1 MAG        1 GRID       1
  3 1            1            1 SE         1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  4 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  5 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  6 1            1            1            1            1
    1------------1------------1------------1------------1
```

```
                         SWITCH PANEL CONFIGURATION

                         5.
                         5.6.

                                    LOGICAL LEVEL=        3

       COLUMN
            1          2          3          4
  ROW  1----------1----------1----------1----------1
       1          1          1          1          1
       1          1          1          1          1
    1  1          1          1          1          1
       1----------1----------1----------1----------1
       1          1          1          1 5.6.1     1
       1          1          1          1 FREQ      1
    2  1          1          1          1 SEL       1
       1----------1----------1----------1----------1
       1 5.6.2    1 5.6.3    1 5.6.4    1          1
       1 REC      1 TR       1 A/A      1          1
    3  1          1          1          1          1
       1----------1----------1----------1----------1
       1          1          1          1          1
       1          1          1          1          1
    4  1          1          1          1          1
       1----------1----------1----------1----------1
       1          1          1          1          1
       1          1          1          1          1
    5  1          1          1          1          1
       1----------1----------1----------1----------1
       1          1          1          1          1
       1          1          1          1          1
    6  1          1          1          1          1
       1----------1----------1----------1----------1
```

SWITCH PANEL CONFIGURATION

5.
5.7.

LOGICAL LEVEL=   3

```
     COLUMN
          1            2            3            4
ROW 1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  1 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1 5.7.1      1
    1            1            1            1 POWER      1
  2 1            1            1            1            1
    1------------1------------1------------1------------1
    1 5.7.2      1 5.7.3      1 5.7.4      1            1
    1 STBY       1 SINGLE     1 DOUBLE     1            1
  3 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  4 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  5 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  6 1            1            1            1            1
    1------------1------------1------------1------------1
```

SWITCH PANEL CONFIGURATION

6.
6.1.

LOGICAL LEVEL= 3

```
         COLUMN
               1            2            3            4
   ROW 1------------1------------1------------1------------1
       1            1            1            1            1
       1            1            1            1            1
     1 1            1            1            1            1
       1------------1------------1------------1------------1
       1            1            1            1 6.1.1      1
       1            1            1            1 POWER      1
     2 1            1            1            1            1
       1------------1------------1------------1------------1
       1 6.1.2      1 6.1.3      1 6.1.4      1 6.1.5      1
       1 STBY       1 BCN        1 T/A        1 GMP        1
     3 1            1            1            1            1
       1------------1------------1------------1------------1
       1 6.1.6      1 6.1.7      1            1            1
       1 GMS        1 AGR        1            1            1
     4 1            1            1            1            1
       1------------1------------1------------1------------1
       1            1            1            1            1
       1            1            1            1            1
     5 1            1            1            1            1
       1------------1------------1------------1------------1
       1            1            1            1            1
       1            1            1            1            1
     6 1            1            1            1            1
       1------------1------------1------------1------------1
```

SWITCH PANEL CONFIGURATION

6.
6.2.

LOGICAL LEVEL=   3

```
        COLUMN
             1              2              3              4
ROW  1-------------1-------------1-------------1-------------1
     1             1             1             1             1
     1             1             1             1             1
  1  1             1             1             1             1
     1-------------1-------------1-------------1-------------1
     1             1             1             1             1
     1             1             1             1             1
  2  1             1             1             1             1
     1-------------1-------------1-------------1-------------1
     1 6.2.1       1 6.2.2       1 6.2.3       1 6.2.5       1
     1 FREQ        1 LINEAR      1 CIRC        1 RANGE       1
  3  1 SEL         1 POLAR       1 POLAR       1 SEL         1
     1-------------1-------------1-------------1-------------1
     1 6.2.6       1             1             1             1
     1 PATH        1             1             1             1
  4  1 ALTITUDE    1             1             1             1
     1-------------1-------------1-------------1-------------1
     1             1             1             1             1
     1             1             1             1             1
  5  1             1             1             1             1
     1-------------1-------------1-------------1-------------1
     1             1             1             1             1
     1             1             1             1             1
  6  1             1             1             1             1
     1-------------1-------------1-------------1-------------1
```

SWITCH PANEL CONFIGURATION

5.
5.5.

LOGICAL LEVEL=   3

```
          COLUMN
                   1            2            3            4
    ROW  1------------1------------1------------1------------1
         1            1            1            1            1
         1            1            1            1            1
      1  1            1            1            1            1
         1------------1------------1------------1------------1
         1            1            1            1            1
         1            1            1            1            1
      2  1            1            1            1            1
         1------------1------------1------------1------------1
         1            1 6.5.1      1 6.5.2      1            1
         1            1 TF         1 LOG        1            1
      3  1            1            1            1            1
         1------------1------------1------------1------------1
         1            1            1            1            1
         1            1            1            1            1
      4  1            1            1            1            1
         1------------1------------1------------1------------1
         1            1            1            1            1
         1            1            1            1            1
      5  1            1            1            1            1
         1------------1------------1------------1------------1
         1            1            1            1            1
         1            1            1            1            1
      6  1            1            1            1            1
         1------------1------------1------------1------------1
```

```
                                    SWITCH PANEL CONFIGURATION

                                    6.
                                    6.7.

                                          LOGICAL LEVEL=        3

     COLUMN
            1            2            3            4
ROW 1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  1 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  2 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1 6.7.1      1            1
    1            1            1 CLASS      1            1
  3 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  4 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  5 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  6 1            1            1            1            1
    1------------1------------1------------1------------1
```

SWITCH PANEL CONFIGURATION

5.
5.5.

LOGICAL LEVEL= 3

```
        COLUMN
              1         2         3         4
ROW  1---------1---------1---------1---------1
     1         1         1         1         1
     1         1         1         1         1
  1  1         1         1         1         1
     1---------1---------1---------1---------1
     1         1         1         1         1
     1         1         1         1         1
  2  1         1         1         1         1
     1---------1---------1---------1---------1
     1         1         1         1 6.8.1   1
     1         1         1         1 CLASS   1
  3  1         1         1         1         1
     1---------1---------1---------1---------1
     1         1         1         1         1
     1         1         1         1         1
  4  1         1         1         1         1
     1---------1---------1---------1---------1
     1         1         1         1         1
     1         1         1         1         1
  5  1         1         1         1         1
     1---------1---------1---------1---------1
     1         1         1         1         1
     1         1         1         1         1
  6  1         1         1         1         1
     1---------1---------1---------1---------1
```

SWITCH PANEL CONFIGURATION

6.
6.9.

LOGICAL LEVEL= 3

ROW \ COLUMN	1	2	3	4
1				
2				
3				6.9.1 POWER
4	6.9.2 STBY	6.9.3 VIS ATTK	6.9.4 VIS ATTK OFFSET	6.9.5 OFFSET
5	6.9.6 RDP BOMB	6.9.7 RDR BOMB OFFSET	6.9.- NAV BOMB	6.9.9 GUN
6	6.9.10 ROCKET			

SWITCH PANEL CONFIGURATION

```
                                  5.
                                  5.10.
                                                     LOGICAL LEVEL=        3

        COLUMN
              1            2            3            4
ROW  1------------1------------1------------1------------1
     1            1            1            1            1
     1            1            1            1            1
   1 1            1            1            1            1
     1------------1------------1------------1------------1
     1            1            1            1            1
     1            1            1            1            1
   2 1            1            1            1            1
     1------------1------------1------------1------------1
     1            1            1            1 6.10.1     1
     1            1            1            1 POWER      1
   3 1            1            1            1            1
     1------------1------------1------------1------------1
     1 6.10.2     1 6.10.3     1 6.10.4     1 6.10.5     1
     1 STBY       1 TEST       1 VIDEO      1 VIDEO      1
   4 1            1            1 NORM       1 REV        1
     1------------1------------1------------1------------1
     1 5.10.6     1            1            1            1
     1 LAMP       1            1            1            1
   5 1 TEST       1            1            1            1
     1------------1------------1------------1------------1
     1            1            1            1            1
     1            1            1            1            1
   6 1            1            1            1            1
     1------------1------------1------------1------------1
```

SWITCH PANEL CONFIGURATION

6.

6.11.

LOGICAL LEVEL= 3

```
      COLUMN
               1            2            3            4
 ROW  1------------1------------1------------1------------1
      1            1            1            1            1
      1            1            1            1            1
    1 1            1            1            1            1
      1------------1------------1------------1------------1
      1            1            1            1            1
    2 1            1            1            1            1
      1------------1------------1------------1------------1
      1            1            1            1 6.11.2     1
      1            1            1            1 AUTO LT    1
    3 1            1            1            1 CONT FULL  1
      1------------1------------1------------1------------1
      1 6.11.3     1 6.11.3     1 6.11.5     1 6.11.7     1
      1 AUTO LT    1 CONTS      1 POWER      1 STBY       1
    4 1 CONT 1/4   1 LOCK ON    1            1            1
      1------------1------------1------------1------------1
      1 6.11.8     1 6.11.4     1 6.11.13    1            1
      1 HI    SENS 1 HI    RES  1 LAMP       1            1
    5 1            1            1 TEST       1            1
      1------------1------------1------------1------------1
      1            1            1            1            1
      1            1            1            1            1
    6 1            1            1            1            1
      1------------1------------1------------1------------1
```

SWITCH PANEL CONFIGURATION

6.
6.12.

LOGICAL LEVEL=   3

```
      COLUMN
            1            2            3            4
ROW 1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  1 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  2 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1 6.12.1     1
    1            1            1            1 BNS        1
  3 1            1            1            1            1
    1------------1------------1------------1------------1
    1 6.12.2     1 6.12.3     1 6.12.4     1 6.12.5     1
    1 MAN        1 STOW       1 WFOV       1 NFOV       1
  4 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  5 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  6 1            1            1            1            1
    1------------1------------1------------1------------1
```

```
                         SWITCH PANEL CONFIGURATION

                         6.
                         6.13.

                                    LOGICAL LEVEL=        3

        COLUMN
              1          2          3          4
   ROW 1----------1----------1----------1----------1
       1          1          1          1          1
       1          1          1          1          1
     1 1          1          1          1          1
       1----------1----------1----------1----------1
       1          1          1          1          1
       1          1          1          1          1
     2 1          1          1          1          1
       1----------1----------1----------1----------1
       1          1          1          1          1
       1          1          1          1          1
     3 1          1          1          1          1
       1----------1----------1----------1----------1
       1 6.13.1   1 6.13.2   1 6.13.3   1 6.13.4   1
       1 BNS      1 MAN      1 STOW     1 WFLV     1
     4 1          1          1          1          1
       1----------1----------1----------1----------1
       1 6.13.5   1          1          1          1
       1 NFDV     1          1          1          1
     5 1          1          1          1          1
       1----------1----------1----------1----------1
       1          1          1          1          1
       1          1          1          1          1
     6 1          1          1          1          1
       1----------1----------1----------1----------1
```

SWITCH PANEL CONFIGURATION

6.
6.14.

LOGICAL LEVEL=   3

```
       COLUMN
            1            2            3            4
ROW  1------------1------------1------------1------------1
     1            1            1            1            1
     1            1            1            1            1
  1  1            1            1            1            1
     1------------1------------1------------1------------1
     1            1            1            1            1
     1            1            1            1            1
  2  1            1            1            1            1
     1------------1------------1------------1------------1
     1            1            1            1            1
     1            1            1            1            1
  3  1            1            1            1            1
     1------------1------------1------------1------------1
     1 6.14.1     1 5.14.2     1 6.14.3     1 6.14.4     1
     1 E-D        1 HUD        1 VSD        1 HSD        1
  4  1 SYMB       1            1            1            1
     1------------1------------1------------1------------1
     1            1            1            1            1
     1            1            1            1            1
  5  1            1            1            1            1
     1------------1------------1------------1------------1
     1            1            1            1            1
     1            1            1            1            1
  6  1            1            1            1            1
     1------------1------------1------------1------------1
```

SWITCH PANEL CONFIGURATION

8.
8.4.

LOGICAL LEVEL= 3

```
     COLUMN
            1            2            3            4
ROW 1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  1 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  2 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  3 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1 8.4.1      1 8.4.2      1 8.4.5      1
    1            1 AUTO TEMP  1 MAN TEMP   1 RAIN       1
  4 1            1            1            1 REMOVE     1
    1------------1------------1------------1------------1
    1 8.4.6      1 8.4.7      1 8.4.3      1            1
    1 DEFOG      1 RAIN       1 PITOT      1            1
  5 1            1 REPEL      1 HEAT       1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  6 1            1            1            1            1
    1------------1------------1------------1------------1
```

SWITCH PANEL CONFIGURATION

3.
3.6.

LOGICAL LEVEL= 3

```
     COLUMN
          1            2            3            4
ROW 1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  1 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  2 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1            1            1
    1            1            1            1            1
  3 1            1            1            1            1
    1------------1------------1------------1------------1
    1            1            1 3.6.6      1 3.6.7      1
    1            1            1 WING FUEL  1 WING FUEL  1
  4 1            1            1 MON 1      1 MON 2      1
    1------------1------------1------------1------------1
    1 3.6.8      1 3.6.9      1 3.6.10     1 3.6.15     1
    1 WING FUEL  1 EXT L.     1 EXT R.     1 REFUEL     1
  5 1 MON 3      1 FUEL MON   1 FUEL MON   1 DOORS      1
    1------------1------------1------------1------------1
    1 3.6.16     1            1            1            1
    1 REFUEL     1            1            1            1
  6 1 AMP        1            1            1            1
    1------------1------------1------------1------------1
```

SWITCH PANEL CONFIGURATION

```
                                       8.
                                       8.8.
                                                   LOGICAL LEVEL=        3

         COLUMN
               1            2            3            4
   ROW 1------------1------------1------------1------------1
       1            1            1            1            1
       1            1            1            1            1
     1 1            1            1            1            1
       1------------1------------1------------1------------1
       1            1            1            1            1
       1            1            1            1            1
     2 1            1            1            1            1
       1------------1------------1------------1------------1
       1            1            1            1            1
       1            1            1            1            1
     3 1            1            1            1            1
       1------------1------------1------------1------------1
       1            1            1 8.8.1      1 8.8.2      1
       1            1            1 WING       1 TAIL       1
     4 1            1            1 POS        1 POS        1
       1------------1------------1------------1------------1
       1 8.8.3      1 8.8.4      1 8.8.5      1 8.8.6      1
       1 FMATN      1 UPPER      1 LOWER      1 FLASH      1
     5 1            1 ANTI-COLL  1 ANTI-CO..  1 POS        1
       1------------1------------1------------1------------1
       1 8.8.7      1            1            1            1
       1 EXT        1            1            1            1
     6 1 DIM        1            1            1            1
       1------------1------------1------------1------------1
```

APPENDIX B

Pilot Test Condition Run Sequences

NAME ____________________ DATE ________

MINIMISSIONS		AIR-TO-GROUND				LANDING				AIR-TO-AIR	
HUD CONFIGURATION		FIXED HUD		HELMET HUD		FIXED HUD		HELMET HUD		FIXED HUD	HELMET HUD
SENSOR & TIME CONDITIONS		SENSOR OVERLAY	SENSOR DED.	SENSOR OVERLAY	SENSOR DED.	NIGHT	DAY	NIGHT	DAY	DAY	DAY
FAILURE MODE	N	4	3	2	8	19	15	20	17	9	10
	F	7	6	1	5	16	13	14	18	11	12

N = NORMAL CONDITION

F = FAILURE CONDITION

Pilot No. 1 *Test Condition Run Sequence*

NAME ____________________   DATE __________

MINIMISSIONS		AIR-TO-GROUND				LANDING				AIR-TO-AIR	
HUD CONFIGURATION		FIXED HUD		HELMET HUD		FIXED HUD		HELMET HUD		FIXED HUD	HELMET HUD
SENSOR & TIME CONDITIONS		SENSOR OVERLAY	SENSOR DED.	SENSOR OVERLAY	SENSOR DED.	NIGHT	DAY	NIGHT	DAY	DAY	DAY
FAILURE MODE	N	20	18	15	13	4	5	3	7	9	12
	F	16	19	17	14	6	8	2	1	10	11

N = NORMAL CONDITION

F = FAILURE CONDITION

Pilot No. 2 *Test Condition Run Sequence*

NAME ______________________ DATE __________

MINIMISSIONS		AIR-TO-GROUND				LANDING				AIR-TO-AIR	
HUD CONFIGURATION		FIXED HUD		HELMET HUD		FIXED HUD		HELMET HUD		FIXED HUD	HELMET HUD
SENSOR & TIME CONDITIONS		SENSOR OVERLAY	SENSOR DED.	SENSOR OVERLAY	SENSOR DED.	NIGHT	DAY	NIGHT	DAY	DAY	DAY
FAILURE MODE	N	6	5	3	1	9	11	12	14	18	20
	F	2	4	8	7	16	13	10	15	19	17

N = NORMAL CONDITION

F = FAILURE CONDITION

Pilot No. 3 *Test Condition Run Sequence*

NAME ______________________ DATE __________

MINIMISSIONS		AIR-TO-GROUND				LANDING				AIR-TO-AIR	
HUD CONFIGURATION		FIXED HUD		HELMET HUD		FIXED HUD		HELMET HUD		FIXED HUD	HELMET HUD
SENSOR & TIME CONDITIONS		SENSOR OVERLAY	SENSOR DED.	SENSOR OVERLAY	SENSOR DED.	NIGHT	DAY	NIGHT	DAY	DAY	DAY
FAILURE MODE	N	6	10	9	11	13	17	18	20	2	3
	F	12	8	5	7	19	14	16	15	4	1

N = NORMAL CONDITION

F = FAILURE CONDITION

Pilot No. 4 *Test Condition Run Sequence*

NAME ______________________ DATE __________

MINIMISSIONS		AIR-TO-GROUND				LANDING				AIR-TO-AIR	
HUD CONFIGURATION		FIXED HUD		HELMET HUD		FIXED HUD		HELMET HUD		FIXED HUD	HELMET HUD
SENSOR & TIME CONDITIONS		SENSOR OVERLAY	SENSOR DED.	SENSOR OVERLAY	SENSOR DED.	NIGHT	DAY	NIGHT	DAY	DAY	DAY
FAILURE MODE	N	13	14	16	9	1	6	8	7	18	19
	F	10	15	12	11	5	3	4	2	20	17

N = NORMAL CONDITION

F = FAILURE CONDITION

Pilot No. 5 *Test Condition Run Sequence*

NAME ____________________ DATE __________

MINIMISSIONS		AIR-TO-GROUND				LANDING				AIR-TO-AIR	
HUD CONFIGURATION		FIXED HUD		HELMET HUD		FIXED HUD		HELMET HUD		FIXED HUD	HELMET HUD
SENSOR & TIME CONDITIONS		SENSOR OVERLAY	SENSOR DED.	SENSOR OVERLAY	SENSOR DED.	NIGHT	DAY	NIGHT	DAY	DAY	DAY
FAILURE MODE	N	14	17	13	16	11	5	9	10	1	2
	F	18	20	19	15	7	12	6	8	4	3

N = NORMAL CONDITION

F = FAILURE CONDITION

Pilot No. 6 *Test Condition Run Sequence*

NAME ______________________ DATE __________

MINIMISSIONS		AIR-TO-GROUND				LANDING				AIR-TO-AIR	
HUD CONFIGURATION		FIXED HUD		HELMET HUD		FIXED HUD		HELMET HUD		FIXED HUD	HELMET HUD
SENSOR & TIME CONDITIONS		SENSOR OVERLAY	SENSOR DED.	SENSOR OVERLAY	SENSOR DED.	NIGHT	DAY	NIGHT	DAY	DAY	DAY
FAILURE MODE	N	6	5	7	8	13	19	17	14	2	3
	F	12	10	9	11	18	16	20	15	4	1

N = NORMAL CONDITION

F = FAILURE CONDITION

Pilot No. 7 Test Condition Run Sequence

NAME ____________________ DATE __________

MINIMISSIONS		AIR-TO-GROUND				LANDING				AIR-TO-AIR	
HUD CONFIGURATION		FIXED HUD		HELMET HUD		FIXED HUD		HELMET HUD		FIXED HUD	HELMET HUD
SENSOR & TIME CONDITIONS		SENSOR OVERLAY	SENSOR DED.	SENSOR OVERLAY	SENSOR DED.	NIGHT	DAY	NIGHT	DAY	DAY	DAY
FAILURE MODE	N	13	19	18	17	8	4	5	3	12	9
	F	20	15	16	14	2	1	6	7	11	10

N = NORMAL CONDITION

F = FAILURE CONDITION

Pilot No. 8 Test Condition Run Sequence

APPENDIX C

Pilot's Questionnaire

INTRODUCTION

The purpose of this questionnaire is to elicit observations and comments pertaining to the operational aspects of this cockpit from your point of view. It is not a test and you may take as long as you need.

Please answer all questions completely. Your answers will be used as part of an overall evaluation of this cockpit and your candid opinions are a valuable contribution to the evaluation process.

The questionnaire is divided into three sections that represent the specific areas of interest at this time. The sections are:

A. Operation of the controls, especially the integrated multi-function keyboard.

B. Functional use of the helmet mounted head up display as compared with the cowl mounted unit.

C. Presentation and suitability of the IR imagery mixed with HSD symbology as compared with separation of the displays.

SECTION A

MULTIFUNCTION CONTROLS

The multifunction control panel has been designed to integrate the many dedicated control functions found in present day fighter cockpits into a more efficient arrangement. The following questions pertain to the multifunction keyboard (MFK). For each question, fill in the circle which most nearly describes your feelings about the MKF and explain why you filled in the circle in the comment section.

A-1

The Multifunction Keyboard was

3/8	0	Very easy to operate
4/8	0	Moderately easy to operate
1/8	0	Moderately difficult to operate
	0	Very difficult to operate

COMMENTS

Hard to see numbers - bad lighting.

Good concept. It will work.

Although the MFK was easy to operate, I felt the clarity of the numbers and/or digits could be more clear for easier identification.

Lag time too great on milar relays. Found digits difficult to read. Suggest that once access is gained to the keyboard that it remain there until another function is desired. Erase all entries versus just last digit.

Should have slightly larger characters for us weak-eyed troops.

I was unable to operate the keyboard without looking at it. Also, even while looking at it, I very often touched the wrong button accidently, and it was entered without a positive action on my part. It would have been very difficult had I been flying close formation in the weather. I need a keyboard that I can find and operate by feel with only a glance or two to insure that the results were correct.

I should say somewhere between easy and moderately easy. We worked with no gloves. Normal cockpit operations are performed wearing gloves. The sensitivity lost with gloves on may make it more difficult to only press and receive one digit or may turn double digits into triple numbers.

A definite click on identation might make the selection more satisfactory.

Pressure sensitive (touch tone?) keys do not provide a tactile feedback when activated. The result was erroneous entries.

Wording on keys was blurred, very difficult to read.

Arrangement of digits was not MIL SPEC., i.e.

123
456
789
Clr 0 Enter

Clear button clears only last digit entered.
Would prefer that it clear all digits.

Visual feedback for entry should appear on "Pre-entry data readout"

When frequencies are selected, button [CHN SEL] should be located in same place for all radios.

(neat and orderly arrangement is not as important as locatability which enhances HABIT PATTERNS - which, in turn improve performance).

Would prefer "telephone" arrangement for digit entry.

Lights too dim. Legends hard to read.

Progressing through the four logic levels to enter data on the MFK was

	0	Very inefficient
4/8	0	Moderately inefficient
3/8	0	Moderately efficient
1/8	0	Very efficient

COMMENTS

It was no problem. I do feel that once the 4 logic levels are processed through the data (i.e. UHF freq. or IFF mode), should be shown on a single MDU.

Indenture concept is good. As stands, however, unnecessary steps to get at keyboard e.g. COMM → UHF → keyboard entry → freq. display.

To change the pre-set channel on the current radio involved changing one dial a max of 10 clicks. To change a channel on the MFK involved pressing 6 different buttons in the proper sequence. It seems less efficient to me. To change IFF code only four dials need to be changed in any sequence. Also although the ident feature was not used in the test, I'm sure that the present system would be much more efficient.

Once again, I'm between circles. I think it is inefficient. It took six selections to change one radio channel: more are required to change IFF SQWK.

Very limited evaluation UHF
IFF

Since stores management panel appears to be similar, this could/should be displayed on MFK - will four levels of logic still work?

Was more efficient than I imagined it would be. Some waste to time to correct errors.

A-3

The control actions required to correct failures in the MFK were

3/8	0	Very easy to perform
3/8	0	Moderately easy to perform
1/8	0	Moderately difficult to perform
1/8	0	Very difficult to perform

COMMENTS

The problem was that some failures were not pre-briefed as to what do do to correct the failure. Also, how many tries is enough to correct a failure? Manual switch for channel change is very bad.

They were moderately easy to perform; however, there were two items worthy of comment. The manual backup for the channel selector was in a very awkward position. Also, I don't feel that the master caution light should illuminate because I cannot change radio channels in the primary mode. Another failure warning on the MFK itself would be more appropriate.

Once the procedures were learned, it was no problem to correct errors. I'm sure short cuts are available but unknown to the subjects due to limited training.

However, once again it seems that a lot of effort is expended to correct a MFK panel error. When with normal cockpit equipment, it may be a one step process.

UHF channel/slew button was nearly impossible to reach.

Activating wrong digit when touching panel was frustrating because it was necessary to return to previous logic level. A properly programmed clear button would simplify this.

No problems at all, except perhaps too time consuming.

Switches for UHF and TACAN were hard to reach.

A-4

The number of integrated functions contained in the MFK

3/8	0	Should be greatly increased
1/8	0	Should be slightly increased
2/8	0	Are just about right
1/8	0	Should be slightly decreased
	0	Should be greatly decreased

COMMENTS

There really isn't all that many now but in order to get everyone who flies to buy and accept the concept, I feel some things could be left out. The less clutter the better.

Feel entire cockpit could be run from 4 x 6 matrix. Proposed change attached. Less dedicated switches.

The data we were given did not inform me sufficiently on the system to be able to make a comment on the number of functions available and their uses.

It is difficult to answer this question due to limited use of all of the functions now existing. I still do not know how the entire system operates. I feel that the amount of money spent on an MFK for just the COMM and NAV functions which we utilized would not be justified without adding more functions. Should they be increased, cannot answer from an operational viewpoint without a larger data base.

I feel they are just about right.

A-5

The MFK should contain

	0	More keys and more logic levels
1/8	0	More keys and fewer logic levels
2/8	0	The same number of keys and logic levels as it now has
1/8	0	Fewer keys and more logic levels
2/8	0	Fewer keys and fewer logic levels
2/8	0	The same number of keys and more logic levels

COMMENTS

Going through the logic levels takes time to level off the level and the reselect. Fewer logic levels should help.

4 x 6 matrix adequate. Levels of indenture off master function could be condensed. Use switches that are unused rather than switching to 2nd or 3rd lower level. Make keyboard available whenever possible.

Let's not turn a one step operation into an all day event. As said before it takes several actions to change a radio channel or a SQWK while with dedicated controls in my present aircraft, one action can complete a task.

This is an approximate answer. Why do the data entry keys have to be different from the logic level keys?

I think that twelve keys would be adequate provided the computer can handle it. A better data entry layout would be as below.

1 2 3 ENTER

4 5 6 CLEAR

7 8 9 0

I had no problems with the numbers of keys or logic levels.

A-6

Considering the overall mission workload, operation of the MFK

	0	Interferred greatly with completion of other mission tasks
1/8	0	Interferred slightly with completion of other mission tasks
3/8	0	Did not interfer with completion of other mission tasks
2/8	0	Aided slightly with completion of other mission tasks
2/8	0	Aided greatly with completion of other mission tasks

COMMENTS

Well located and easier to work than a different set of dials and keys for each function.

No general comment. A switch is a switch.

We were not asked to use the MFK during critical phases of flight nor while we were manually flying the aircraft. To be on autopilot and push buttons, even strange ones with help is not a difficult task. Making use of the MFK while the pilot was flying himself would net a completely different set of results.

I would say the MFK had no effect on the missions I flew at all.

Note: "When it worked."
MFK failure modes (degraded operation) demanded so much attention that only through use of autopilot was I able to correct for the malfunctions.

In conjunction with MPD's it really helped.
Note: "STORES SELECT" display letters were adequate
"SENSORS" display letters were too small + (display crowded).

I would like a better comparison of dedicated vs. MFK and the results reached in each situation.

I feel that the current UHF Radio Control head is easier to use and more accurate. The same would probably be true with IFF.

These two items are frequently used and it would be interesting to compare time and error analyses of the two methods.

The primary reason that the operation did not interfere with the other mission tasks were that all MFK functions were performed while operating an autopilot. In a more demanding environment, it could have interfered due to having to divert attention to look at the MFK.

I did not think they interfered but I also did not think they aided other tasks.

A-7

In comparing suitability of the MFK in daytime and nighttime operations, the MFK was

	0	Much more suitable for day operations
1/8	0	Slightly more suitable for day operations
6/8	0	Equally well suited for day or night operations
1/8	0	Slightly more suitable for night operations
	0	Much more suitable for night operations

COMMENTS

However, how will it work in bright sunlight directly on the MFK?

If the system were implemented the added work load would be a disadvantage at night. Day and night, I think it would take longer to do simple tasks.

Add weather and formation flying to day or night and the task would become more difficult.

Do not recall any specific "daytime cockpit conditions".

Couldn't see any difference.

With the backlighted keys, the nighttime or overcast daytime operation made them easy to read. (Test conditions were semi-night). I am sure the direct sunlight on the keyboard would have made it almost impossible to read.

Day vs. night made no diffèrence to me.

A-8

The MPD pre-entry read out was

3/8	0	Very useful in detecting data input errors from the MFK
3/8	0	Slightly useful in detecting data input errors from the MFK
2/8	0	Not useful in detecting data input errors from the MFK

COMMENTS

You just didn't need to use all the pre-entry information.

Unit useful but present display and size of #'s inadequate (too small and improperly shaped).

Again I'm between circles. With the limited training I was not used to the pre-entry read out being available. With the present aircraft computer I use, the pre-entry read out is co-located with the keyboard. This makes errors immediately known. Re-location of the pre-entry read out might make it more useful.

Efficient use requires Complete Entry, then a visual check, then enter data.

Clear button, as currently programmed, requires check after each digit entry.

Terms for logic level were not needed. LVL 1
LVL 2
LVL 3, etc.

This is definitely required. I made several errors that would not have been detected very rapidly without the read out.

It would have been much more useful under one or the other of the following conditions:

a. If the MFK could be operated by feel I could have watched pre-entry read out.

b. If the pre-entry read out was located on or closer to the MFK.

One other comment: I feel that the clear button should clear all digits rather than the last one. Most entries are made by typing all info then checking for corrections. If at this point there is an error, the current design use of the clear button is valueless unless the error is on the last digit.

It was useful but the info presented should be enlarged for easier ID.

SECTION B

HEAD UP DISPLAYS

Two head up display concepts have been installed for evaluation. The purpose of this part of the investigation is to compare the effectiveness of the two displays on the three flight phases.

B-1

In comparing the suitability of the two HUDs

	0	The helmet-mounted HUD was much more suitable
	0	The helmet-mounted HUD was slightly more suitable
	0	Both HUDs were equally suitable
	0	The aircraft-mounted HUD was slightly more suitable
8/8	0	The aircraft-mounted HUD was much more suitable

COMMENTS

The helmet mounted HUD was very bad. It was too cluttered and too hard to see. Also, the helmet HUD was harder to change your focus on.

The helmet mounted HUD was very bulky and cluttered and I had difficulty concentrating with only one eye. It tended to block out of view the outer marker and VVI.

Where you are looking is where you think you are going at 200 KT airspeed. This can be overcome in time at 450 KT. I doubt you could make the adjustments of tracking flying - tracking flying.

The following statements cover all questions in the helmet HUD.

1. Too cumbersome in moving around the C/P.
2. Symbology too cluttered in small area making tracking very difficult.
3. It destroyed my depth perception in both A/G and A/A modes.
4. In A/A it was very "unnatural" to try to track the bogey.

The drawback to the helmet mounted HUD was that most looking or searching is done with eye movement and not head movement, especially small deviations. I found it difficult to move my head and keep my eyeballs caged.

The helmet mounted HUD was unuseable for me. The picture was cluttered with data which was instantly available in the cockpit. The pitch lines were too thick, the aircraft symbol was too large, no flight performance data was available in the eye piece, and the red cross-hair seemed to be there just to add to the confusion.

The aircraft mounted HUD was bad also but with symbols which are of proper proportion and flight data which gives trends it would be a useful tool as in the A7.

Under a high G load the helmet mounted HUD would be unuseable or I should say the pilot would be hampered greatly in movement.

Neither was very suitable in this situation.
HMD was extremely aggravating. It detracted from performance. HUD did not detract, but it wasn't very helpful either. I believe this was due to the inadequate simulation of the terrain, the runway and the air view outside the cockpit. Of the three views, air was the worst; runway was marginally acceptable.

The purpose of displays is to input information. We should do this efficiently. When a lot of info must be presented, the simplest display, with minimum excess clutter (noise), or redundancy is best.

Had problems with eye alighment on helmet mounted system. It is too heavy.

B-2

Which HUD configuration was more suitable in the Air-to-Ground mission

6/8	0	Aircraft-mounted HUD was much more suitable
2/8	0	Aircraft-mounted HUD was slightly more suitable
	0	Both HUDs were equally suitable
	0	Helmet-mounted HUD was slightly more suitable
	0	Helmet-mounted HUD was much more suitable

COMMENTS

Never used the helmet mounted HUD.

No question. Where you point the aircraft is where the bombs going. A-7 has capability for slewing aiming symbol, but so difficult to do and fly toward the ground that it is seldom used. Helmet HUD presents same problem.

I found it more difficult with the helmet mounted HUD, although I found that I did not use either very much.

Terrain was not clear enough to visually acquire target. HUD displays are designed to be used when pilots can acquire the displays visually. This was not the case in this simulation.

Display should have had something like

(Check TFR HUD displays?)

1. Sight reticle
2. Path over ground
3. A/S
4. Altitude digital/altitude warning
5. Command altitude

What is wrong with "standard" flight director pitch and bank steering bars?

I did not like the power command, once I learned to use it.

Show only what pilot needs to know.

Was easier to "look through" aircraft mounted HUD.

B-3

Which HUD configuration was more suitable in the Landing mission

1/8	0	Helmet-mounted HUD was much more suitable
	0	Helmet-mounted HUD was slightly more suitable
	0	Both HUDs were equally suitable
	0	Aircraft-mounted HUD was slightly more suitable
7/8	0	Aircraft-mounted HUD was much more suitable

COMMENTS

Never used the helmet-mounted HUD.

The pitch lines tended to block out the runway lights in night landings.

Same. Where you point is where you land.

With the helmet-mounted HUD, I found that I was cocking my head to eliminate the HUD so I could see to land. I feel that this was due to the amount of clutter in the HUD. This way I could eliminate it, whereas I could not with the A/C mounted HUD.

The aircraft-mounted HUD with performance data would allow heads-up WX flying as in the A-7. Symbology is the only drawback.

An aircraft vector symbol would also be helpful.

Neither was worthwhile.

Both were too cluttered. Someone forgot to ask the key question: "What additional information does a pilot need to complete a landing once he has visually acquired the runway?"

Restricted Glide Path?	A/S? Angle of Attack? Power Setting? Altitude? Vertical Speed? but certainly not reading (he can see the runway) and only a limited amount of pitch information (horizon bar and A/C) Not the pitch ladder.
"Highway in the Sky"	HMD should compensate for head tilt so that horizon bar always lays on the horizon. Is the display of horizon information via a HMD vital enough to warrant the hardware?

Was unable to use helmet-mounted HUD. Don't know why.

B-4

Freedom of movement within the cockpit was restricted

4/8	0	Much more by the helmet-mounted HUD
	0	Slightly more by the helmet-mounted HUD
1/8	0	Equally by both HUDs
1/8	0	Slightly more by the aircraft-mounted HUD
2/8	0	Much more by the aircraft-mounted HUD

COMMENTS

The helmet-mounted HUD was no problem in the simulation. It would be a problem in an A/C. Most forward mounted HUDs should not be a problem. This simulation HUD was a little confining.

Cumbersome and restrictive.

This was due to the simulator HUD configuration. Had the A/C mounted HUD been like the A-7's, it would have been better.

Under high G loads the pilot's head would be pinned in one position. Air to air flying capability would be greatly reduced.

Flying inst. approaches the marker beacon light was completely blocked out.

Rube Goldberg HUD rig. unique to this simulator, was a pain. When seat was high enough to see, head was locked in one position. Real airplanes don't have this problem.

HMD too heavy. It causes helmet to tilt sideways on head - even at 1 g. Imagine 6 or 7 g's!

This was caused by the overhead structure. Would not be a problem in aircraft with HUD "stuff" in front panel.

B-5

In comparing the suitability of the two HUDs for daytime operations the

6/8	0	Aircraft-mounted HUD was much more suitable
	0	Aircraft-mounted HUD was slightly more suitable
2/8	0	Both HUDs were equally suitable
	0	Helmet-mounted HUD was slightly more suitable
	0	Helmet-mounted HUD was much more suitable

COMMENTS

Easier to interpret. Focus on A/C HUD was easier. It is also less destracting.

The helmet-mounted HUD was unacceptable to me in all phases of flight. It gave me no useful information.

When advances in technology (fiber optics or matrix LED's) enable us to have a light weight HMD that does not have a banana sized obstruction interfering with the pilot's view of the cockpit.

And when designers determine what information can be used by the pilot, then with adequate simulation of the "outside world" (180°, high resolution, color), the HUD and HMD should be properly evaluated.

To get a true evaluation of HUD's eliminate the VSD.

A. Put info on HUD only.

B. Put some on HUD and some on HMD.

Pilots will have to use HUDs (I did not during this experiment).

But first - we need an adequate, light HMD, and more information on uncluttered display formats.

B-6

In comparing the suitability of the two HUDs for nighttime operations the

	0	Helmet-mounted HUD was much more suitable
	0	Helmet-mounted HUD was slightly more suitable
1/8	0	Both HUDs were equally suitable
1/8	0	Aircraft-mounted HUD was slightly more suitable
6/8	0	Aircraft-mounted HUD was much more suitable

COMMENTS

Superior

I think that the green was too bright and should have a night filter. The A/C mounted HUD could be tuned down.

Could be automatically controlled to adjust brightness on a differential level is selected.

B-7

Shifting attention from the HUD symbology to a bogey located a great distance away from the boresight was

	0	Much more difficult with the aircraft-mounted HUD
1/8	0	Slightly more difficult with the aircraft-mounted HUD
	0	Equally difficult with both HUDS
2/8	0	Slightly more difficult with the helmet-mounted HUD
5/8	0	Much more difficult with the helmet-mounted HUD

COMMENTS

Focusing was hard with helmet-mounted HUD. Also you have a boresight, pitch reference, pitch lines, etc. in helmet HUD. Too many variables going too many ways.

There seem to be operating in 3 dimensions. Also rate of closure was much more difficult with Helmet HUD.

This is only true if bogey is not located in the combining glass. Otherwise, the AK mounted dominates.

The helmet-mounted HUD could trick me into thinking the A/C was pointed toward the bogey when it was not. This never happened with the A/C mounted HUD.

When attempting to locate a bogey with the helmet-mounted HUD the HUD picture would get in my way. The clutter would enter my vision at times blocking my target.

Blurred bogey made "focus" on the "distant" object highly questionable. Unable to obtain adequate rate of closure from the simulation.

Limited horizon made a mockery of this comparison by eliminating air to air maneuvering (a case where the bogey was at 5 o'clock would greatly change the evaluation.)

Helmet-mounted advantages do not become really apparent unless there is a 360° visible horizon. I do not believe that this experiment is properly structured to reach any really valid conclusions on these two methods.

Wavy "horizon line" was too short to be compelling enough to be really used.

The "one eye" look seemed to cause problems in this area. Also, the target was blocked out by HUD symbology on 2 occasions when using helmet-mounted system. This was not a problem with aircraft mounted HUD.

B-8

As compared with using two eyes to look through the aircraft-mounted HUD, the fact that you only used one eye to look through the helmet-mounted HUD

	0	Helped greatly in accomplishing your mission
	0	Helped slightly in accomplishing your mission
3/8	0	Made no difference in accomplishing your mission
	0	Hindered slightly in accomplishing your mission
5/8	0	Hindered greatly in accomplishing your mission

COMMENTS

Did not like the obstruction caused by the eyepiece. One might become used to it however.

It was a great problem to me.

Degrades depth perception.

I did not seem to have that problem with helmet.

This question cannot be answered with the runs we have made. With training the problems with the helmet-mounted HUD could be overcome, however, those problems would be nonexistent with the aircraft-mounted HUD.

I was able to adapt to the one eye method after 3 or 4 missions but why give a pilot additional problems to overcome with his equipment if he gets no benefit from the equipment.

Except that the metal bar is not transparent, and cannot be looked through.

That is an unnatural act.

SECTION C

DEDICATED/OVERLAID ELECTRONIC DISPLAYS

The concept of overlaying symbology information on real-time imagery has been given to you in the form of a map display associated with IR imagery. The following questions pertain to the overlay concept.

C-1

Considering the overall suitability of the two types of displays in performing the Air-to-Ground mission, the

	0	Dedicated display was much more effective
	0	Dedicated display was slightly more effective
	0	Dedicated and overlapping displays were equally effective
	0	Overlapping display was slightly more effective
8/8	0	Overlapping display was much more effective

COMMENTS

The overlapping superiority is very self-evident.

The overlay showed exact differences in error. The dedicated display caused a decision to be made and increased the time to make the decision if there is an error in the system.

Completely dominates.

On dedicated/overlaid displays:

1. Very difficult to accurately update split screen.
2. In trying to update split screen I spent too much time in the C/P.

The overlapping display allows for a very precise nav update; whereas, the dedicated display is only an estimate.

The overlapping was far better. There was no question where to update and good update points were easy to find. With the overlay in VFR conditions, target acquisition would become much easier if it had IR energy.

Azimuth corrections, although seldom required by the dipslay driving devices could be corrected only with the overlapping display.

I could visualize the situation much easier and could update the map much easier.

C-2

The map update procedure was

8/8	0	Much easier with the overlayed displays
	0	Slightly easier with the overlayed displays
	0	Equally easy with overlayed and dedicated displays
	0	Slightly easier with dedicated displays
	0	Much easier with dedicated displays

COMMENTS

Both displays need the A/C symbol closer to the center of the display. You need an earlier reference point than the bottom of the map to go by. Also, it would be nice to be able to quickly see how your update did. This was possible with the overlay but not the deciated displays.

Relative keyboards and lateral displacement is difficult to judge.

There was no question of where you were with the overlay. The dedicated system left considerable room for error.

Stick to move map was too long. It interfered with overlay display, covering aircraft symbol.

C-3

When the map and IR were not aligned the interpretation of information on the HSD was

	0	Much easier with dedicated (split screen) displays
	0	Slightly easier with dedicated (split screen) displays
	0	Equally easy with dedicated and overlayed displays
	0	Slightly easier with overlayed displays
8/8	0	Much easier with overlayed displays

COMMENTS

The map without the IR under it rendered me approximated zero intelligible information. With the IR under it, I was using IR to interpret the map. This is not the proper way to use IR or Radar. Overlayed displays could become difficult with a map of greater detail such as those in the A-7.

As before it was just better all around. I feel errors would be smaller and less frequent.

Map scale was not as good as it could be. Map moved too fast. Map symbology should be standard with AF (or TAC) regulation on mission folder preparation.

APPENDIX D

PILOT DATA

DATE________________

NAME__________________________ RANK__________ SN____________

PRESENT DUTY ASSIGNMENT____________________________________

ORGANIZATION____

MAIL ADDRESS____

TOTAL ACTIVE DUTY___________________________ AGE_____________

DATE PILOT RATING OBTAINED___________________________________

TOTAL FLYING HOURS____________________ TOTAL JET______________

HOURS IN A/C BY TYPE: __________________________

____

____

____

COMBAT EXPERIENCE ______________________________________

____

____

(Crew Member Data (Cont'd)

DATE OF LATEST WEAPON DELIVERY EXERCISE______________________________

	OPERATIONAL	TRAINING
WEAPON TYPES:	________	________
	________	________
	________	________

GIVE CEP ATTAINED IF KNOWN OR RECORDED______________________________

APPROXIMATE HOURS OF GROUND RADAR AND AIR RADAR TARGET INTERPRETATION EXPERIENCE______________________________

ANTHROPOMETRICS:

HEIGHT ____________________

WEIGHT ____________________

SEATED EYE HEIGHT ____________________

FUNCTIONAL REACH ____________________

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