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EVALUATION OF FACTORS UNIQUE TO MULTIFUNCTION CONTROLS/DISPLAYS DEVICES

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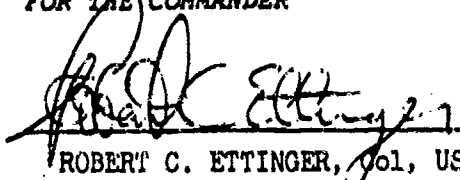
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Aircraft which utilize computers will require the use of multifunction displays and keyboards (MFK). Eight arrangements of formats which present flight control, navigation, and status information were examined. All were found useable but arrangements in which attitude information was placed above navigation information and those utilizing electro-optical devices rather than conventional flight instruments were slightly better. Two types of MFK logic were also examined. MFK operation was more efficient with Tailored Logic (frequently used functions presented) than with Branching Logic (functions presented by systems).		

FOREWORD

This Technical Report is the result of a work effort performed by the Requirements and Analysis Group of the Crew Systems Development Branch (FIGR), Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio. Major Robert Bateman was the group leader and Dr. John Reising is responsible for human factors. Mr. Emmett Herron of the Bunker Ramo Corporation provided pilot inputs to the work efforts, and Ms. Gloria Calhoun of the same company provided statistical and experimental design support. Software support was provided by Mr. William Wessale of Systems Consultants Incorporated and Mr. Larry Evilsizer of Bunker Ramo Corporation; hardware support was provided by Mr. Al Meyer of Technology Incorporated. The objective of this effort was to evaluate (1) the use of eight different format arrangements of flight information and (2) the use of two different types of multifunction keyboard control logic.

The Bunker Ramo portion of the work effort was performed under USAF Contract Number F33615-78C-3614. The contract was initiated under Task Number 240304, "Control-Display for Air Force Aircraft and Aerospace Vehicles" which is managed by the Crew Systems Development Branch (AFWAL/FIGR), Flight Control Division, Flight Dynamics Laboratory, Air Force Wright Aeronautical Laboratories.

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GLOSSARY OF TERMS

AAE - average absolute error - see Appendix G.

AE - average error - see Appendix G.

BRANCHING LOGIC - control logic programmed in parallel with system operation so that each switch activation causes various sublevels for the applicable system to appear.

BRUTE FORCE LOGIC - original term for systems logic - see Branching Logic.

CDC 6600 - Control Data Corporation general purpose computer.

CRT - Cathode Ray Tube.

CRT MFK - hardware in which the legends on a display adjacent to the switch changed according to the function the switch was serving at the time.

DATA ENTRY KEYBOARD - panel with twelve dedicated switches; the switches were in a 4 rows x 3 columns telephone type layout with the CLEAR and ENTER keys on the left and right sides of the zero, respectively.

DEDICATED DISPLAY - single display capable of performing only one function.

DEDICATED SWITCH - single switch capable of performing only one function.

DEK - see data entry keyboard.

DISCRIMINANT ANALYSIS - statistical procedure used in data analysis - see Appendix G.

DISPLAY - programmable electro-optical device on which a variety of formats can be shown.

DISPLAY ARRANGEMENT - original term for location of formats - see Format Arrangement.

ELECTRO-OPTICAL DISPLAY - programmable electronic display on which a variety of symbology can be shown.

FLIGHT PLAN - Modified AF Form 70 specifying radio channels and frequencies, IFF codes, TACAN channels, waypoint information, altimeter settings, ILS frequencies and courses, field elevations and decision heights, and weapon options.

FLIGHT PHASE SWITCHES - dedicated switches, which in the present study, determined the status display format and the logic page displayed on the MFK.

FLYING TASK - maintaining groundspeed and keeping the flight director centered on the HUD, VSF or ADI.

FORMAT - symbols and their arrangement; formats can be presented on a number of displays.

FORMAT ARRANGEMENT - location of flight information (attitude and navigation) on CRTs or conventional instruments.

HEAD UP DISPLAY - presents flight control information on a combiner glass in the pilot's forward field of view.

HORIZONTAL SITUATION DISPLAY - original term for Horizontal Situation Format.

HORIZONTAL SITUATION FORMAT - navigation information.

HSD - see Horizontal Situation Display.

HSF - see Horizontal Situation Format.

HUD - see Head Up Display.

INFORMATION LOGIC DESIGN - determination of the meaning or function of each switch and the sequence of actions the pilot used to perform required tasks.

KEYBOARD TASK - operating the MFK to complete communication, navigation and stores tasks.

KOLMOGOROV-SMIRNOV TEST - nonparametric test of significance used in the analysis of the questionnaire data - see Appendix G.

LATIN SQUARE DESIGN (BALANCED) - experimental design in which any one treatment is preceded equally often by each of the other treatments.

LOGIC LEVELS - means by which pilots selected and executed tasks; each change of a set of legends constituted a single logic level.

MANOVA - see Multivariate Analysis of Variance.

MFK - see Multifunction Keyboard.

MPD - see Multipurpose Display.

MULTIFUNCTION CONTROLS - several multifunction switches on a single panel.

MULTIFUNCTION DISPLAYS - single display capable of performing more than one function.

MULTIFUNCTION KEYBOARD - several multifunction push button type switches on a single panel.

MULTIFUNCTION SWITCH - a switch whose function changes, depending upon the task being performed by the operator.

MULTIFUNCTION SWITCH LEGEND - name on or associated with a switch which identifies the switch's current function.

MULTIPURPOSE DISPLAY - original term for Status Format.

MULTIVARIATE ANALYSIS OF VARIANCE - statistical procedure used in data analysis - see Appendix G.

OPERATING SEQUENCE - logic levels or sequence of actions the pilot used to complete required tasks on the MFK.

PDP 11/45 - Digital Equipment Corporation general purpose mini-computer.

RAMTEK RASTER SYMBOL GENERATOR - a display system which converts computer generated alphanumeric and graphic display information into industry compatible video signals.

RMS - root mean square - see Appendix G.

STATUS FORMAT - systems information.

SD - standard deviation - see Appendix G.

SF - see Status Format.

SUBTASK - set of specified MFK and DEK selections which logically could be considered a complete task if accomplished independently.

SYSTEM SELECT SWITCHES - dedicated switches that when activated, determined which set of logical functions were to be addressed. The system select switches labeled COMM, NAV and STORES were used in the present study.

TAILORED LOGIC - control logic programmed according to what functions are most likely to be used in the current flight phase--sublevels for several systems are available without switch activation.

TASK - operation the pilot was required to complete on the MFK. Each task involved either one task or several subtasks.

VERTICAL SITUATION DISPLAY - original term for Vertical Situation Format.

VERTICAL SITUATION FORMAT - flight information.

VSD - see Vertical Situation Display.

VSP - see Vertical Situation Format.

SUMMARY

Computer controlled multifunction displays and keyboards have been designed to integrate most of the information required by the pilot onto a few electro-optical devices. One purpose of this study was to measure the changes in pilot performance as a function of the location of flight information. Eight arrangements/locations of display formats which present vertical situation, horizontal situation, and status information were examined. These arrangements have potential use in the flight conditions likely to be encountered in the fighter mission and in cases where electro-optical display(s) fail. A second purpose of the study was to examine the ease of data selection on the multifunction keyboard (MFK). Two types of logic were examined: Branching Logic (programmed in parallel with system operation) and Tailored Logic (programmed according to what functions are most likely to be used in the current phase of flight).

Analysis of the flight performance data showed that any of the format arrangements examined in this study are useable as a backup in the event of display failure. However, some arrangements were found slightly better than others -- arrangements in which the flight control information was placed above the navigation information and arrangements utilizing electro-optical displays rather than conventional dedicated flight instruments. Performance on flying the simulator and completing communications, navigation, and weapons tasks on the MFK indicated that MFK operation was more efficient with the Tailored Logic than with the Branching Logic. Recommendations for applications and further evaluation are made.

1. INTRODUCTION

1.1 BACKGROUND

The use of digital avionics in modern military aircraft has increased dramatically in the past decade. Both the Air Force's F-16 (Ref. 1) and the Navy's F-18 (Ref. 2) are primary examples of this development. The cockpits of these two aircraft reflect the ability to use digital avionics to reprogram electro-optical displays. The F-16 contains a programmable stores panel, and the F-18 contains three programmable displays. One advantage of these devices is that a format from one display can be presented on any other display. For example, if one of the displays fails, the format presented on that display can be moved to another display. This feature results in a great deal of flexibility regarding display formats, but also may create problems. Just because it is possible to place the formats in various places around the cockpit, it does not necessarily follow that the pilot can fly efficiently using these formats when they are placed in positions which are different from those which are normally used.

Not only are the displays programmable but multifunction keyboards (MFK) are also programmable, enabling many switch legends to appear on the same physical device (Ref. 3). An MFK is a panel made up of several multifunction switches; each switch is capable of performing more than one function. Each switch of the MFK addresses computer logic which determines the functions of the switch, displays information appropriate to its current function, and initiates the execution of those functions when selected.

Since only a portion of the switching functions are available at any one time (one legend or function per switch), it is vital that the design and implementation of the computer control logic receive careful attention if the pilot is to benefit from the full potential of the digital avionics. Control logic might be designed and implemented in a number of ways.

One means of designing the control logic is to program it so that each switch activation causes various sublevels for the applicable system to appear. In the study, this type of control logic was referred to as Branching Logic and can be illustrated as shown in Figure 1. Tasks are initiated by a set of dedicated switches which are used to determine which set of logic functions will be addressed. For example, an MFK designed for aircraft cockpits is shown in Figure 2. It consists of a Cathode Ray Tube (CRT) with push button switches mounted along the outside edges. Across the top of the CRT display are nine, dedicated, single-purpose, system select switches which, if activated, call up a particular set of options, which constitute a logic level. The multifunction switches are mounted on the left and right sides of the CRT. When one of the system select switches is pushed, the functions/legends relative to that system are displayed on the CRT next to the switches. For example, when the switch labeled COMM (abbreviation for communication) is selected, a set of radios assigned to that system will be displayed (see Figure 2). At this logic level, each of the radio options is associated with one of the multifunction switches. The next step in the control sequence would be for the pilot to select the specific radio to be operated. This selection would change the legends so that, at this logic level, the pilot could turn on the radio, change a frequency, etc. Thus, each switch activation sets up new switch legends which

BRANCHING LOGIC

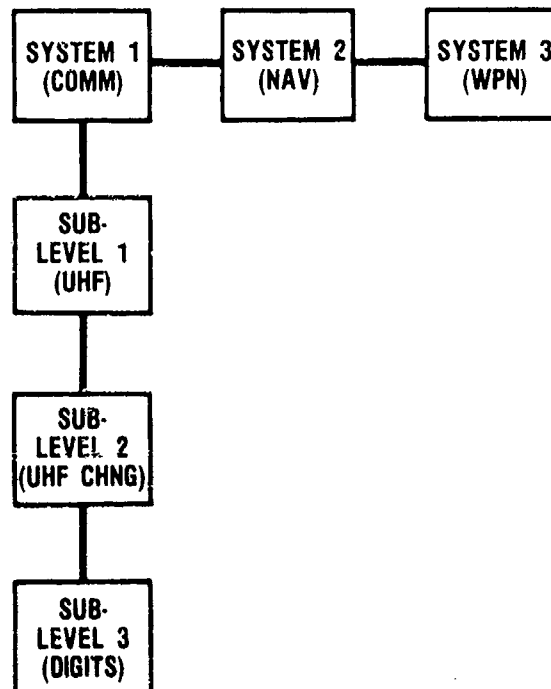


Figure 1. Schematic Representation of Branching Logic

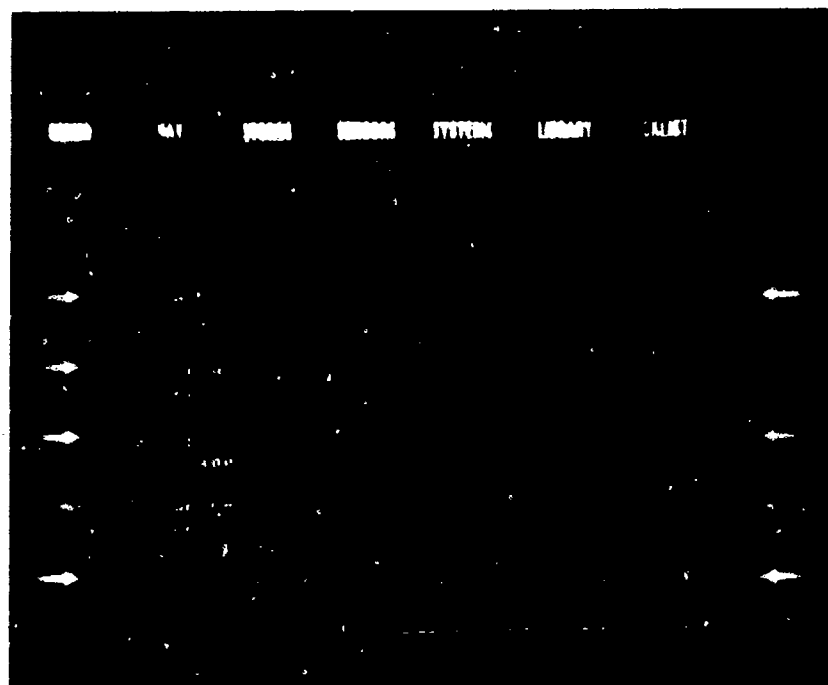


Figure 2. An Example of Branching Logic on a Multifunction Keyboard

identify new purposes for each switch. In this manner, a great number of operations may be completed using only a small number of switches. When data entry is required, a separate data entry keyboard (dedicated switches in a 4 rows x 3 columns configuration) is illuminated and active.

A second way of programming control logic was referred to as Tailored Logic. It was thought that operator efficiency might be enhanced when the logic was not programmed according to the system operation but rather was programmed according to the functions most likely to be used in the current phase of operation. For example, the logic might be programmed to present options from several systems (e.g., JHF frequency change, weapon option selection, and navigation input) depending upon the flight phase (Figure 3).

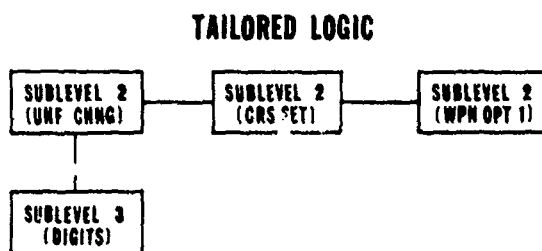


Figure 3. Schematic Representation of Tailored Logic

This type of control logic is shown in Figure 4. The format shown in this

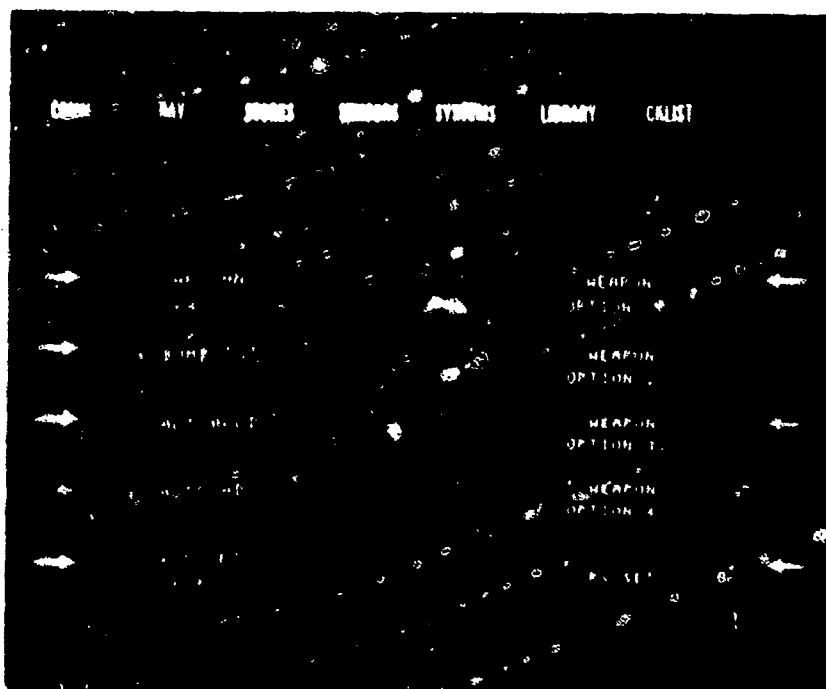


Figure 4. Multifunction Keyboard with Tailored Options Displayed

example presents the options most frequently used in a bombing phase. Different options would be presented in the landing phase. With the logic tailored to a phase of operation (flight phase), the UHF change option is immediately available and some of the levels of indenture in the control logic are eliminated.

The inclusion of an MFK in the cockpit should optimize the control capability of the switch functions, increase the information available to the pilot, and make the completion of required tasks, including all the controls and displays, more efficient (Ref. 4). The advantage of having all switching controls within easy view and reach should offset the inconvenience of additional necessary switch operations, especially if the Tailored Logic is utilized as the primary operating interface.

1.2 PURPOSE

One of the purposes of this study was to examine pilot useability and acceptability of different arrangements of flight information formats in the cockpit. To accomplish this, flight performance was examined under eight different arrangements of vertical situation information, horizontal situation information, and status information. Figure 5 shows the location of the flight information for the eight format arrangements evaluated.

A second purpose of the study was to determine the most efficient method of utilizing the MFK. Two types of logic were examined in the context of a fighter aircraft simulation: Branching Logic (programmed according to system operation; Figure 2) and Tailored Logic (programmed according to what functions are most likely to be used in the current phase of flight; Figure 4).

The test design provided for the analysis of the pilot's ability to maintain specific flight parameters and operate the MFK to complete various mission related tasks. Subjective evaluations of the MFK and format arrangements were also obtained by the administration of debriefing questionnaires.

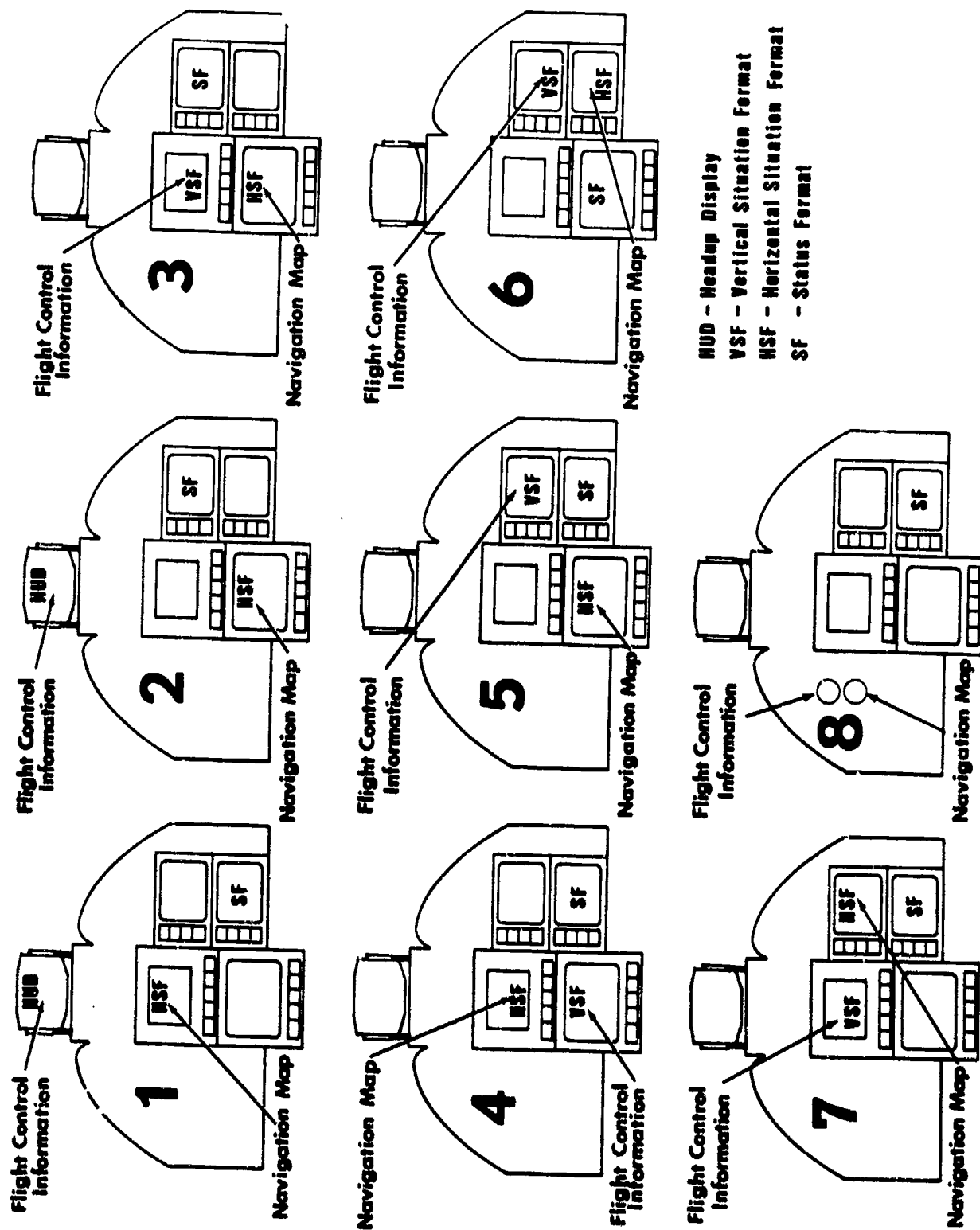


Figure 5. Arrangements of Flight Information Formats Evaluated

2. TEST APPARATUS

2.1 COCKPIT SIMULATOR

A single-place cockpit of A-7D geometry was fabricated to accommodate the electro-optical displays and MFK. The canopy of the simulator was covered during testing to help eliminate distractions to the pilot. The cockpit layout is shown in Figure 6.

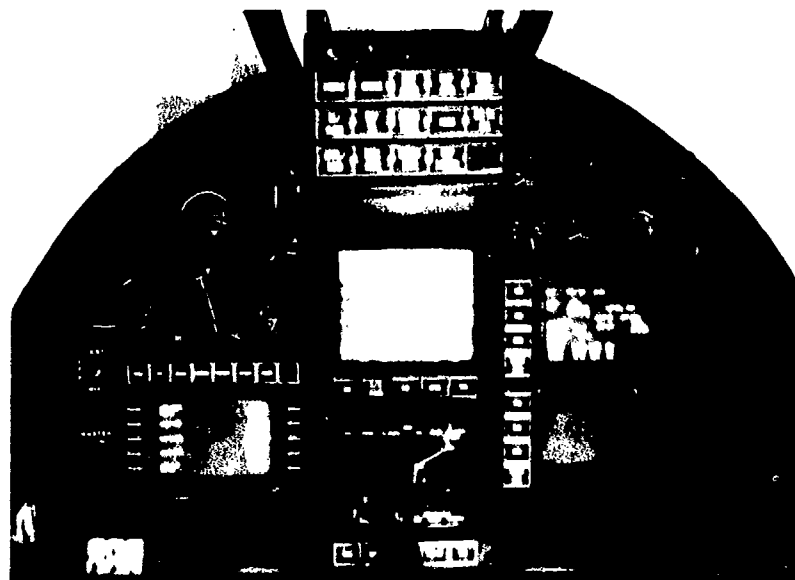


Figure 6. Cockpit Simulator Used in the Evaluation

2.1.1 Format Arrangements

A total of eight arrangements were examined (Figure 5). In seven of the eight arrangements, flight control and navigation information were presented on CRTs. In the eighth arrangement, the information was presented on conventional dedicated flight instruments.

2.1.1.1 Flight Information Presented on CRTs

2.1.1.1.1 Electro-optical Formats

Four electro-optical formats were used in the present study to provide information to the pilot. The Head-Up Display (HUD; Figure 7) and the Vertical Situation Format (VSF; Figure 8) presented flight control

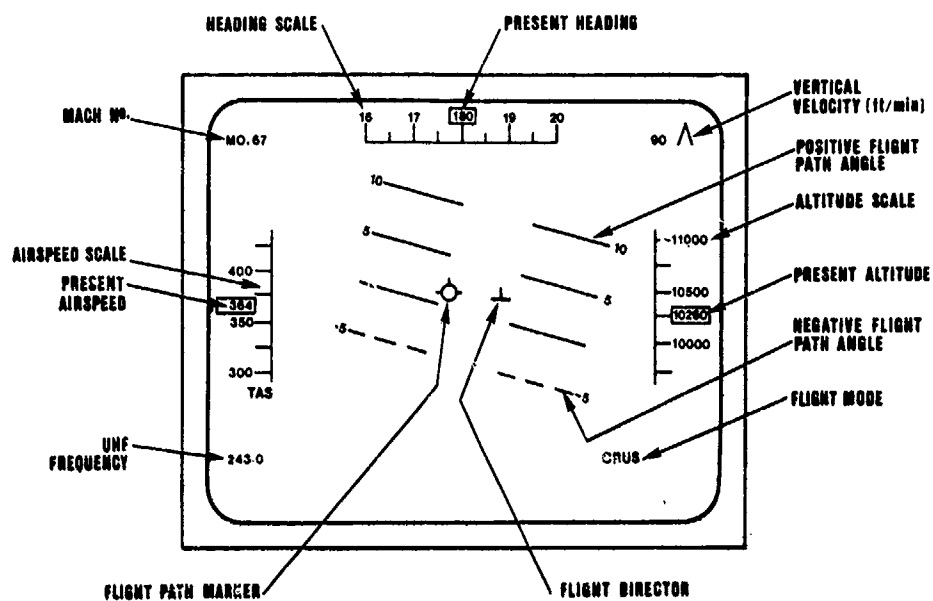


Figure 7. Head-Up Display Format

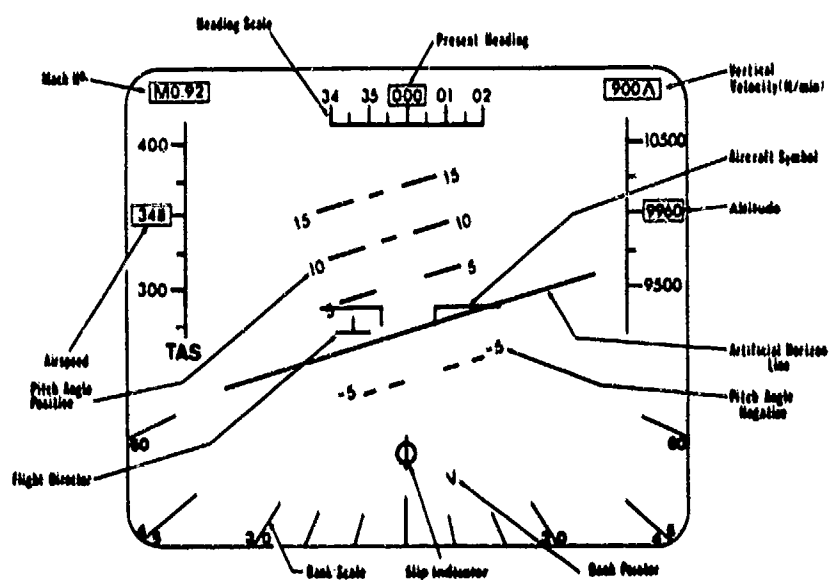


Figure 8. Vertical Situation Format

information along with additional data. The Horizontal Situation Format (HSF) consisted of a representation of the route of flight and navigation information (Figure 9). The Status Format (SF) displayed communications and navigation data during

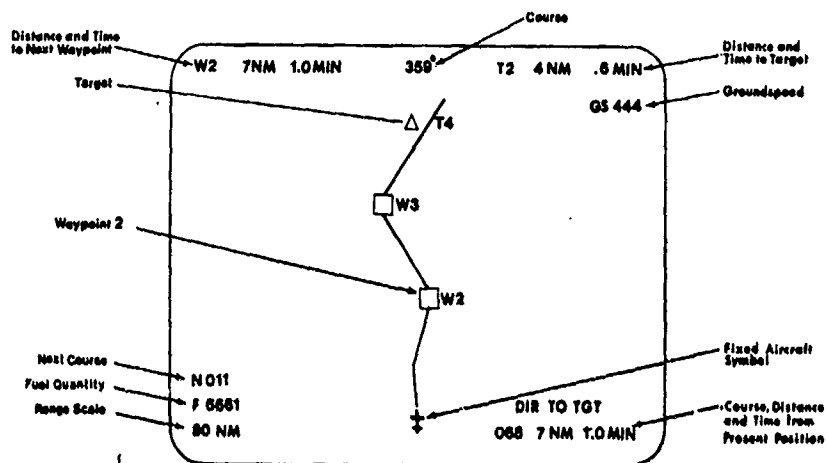


Figure 9. Horizontal Situation Format

the TAKEOFF/CLIMB, CRUISE and PRECISION APPROACH flight phases (Figure 10) and in addition displayed stores data during the NAV BOMB phase (Figure 11). For a more complete description of the electro-optical formats, see Appendix A.

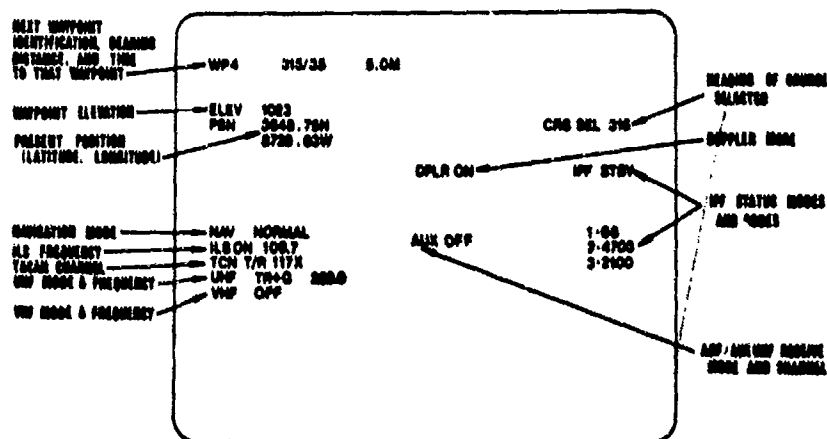


Figure 10. Status Format for TAKEOFF/CLIMB, CRUISE, and PRECISION APPROACH Flight Segments

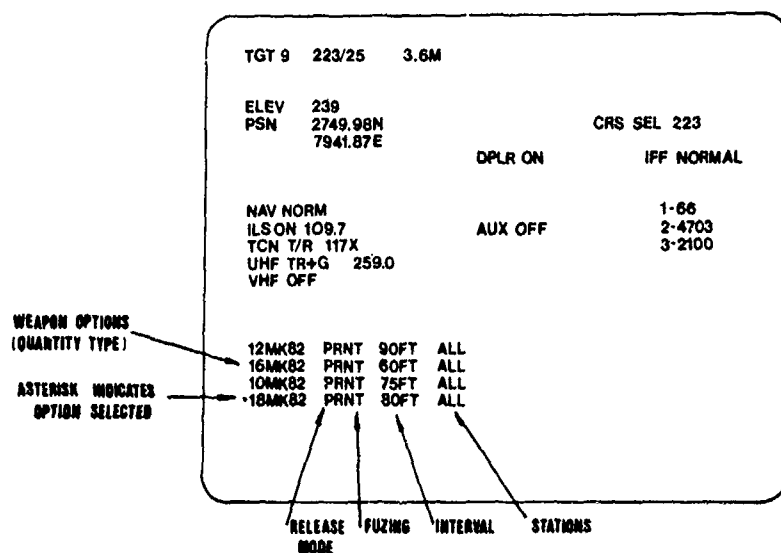


Figure 11. Status Format for NAV BOMB Flight Segment

2.1.1.1.2 Electro-optical Format Arrangements

The cockpit contained five black and white CRTs on which the flight information formats were presented to the pilot (Figure 12).

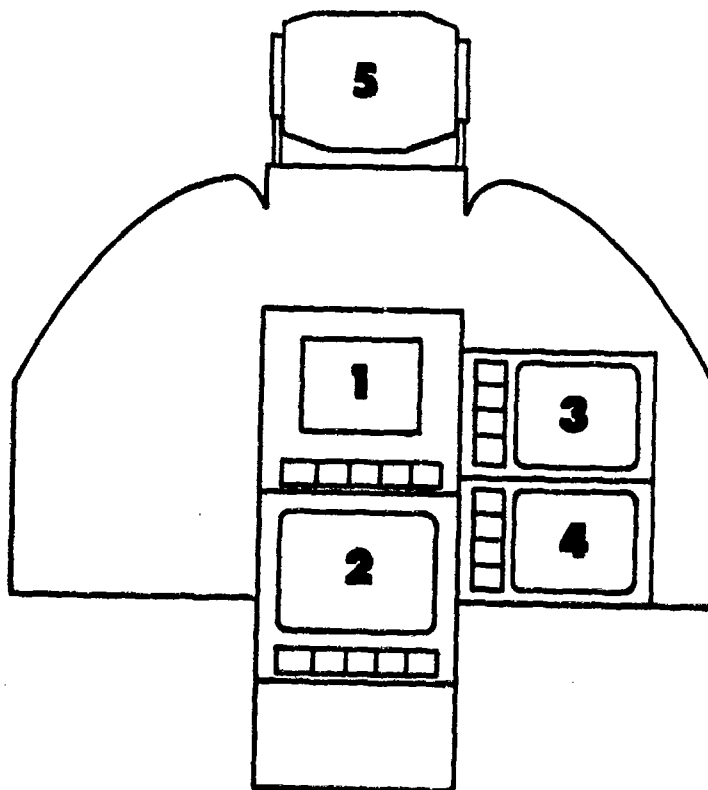


Figure 12. Electro-optical Displays in the Cockpit Simulator

Besides the two seven-inch diagonal CRTs on the center front instrument panel and the two 6-inch diagonal CRTs on the right front instrument panel, there was a HUD by which information could be presented on the combiner glass. There were two restrictions on the types of format arrangements. First, due to computer limitations, it was not possible to present the HUD and VSF simultaneously during a flight phase. In addition, the HUD format was only displayed on the combining glass above the cowl whereas the VSF, HSF and SF were presented on several of the four CRT displays on the front instrument panel.

Seven different arrangements of the electro-optical formats which were examined are shown in Figure 5. Two standard arrangements were examined (Figure 5, Numbers 2 and 3): flight control information located centrally or on the windscreen with the HSF on a lower display. An alternate arrangement (Figure 5, Number 1) was evaluated in which the HSF was placed in a central location to minimize crosscheck distance from the HUD, the primary flight instrument. Since computer driven displays are subject to failure, pilot performance was also evaluated for arrangements in which one of the center displays was inoperative (Figure 5, Numbers 5, 6, and 7). Additionally, an arrangement consisting of the HSF on the upper center CRT and VSF on the lower center CRT (Figure 5, Number 4) was examined for potential application in lightning conditions where the pilot might want his primary flight display head-down.

2.1.1.2 Flight Information Presented on Conventional Instruments

In one of the eight arrangements, the HUD and VSF were inoperable. In addition, the HSF was covered except for the groundspeed readout which remained visible to the pilot. The information was presented on the SF and several dedicated flight instruments located to the left of the center CRT (Figures 5 and 13). The following dedicated instruments were operable:

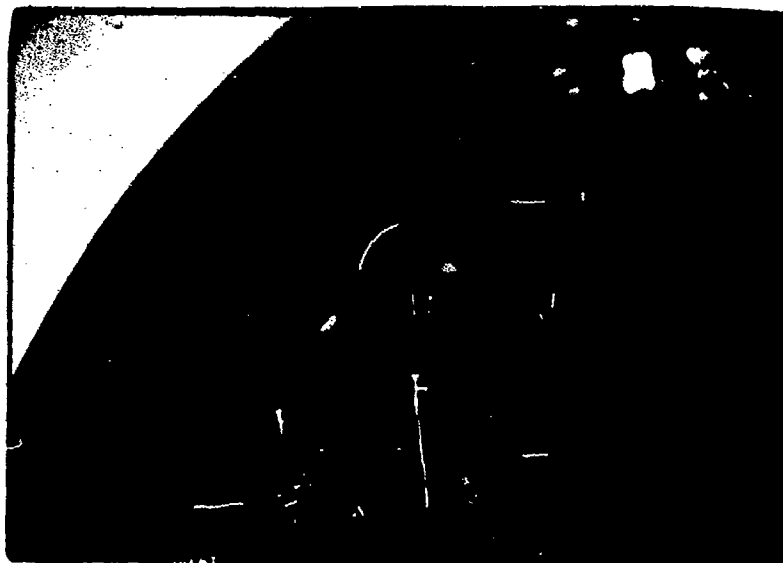


Figure 13. Conventional Flight Instruments Used in Evaluation of Format Arrangements

- a) Attitude Director Indicator (ADI) - The pitch trim knob adjusted the alignment of the horizon line and the aircraft symbol.
- b) Horizontal Situation Indicator (HSI)
- c) Altimeter
- d) Calibrated Airspeed Indicator
- e) Vertical Velocity Indicator

2.1.2 Multifunction Keyboard (MFK)

The MFK hardware was located on the left front instrument panel (Figure 6). It consisted of eight dedicated push button system select switches in a row across the top of the CRT and ten push button multifunction switches mounted in columns on the left and right sides of the CRT (Figure 2). Only seven of the dedicated system select switches were operable and had legends displayed on the switch faces. For the ten multifunction switches, the legend was displayed adjacent to each switch and changed according to the function the switch was serving. These switches were only operable when a legend was displayed adjacent to the switches and when the experimenter initiated a task. The switches remained operable until task completion. The left console data entry keyboard (DEK) became operable and lighted when the pilot was required to select and enter digits. Once the ENTER key was selected, the DEK became inoperable and unlighted. The DEK consisted of twelve dedicated push button keys; the switches were arranged in 4 rows x 3 columns telephone layout with the CLEAR and ENTER keys on the left and right sides of the zero, respectively. For some tasks, the letter N, S, E, W, X, and Y could be selected on the keys labeled 2, 8, 4, 6, 7, and 9, respectively.

2.1.3 Dedicated Displays and Controls

Most of the backup flight instruments in the simulator were inoperable in Arrangements 1-7 so that the pilot was forced to use the information displayed on the HUD or VSF and HSF to maintain control of the aircraft simulator. However, the following devices were operable and available for use by the pilot during all eight arrangements:

- a) Angle of Attack Indicator
- b) Engine Instrumentation (RPM, Turbine Outlet Pressure, Fuel Flow Indicator, Fuel Quantity, Turbine Outlet Temperature, Oil Pressure)
- c) EADI Pitch Trim Knob on left console and ADI Pitch Trim Knob
- d) Master Arm Switch
- e) Control Stick and Rudders
- f) Trim Button and Bomb Release Button on the Stick
- g) Throttle

During each test flight segment, one of the following flight phase switches below the HUD was lighted: T.O. CLIMB, CRUISE, NAV BOMB, and PREC APPR. When the branching logic was implemented, all the flight phase switches were inoperable, making the tailored logic inaccessible; when the tailored logic was implemented, the lighted flight phase switch was operable. In both logic implementations, selection of any flight phase switch counted in the switch hit index (Appendix G). Appendix A provides a more complete description of the dedicated instruments and switches.

2.2 EXPERIMENTERS' CONSOLE AND SIMULATION FACILITIES

The experimenters' console was equipped with CRT displays and status lights which provided the experimenters with the capability of monitoring both the displays in the simulator and the switch hits (Figure 14). The experimenters could also control the initiation of keyboard tasks and the termination of test flights. A layout and description of each piece of equipment on the console that was used in the present study is provided in Appendix B. A functional description of each system element of the simulation facilities is also given.



Figure 14. Experimenters' Console

3. TEST METHOD/APPROACH

3.1 TEST OBJECTIVES

One purpose of this study was to measure the changes in pilot performance as a function of the location of flight information. Eight format arrangements were examined (Figure 5). In seven of the eight arrangements, flight control and navigation information were presented on CRTs. In the eighth arrangement, the information was presented on conventional dedicated flight instruments.

A second purpose of the study was to examine the ease of data selection on the MFK. In order to examine this question, two types of logic were examined: Branching Logic (programmed according to system operation) and Tailored Logic (programmed according to what functions are most likely to be used in the current phase of system operation).

The test design provided for analyses of: (1) several objective performance measures for flight director deviations (in vertical and horizontal axes) and groundspeed deviations; and (2) two objective performance measures for keyboard operation. Questionnaire data was also obtained.

3.2 TEST DESIGN

Performance for each pilot was observed under each of the eight format arrangements. Only one of the arrangements was evaluated in each flight segment. A data flight consisted of four 15-minute flight segments (TAKEOFF/CLIMB, CRUISE, NAV BOMB, and PRECISION APPROACH). Thus, two data flights (eight flight segments) were flown by each pilot to evaluate the eight format arrangements. (See Appendix C for daily test schedule.) The order in which the pilots flew each format arrangement was randomized under the restrictions required for a balanced Latin square test design such that a flight segment with any one arrangement was preceded equally often by each of the other arrangements and each arrangement was flown an equal number of times in each flight segment. Two data flight missions (four segments in each one), having the same number and type of task events, were used. The order in which they were flown was balanced across pilots. Eight of the sixteen pilots used the Branching Logic for keyboard operation and the other eight used the Tailored Logic. Specific task order and data entry information was independently randomized for each mission (see Paragraph 3.4.2.1).

3.3 TEST SUBJECTS

A total of sixteen A-7D pilots served as subjects in this experiment. The pilots had an average of 2866 flying hours.

3.4 TEST PROCEDURE

3.4.1 Pilot Briefing and Training

Throughout the briefing and training phases of the experiment the procedures were standardized such that each pilot received the same information and opportunity for familiarization with the format arrangements, keyboard logic, cockpit simulator, and procedures. Initial briefings and training were conducted

for small groups at the pilots' home base prior to their participation in the testing at Wright-Patterson Air Force Base. After familiarizing the pilots with the advanced "digital" airplane cockpit concept, the controls, displays, and procedures to be used in the current study were explained. Training related specifically to the operation of the MFK was then given in order to familiarize the pilots with the logic trees for each type of task to be completed during the test flights. Each pilot was trained on the same logic (Branching or Tailored) that he was scheduled to use during the data flights. One briefing involved the use of a random access slide projector and control panel made up of push button switches which simulated some of the available functions on the MFK mounted in the cockpit simulator. The purpose of this training was to familiarize the pilots with multifunction switches and progression through task logic levels. Also, the subjects heard a detailed logic briefing involving MFK logic packages which showed the operating sequence for each type of task.

After the home base training, each pilot traveled to Wright-Patterson Air Force Base for the on-site cockpit simulator briefing and testing. The information explained or demonstrated during the briefing is as follows:

- 1) The symbology and dynamics of the flight information formats
- 2) The location of information in each arrangement
- 3) The type and location of the MFK
- 4) The operating sequence of the assigned keyboard logic for each type of task to be completed during the test flights
- 5) The pilot's tasks
- 6) Procedural instruction
- 7) Pre-entry readout, error messages, and status information
- 8) Correction procedures after entering the wrong digits or incorrectly progressing through the logic level steps
- 9) The use of the throttle, pitch trim knob, stick switches, backup flight instruments, flight phase switches, engine instruments, master arm switch, intercomm system, and brightness controls

During the briefing, a demonstration was given in which the displays were illuminated and the keyboards were operable, but the scoring program was inactive. The flight dynamics of the displays were also placed in a "hold mode" so that the pilot was not required to fly the simulator while he practiced the selection of appropriate options for each task.

After the cockpit briefing, a simulation training flight consisting of four flight segments was conducted in order to give the pilot experience with the handling qualities of the simulator, keyboard operation, and operational procedures of the test conditions. During the training flight, the pilot completed at least three tasks in each of the four flight segments. At the end of the flight each pilot had completed at least one task of every task type. Each of the four training flight segments had the same format arrangements, in the same order, as the first four data flight segments. A second training flight was conducted after the first data flight. Each pilot again completed three tasks in each of the four flight segments. The format arrangement for each segment, and the order of the flight segments was the same as that for the second data flight. The pilots required a second training flight so that they would have practice using the four new format arrangements while operating the keyboard.

3.4.2 Test Flights

3.4.2.1 Mission and Tasks

Throughout each flight, the symbology and information displayed on the HUD, VSF, ADI, and HSF were dynamic in response to thrust, bank, yaw, and pitch inputs. The ground tracks did not involve any turns greater than 30 degrees or altitude changes greater than 15,000 feet. Each flight segment took approximately 15 minutes to fly at the conditions specified. Information on the status display was updated in response to data inputs on the MFK and aircraft position. During the bombing segment, weapons information was shown on the status display in addition to the communication and navigation status.

The pilot's flying task was to maintain groundspeed and keep the flight director symbol centered on the HUD, VSF, or ADI. The pilot's keyboard task was to complete communication, navigation, and stores management tasks on the MFK. These tasks were typical of tasks encountered on a single-seat fighter aircraft mission. The fact that both flying performance and keyboard operation performance were to be recorded was stressed to the pilots. Each of the test missions consisted of four flight segments: TAKEOFF/CLIMB, CRUISE, NAV BOMB, and PRECISION APPROACH. (See Appendix D for the cockpit configuration and systems status at the initialization of each flight segment.) Each mission involved the same type and number of keyboard tasks. The tasks are shown in Table 1. The data entry information and task order were randomized independently for each mission. Mission scenarios were constructed around each set of randomized tasks in order to provide a high degree of external realism. In this way, the task orders appeared logical. The task instructions were given over the headset using standard controller terminology. (See Appendix D for task order data entry information and mission script excerpts.)

3.4.2.2 MFK Logic

In order to investigate the ease of selecting data on the MFK, two types of logic were examined. The keyboard logic in which the pilot pressed one of the system select switches to call up pages of options appropriate to that single system, is referred to as Branching Logic (Figure 1). The Tailored Logic, rather than presenting the second level options only appropriate to the system select switch chosen, allowed the pilot access to the second or third logic level for several systems (Figure 3). The options provided on the first page were those that the pilot was likely to require during the particular phase of flight selected on the flight phase switches. In order to contrast Branching and Tailored Logic, the following example is given. The Branching Logic used for the UHF communication task previously described required selection of the COMM system select switch, UHF multifunction switch on the first page from the available radios, UHF CHNG multifunction switch, digits and ENTER on the DEK. The Tailored Logic, however, presented immediately available options for several systems (UHF CHNG, BOMB TGT, ALT HOLD, CRS SET, WEAPON OPTION, etc.) when the NAV BOMB flight phase switch was selected. To complete a UHF change, the pilot had to select only the UHF CHNG multifunction switch, digits, and ENTER on the DEK.

Each task that the pilot was required to complete involved either one task or several subtasks. In the Branching Logic, only one activation of

TABLE 1

MFK COMMUNICATIONS, NAVIGATION, AND WEAPONS TASKS

TASK		NUMBER PER MISSION
1.	TASK: Change UHF Channel	2
2.	TASK: Change UHF Frequency	2
3.	TASK: Change UHF Channel and Frequency	1
4.	TASK: Change IFF code	2
5.	TASK: Change IFF mode in/out status	1
6.	TASK: SUBTASK: Change IFF code SUBTASK: Change IFF mode in/out status	2
7.	TASK: Change TACAN channel	5
8.	TASK: Change FLY TO waypoint number	1
9.	TASK: Change FLY TO latitude/longitude	1
10.	TASK: Change altimeter setting	2
11.	TASK: Change field elevation and decision height	1
12.	TASK: Change ILS frequency and course	1
13.	TASK: Change weapon quantity parameter	1
14.	TASK: SUBTASK: Change weapon quantity parameter SUBTASK: Change weapon interval parameter	1
15.	TASK: SUBTASK: Change weapon quantity parameter SUBTASK: Change weapon interval parameter SUBTASK: Change weapon drop mode parameter SUBTASK: Change weapon fuzing parameter	1

15 types of MFK tasks
24 tasks per mission or flight

a system select switch (either COMM for communication functions, NAV for navigation functions, or STORES for weapon functions) was required for each task. A subtask was defined as a set of specific MFK and DEK selections which logically could be considered a complete task if accomplished independently. For example, an IFF mode/code change could be a complete task as could an IFF mode in/out change. When the pilot was instructed to make both changes, they constituted subtasks. Prior to testing, the pilot was instructed that once he had started a subtask, he should complete it before starting another subtask. If the pilot did not correctly complete a subtask he was working on before he initiated another subtask, the computer ignored the selection made for the previous subtask and recognized the selections for the new subtask. In order to correctly complete the task, the pilot eventually had to redo the subtask he did not complete correctly.

Completion of each subtask required a particular operating sequence on the MFK. Each step in these operating sequences was called a logic level. Examples of the logic level sequences and specific legends are shown in Appendix E for both logic types as well as a description of the operating sequence for each task type. In addition, the format of the pre-entry and status information on the MFK display is explained.

3.4.2.3 Test Activity

The experimenters not only had the capability to monitor the pilot's keyboard and flying performance, but were able to control the initiation of keyboard tasks and termination of test flights. A schematic representation of the procedural steps is shown in Figure 15.

3.4.2.3.1 Pre-event Period of Baseline Flight Performance

The experimenter pushed a "PRE-EVENT" switch on the console which started a thirty second timer. Activation of this switch automatically designated the pre-event period of baseline flight performance recording. The PRE-EVENT switch remained lighted during the pre-event period. Concurrently, a countdown by seconds was displayed on the experimenters' status display. When the displayed countdown reached zero, the zero flashed until the experimenters initiated the task.

3.4.2.3.2 Task Event Instruction Period

Once the 30-second pre-event period of baseline performance had been recorded (pre-event switch light off, countdown "zero" flashing), an experimenter requested the pilot to complete a preprogrammed task.

The experimenter followed a written script (Appendix D) to insure that each pilot received the same instructions for a particular task and mission. All the experimenter's instructions were given over the headset using standard controller terminology. The information required by the pilot to complete the tasks was provided on a modified Flight Plan (AF Form 70; Appendix D) and was referenced during the instructions by the corresponding letter, or number. For example, the following were identified by a letter on the Form 70: UHF frequencies, IFF codes, altimeter settings, field elevations/decision heights, and ILS frequencies/courses. Instructions to enter waypoint information and TACAN channels were given by an experimenter as a numerical "November point" and weapon parameter

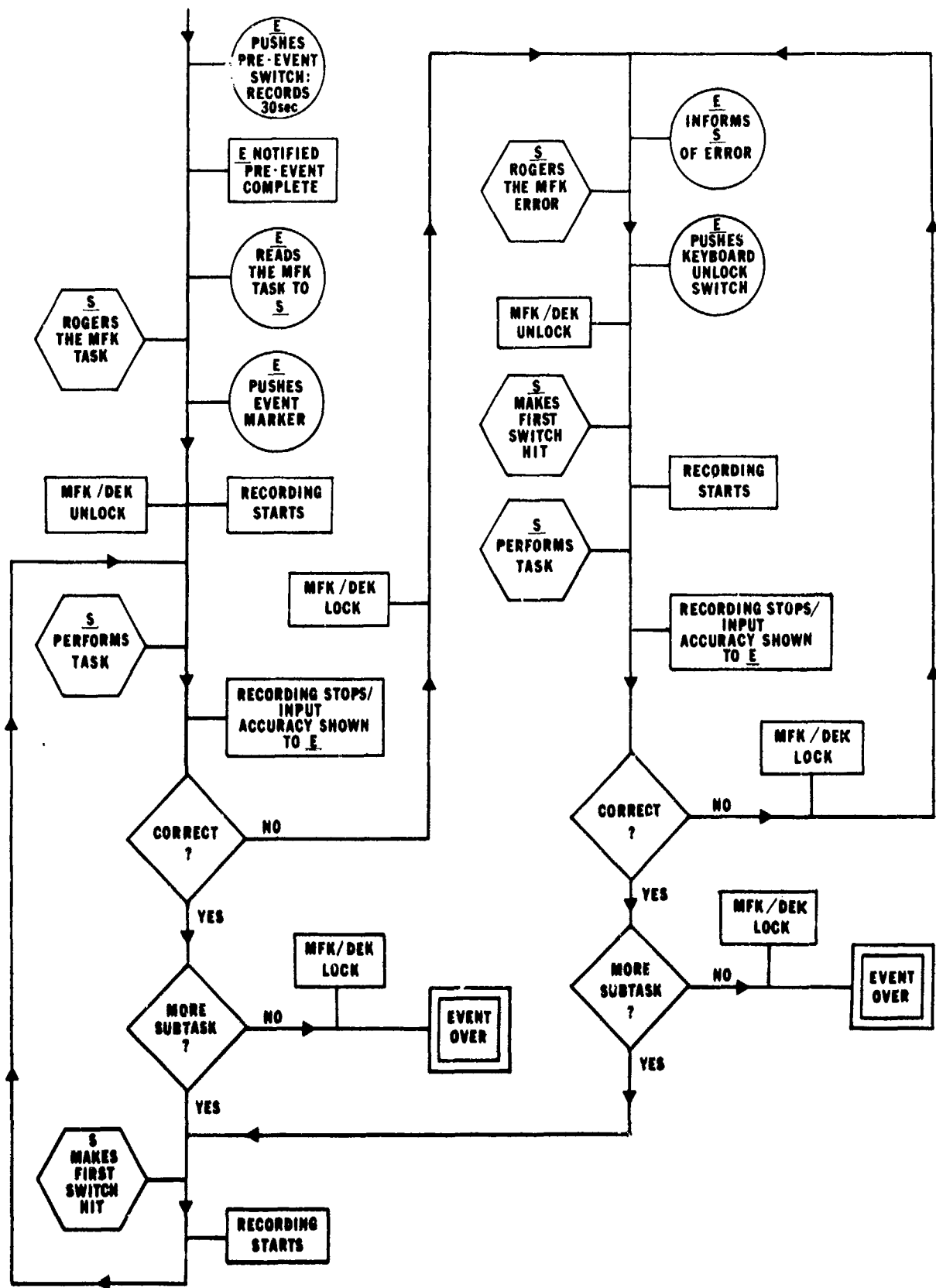


Figure 15. Schematic Representation of Procedural Steps for a Task

information was identified by weapon option numbers. By identifying the information in this way, errors due to forgetting or misunderstanding the information were minimized.

3.4.2.3.3 Task Event Period: MFK Operation Prior to Task or Subtask Completion

Concurrent with the pilot's acknowledgment of the instructions, the experimenter pushed an "EVENT MARKER" switch on the console to initiate the task. Activation of the event switch started recording of the flight parameters and keyboard operation measures and activated the MFK. Once the switch was activated, it remained lighted until the task was successfully completed. (Using these procedures, time to request a task or to acknowledge the instruction was not a part of the pre-event or task event time.)

The activation of the MFK enabled the pilot to select the appropriate options at each logic level for that particular task. Due to computer memory limitations and time constraints, only the options required for the tasks to be used in this experiment were programmed. If the pilot selected an option that was not programmed, he received the message "OPTION N/A" for that switch on the CRT. The legend disappeared with the selection of a programmed option. To correct the mistake, the pilot pushed the correct option for that task. Mistakes made by pushing an inappropriate programmed switch were corrected in the following manner: selecting the correct option if available on the same page or pushing the RETURN or appropriate system select switch (Branching Logic)/flight phase switch (Tailored Logic) and then selecting the correct option.

Once the pilot had progressed through the logic levels to the switch action that activated the DEK (DEK illuminated), each digit selected was displayed to the pilot. The pre-entry readout provided the pilot with the capability to verify that the digits selected were accurate. The readout disappeared when the task was completed. If the pilot made an error that was in the appropriate range or realistic for the task (example: 236.7 instead of 236.6 UHF frequency), the incorrect digit(s) were displayed in the pre-entry readout (236.7). In order to correct the mistake, the pilot had to clear the incorrect digit(s). One push of the CLEAR key on the DEK erased the last selected digit. Two pushes of the CLEAR key erased all the digits selected since the last activation of the ENTER key. The DEK remained activated and lighted after any push of the CLEAR key.

In addition to the pre-entry readout, an error message was displayed to the pilot when an error was made that was out of the appropriate range or unrealistic for a task. For example, if 6 was selected for the first UHF frequency digit, the message "BAD DATA" was displayed to the pilot next to the pre-entry readout. (As a first entry, a 6 is not in the appropriate frequency range for the UHF radio.) The actual illegal digit never appeared on the pre-entry readout, but was ignored by the computer. The DEK remained active and when the pilot made another switch hit on the DEK, the "BAD DATA" message disappeared. A second example involves the pilot selecting 21 instead of 22 as the first two digits of a UHF frequency 225.0. In this case the first digit was legal, but the second digit was out of the appropriate UHF range. Since the computer ignored the illegal digit and the first digit selected was legal, the pre-entry readout was 2 with the "BAD DATA" message displayed also. Of the first two digits, only the second digit had to be reselected.

When the pilot pushed too many legal digits, the message "CHECK DATA" was displayed next to the pre-entry readout, the pre-entry readout remained except that the surplus digits were ignored by the computer, and the DEK remained active. If the remaining selected digits were the desired entry (236.7 displayed if 23677 pushed), the pilot pushed the ENTER button. If the desired entry was 236.6 instead of 236.7, however, the pilot had to operate the CLEAR function to erase the 7 and select 6 in order to complete the task correctly. The "CHECK DATA" message disappeared with the first hit of the CLEAR or ENTER key.

3.4.2.3.4 Task Event Period: Verification after Task or Subtask Completion

The pre-entry readout and various messages described in the previous section only pertain to the keyboard operation prior to actual completion of a task or subtask. The tasks or subtasks to be used were considered complete once the pilot selected the ENTER key on the DEK or the SAVE (see Figure E11) function on the MFK.

Once a task or subtask was completed, whether it was correct or incorrect, all recording of data stopped. If a data entry had been required as part of the task, the DEK deactivated and the pre-entry readout disappeared. The computer then checked to see if the data selections and entry were the same as the information programmed for the subtask. The following describes the MFK configuration and operating procedures after the computer determined whether the completed task or subtask was incorrect or correct.

a) Incorrect task or subtask completion. If a task or subtask was completed incorrectly, the pilot was required to redo it. In the case of a task with several subtasks, the pilot only had to redo the subtask that had an error. Any subtask that was previously completed correctly did not have to be redone. The subtask or task error was displayed to the experimenters on the console and the pilot's MFK locked but remained active at the last level before subtask completion. After the pilot was notified by an experimenter over the headset that an error was made and the pilot responded that he understood, the "KEYBOARD UNLOCK" switch was selected. The pilot then started to redo the task or subtask; the pilot's first switch hit on the MFK of the retry initiated the recording of data. Note that the DEK was deactivated; if the pilot had to make a digit entry to correctly complete the retry, he had to reselect the switch on the MFK which calls up the DEK. When the keyboard operation was completed again, the recording stopped and the computer verified the entry.

b) Correct subtask or task completion. When the computer verified that a completed subtask or task was correct, the computer then checked whether more subtasks were to be completed at that time. If another subtask was to be completed, the MFK remained activated at the last level used during the completion of the previous subtask. (The DEK was automatically deactivated at subtask completion whether correct or incorrect.) The pilot's first switch hit on the MFK for the next subtask initiated data recording. In the case where no more subtasks were to be completed, the MFK and the DEK became locked and the task was considered finished.

An exception where the pre-entry readout remained after subtask completion was when the pilot entered too few legal digits (example: 236 for 236.7 UHF frequency). In addition, the MFK and DEK remained active and the

message "RE-ENTER DATA" was displayed next to the readout. The pilot's first MFK or DEK switch hit of the retry initiated the recording of data and erased the message.

3.4.2.3.5 Task Abort, Segment Complete and Flight Termination

Activation of the "ABORT TASK" switch on the experimenters' console terminated recording of a task and provided the experimenters with the capability to initialize the pre-event period for the next programmed task. This switch was only activated if the experimenters foresaw that the data being recorded was unusable and that the task would eventually have to be rerun.

Activation of the "SEGMENT COMPLETE" switch on the experimenters' console terminated the flight segment and automatically updated the control/display configuration to that specified by the next segment. The automatic sequencing could be overridden via input on the terminal.

After the pilot completed all the required tasks for the flight successfully, the experimenters terminated the flight by pushing the "MISSION COMPLETE" switch on the console. After the flight had been terminated, the summary statistic program was run to insure that all the data had been recorded. It should be noted that the capability existed to record data for any single task without rerunning the whole data flight.

3.4.2.3.6 Debriefing

Immediately after each format arrangement was evaluated (flight segment), the pilot was given a questionnaire concerned with the location of the information. Following the completion of all data flights, each pilot filled out a questionnaire designed to elicit subjective evaluations of the format arrangements, keyboard logic, and simulation qualities. In addition, each pilot completed a form concerning his background flying experience. (See Appendix F.)

3.4.2.3.7 Performance Measures and Data Analysis

The pilot's performance in terms of flying the simulator and operating the MFK was measured. The following flight parameters were recorded two times per second on magnetic tape.

- a) Groundspeed (knots)
- b) Flight director horizontal steering error (arbitrary units)
- c) Flight director vertical steering error (arbitrary units)

Appropriate summary statistics (average error, AE; average absolute error, AAE; root-mean-square error, RMS; standard deviation, SD (see Appendix G for formulae) were computed on these flight parameters for:

- a) The thirty second period prior to each task (pre-event period),
- b) The time period during which the pilot correctly selected and entered information for an assigned task.

The thirty second pre-event time was designated as baseline performance. Summary statistics for the pre-event time for each parameter were subtracted from the corresponding values computed for the time period required by the pilot to correctly complete an assigned task. This difference score quantified the level of flying task performance during keyboard task performance.

Keyboard task performance was evaluated by measuring:

- a) Keyboard operation time to correctly complete an assigned task.
- b) Number of switch hit errors.

The number of switch hit errors was derived by subtracting the actual number of switch hits required to accomplish the particular task without error from the total number of switch hits made. It should be noted that the selection of the master arm switch and pickle button during the weapon release was not recorded as a switch hit.

The flight data, keyboard operation time, and switch hit errors were recorded on magnetic tape for each task. The data were initially analyzed by multivariate analysis of variance (MANOVA) using the SPSS-MANOVA (Statistical Package for the Social Sciences) program available on the ASD CDC 6600 computer system (Ref. 5). In those cases where the MANOVA revealed significant effects, subsequent discriminant analyses were conducted in order to determine which of the dependent variables were most sensitive to changes in independent variables. The five dependent variables which were selected for these analyses are shown in Table 2.

In the first phase of the data analysis, flight performance during pre-event periods (no MFK task) with each format arrangement was examined. In the second phase of the data analysis examining control logic, each type of task completed by the pilots was treated separately. For example, the data recorded during UHF radio changes was treated apart from the data recorded during TACAN channel changes.

Data obtained from the debriefing questionnaires were compiled to be presented in tabular form and appropriate nonparametric analyses were conducted (see Appendix G). Descriptive statistics were computed on the biographical data obtained from the flight experience questionnaire to obtain an overall view of the characteristics of the pilot sample.

TABLE 2

Variables Used in Data Analyses

1. Groundspeed (knots) deviation	RMS
2. Flight director horizontal steering error (arbitrary units)	RMS
3. Flight director vertical steering error (arbitrary units)	RMS
4. Keyboard operation time (seconds)	
5. Switch hit errors	

All five variables were used in the analyses examining MFK logic differences. Only the flight performance variables (first three) were used in the analyses examining differences due to format arrangements.

4. RESULTS

The results of the statistical analyses conducted on the objective performance measures and the subjective questionnaire data are presented. (All tests conducted at $\alpha = 0.05$.) The findings of the data analyses examining format arrangements will be given first followed by the results of the tests comparing Branching and Tailored MFK Logics.

4.1 PERFORMANCE DIFFERENCES AMONG FORMAT ARRANGEMENTS

The MANOVA test conducted on the format arrangements examined flight performance (groundspeed deviation RMS, horizontal steering error RMS, and vertical steering error RMS) during periods with no MFK task. The results indicated that pilot performance significantly differed depending on the format arrangement flown ($F(21,2088) = 7.36$, $p < 0.01$). A discriminant analysis identified horizontal steering error as the variable contributing most to this effect (Figure 16).

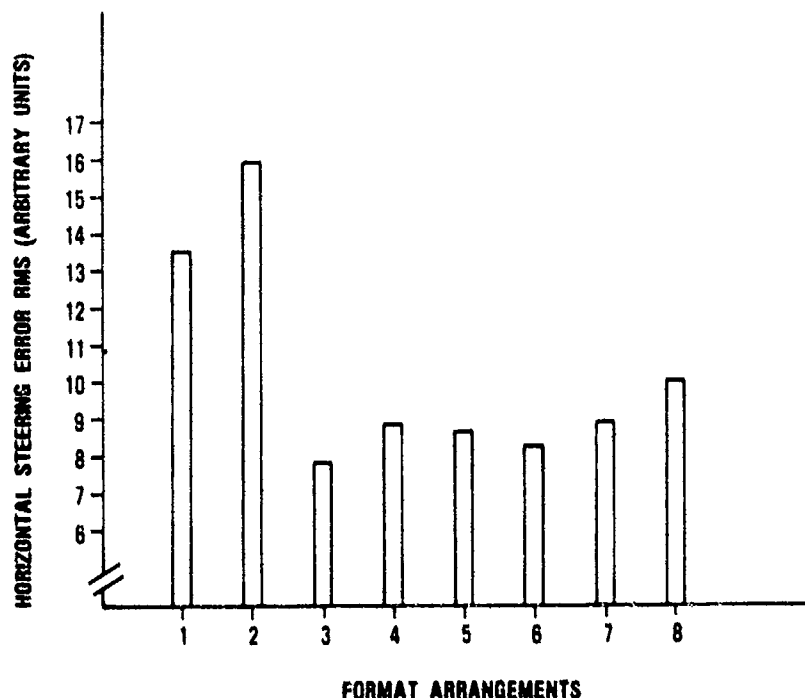


Figure 16. Horizontal Steering Error RMS with Each Format Arrangement

Further analysis by the application of a Tukey (b) procedure revealed a number of significant differences which will be discussed in terms of the arrangements utilizing the VSF, arrangements utilizing the conventional ADI, and arrangements utilizing the HUD. The results showed that horizontal steering performance data for Arrangement 3 (VSF on upper center display, HSF on lower center display) was better than data for Arrangements 4, 5, and 7 ($p < 0.05$, $p < 0.05$, and $p < 0.01$, respectively). Performance with Format Arrangement 8 (conventional instruments) was

worse than with Arrangements 3, 4, 5, 6, and 7 (VSF utilized, $p < 0.01$). Arrangements utilizing the VSF or conventional ADI (Arrangements 3-8) showed better performance than arrangements utilizing the HUD ($p < 0.05$). Furthermore, performance with the HUD in Arrangement 1 was better than that with the HUD in Arrangement 2 ($p < 0.01$).

In the debriefing questionnaires, the pilots rated their ability to use each format arrangement as satisfactory or optimum and they responded that all arrangements were useable as a backup in the event of failure ($p < 0.01$; Appendix F1). The majority of the pilots rated Format Arrangement 3 as efficient ($D(17) = 0.36$, $p < 0.05$) and Arrangements 5, 6, and 8 as inefficient ($D(17) = 0.40$, $p < 0.01$; $D(17) = 0.40$, $p < 0.01$; $D(16) = 0.34$, $p < 0.05$, respectively). Analyses of the other questionnaire items concerning the format arrangements failed to reveal significant differences among responses.

4.2 PERFORMANCE DIFFERENCES BETWEEN MFK LOGIC TYPES

Performance under the control logic types -- branching and tailored -- was analyzed for each type of task. The tasks were: IFF change, ILS course/frequency set, altimeter set, elevation and decision height set, FLY TO set, UHF change, TACAN change and weapon option change. Regardless of task type, keyboard operation time was faster (Figure 17) and more accurate (Figure 18) with the Tailored Logic compared to the Branching Logic.

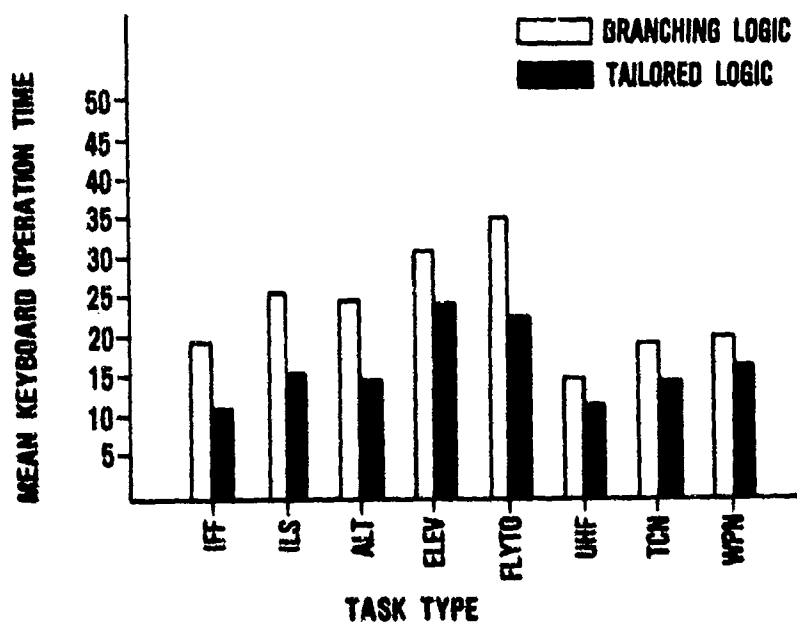


Figure 17. Mean Keyboard Operation Time Required with Each Logic Type for Each Task Type

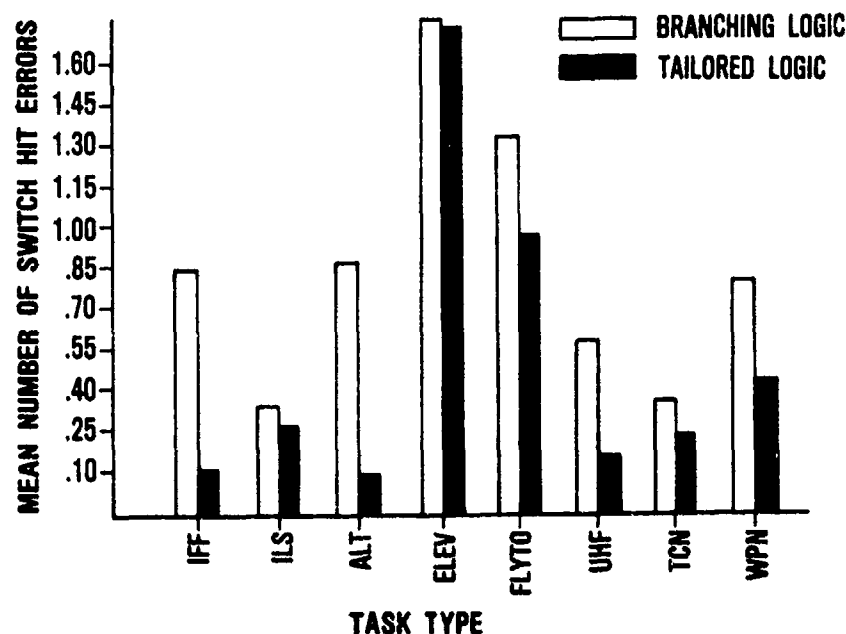


Figure 18. Mean Number of Switch Hit Errors Made with Each Logic Type for Each Task Type

The MANOVA of the IFF tasks indicated that pilot performance significantly differed depending on the type of control logic used ($F(5,10) = 5.40, p < 0.01$). A discriminant analysis showed that keyboard operation time was the dependent variable most sensitive to MFK logic differences. Performance was significantly faster with the Tailored Logic (11.17) than that with the Branching Logic (19.31; $p < 0.01$; Figure 19). These differences are paralleled in the analyses of the ILS and altimeter set tasks. While the data does not achieve significance at the .05 level

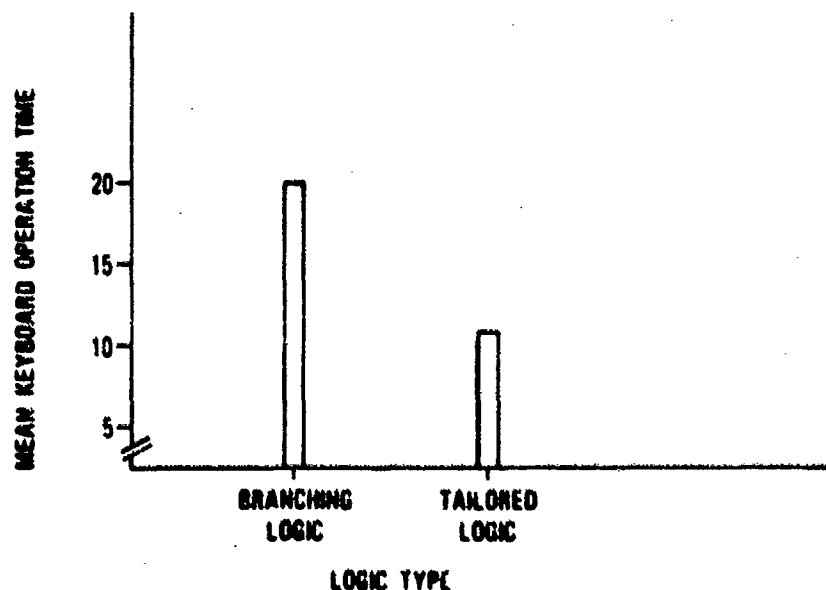


Figure 19. Mean Keyboard Operation Time Required for Completion of IFF Tasks with Each Logic Type

($F(5,10) = 2.57$, $p < 0.10$ and $F(5,10) = 3.13$, $p < 0.06$, respectively), the trends are clearly supportive of the IFF data. Keyboard operation time was the most sensitive variable and operation with the Tailored Logic was faster than that with Branching Logic ($p < 0.01$; Figure 17).

Significant performance differences due to type of control logic were also found in the MANOVA for the elevation tasks ($F(5,10) = 6.51$, $p < 0.01$). However, the variable identified by the discriminant analysis as contributing most to this difference was the vertical steering error measure. Ability to control the vertical steering command during the MFK tasks was better with the Branching Logic (6.27) than with the Tailored Logic (23.92; $p < 0.01$; Figure 20).

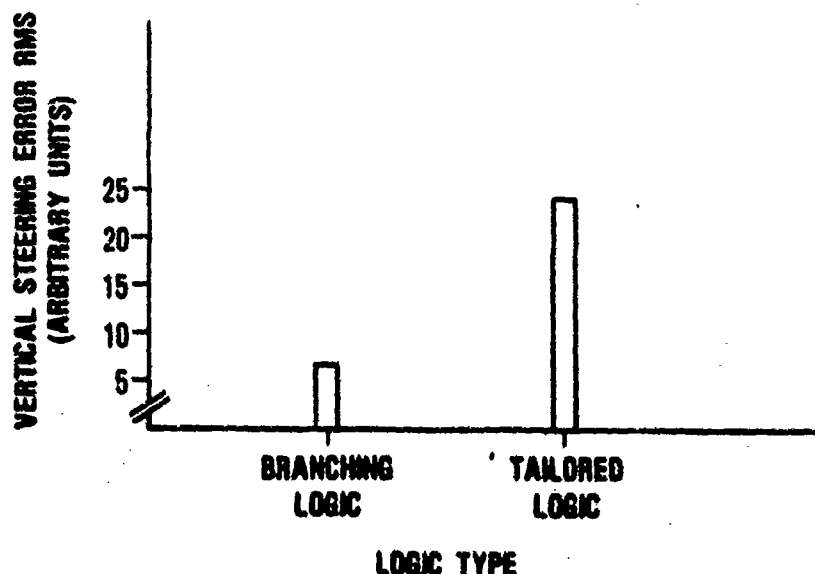


Figure 20. Vertical Steering Error RMS During Elevation Tasks with Each Logic Type

Analyses were also conducted on the FLY TO, UHF, TACAN, and weapon option tasks. The results showed no significant differences in performance between the control logic types. In addition, no significant performance differences were found among subtask types (two of FLY TO tasks and three of IFF, UHF, and weapon tasks (see Section 3.4.2.2)) as a function of logic type. As was expected, due to the varying number of switch hits required for each subtask, MFK operation time performance differed among subtask types. Significant differences were found in those subtasks which required the same MFK switch(es) but varying numbers of digit selections (IFF subtasks — $F(10,218) = 7.49$, $p < 0.01$; UHF subtasks — $F(5,60) = 5.75$, $p < 0.01$; FLY TO subtasks — $F(5,28) = 9.51$, $p < 0.01$).

In the final debriefing questionnaire, the pilots were asked to compare the standard control heads with the logic implemented on the MFK in terms of their ability to complete mission related tasks. All of the pilots who used the Tailored

Logic indicated that the MFK was better than the standard whereas only five of the eight pilots who had the Branching Logic indicated likewise ($\bar{D}(17) = .65$, $p < 0.05$). The pilots were also asked to compare the standard control heads with the MFK for each type of task. The only significant difference found in the responses was for the TACAN task -- all pilots who used the Tailored Logic found the MFK better than the conventional control and two pilots who used the Branching Logic found the MFK better ($\bar{D}(17) = .723$, $p < 0.05$). When the responses for this question were collapsed across logic type, the majority of the pilots felt the MFK was better than the conventional control head to complete UHF, IFF, TACAN, FLY TO, altimeter, ILS, and weapon option tasks ($p < 0.01$; Appendix F2).

5. DISCUSSION

In this section the findings of the data analyses examining format arrangements and MFK logic will be discussed, in turn. When applicable, the subjective comments of the participating pilots are referenced.

5.1 FORMAT ARRANGEMENTS

The main issue in regards to the various format arrangements is whether they are useable and acceptable as backups in the event of a CRT failure. For, if alternate locations of information are acceptable, the flexibility of the computer can be exploited and the pilot will not lose any information.

The results showed that the pilots felt that all arrangements were useable as a backup in the event of failure. However, performance differences were found among the arrangements. Even though some of these differences were significant, whether the differences were practical is questionable. For example, the largest significant difference of the mean horizontal steering error RMS was 8.6 arbitrary units which corresponds approximately to 30° . Such a difference may not be sufficient reason to deem an arrangement unacceptable. The findings regarding format arrangements do, though, provide some indications of which arrangements are best to use when the formats cannot be presented in their usual configuration. The following describes these findings in more detail.

As was expected, Display Arrangement 3 which had the VSF on the center top CRT and the HSF below (similar to the placement of flight control and navigation information in most aircraft) was better than three of the four other arrangements which included the VSF (Arrangements 4, 5, and 7). In Arrangements 4, 5, and 7, the formats were not presented in the same relative location, i.e., flight performance over navigation map. Rather the two formats were either flipped, placed horizontally, or placed diagonally. The pilots commented that the crosscheck among displays in these arrangements was difficult. In Arrangement 6, however, the formats were kept in the same relative vertical positions but moved to the two right CRTs. This latter arrangement did not degrade flight performance significantly.

Performance data for all the display arrangements utilizing the VSF (Arrangements 3-7) were better than data for Display Arrangement 8 in which a conventional ADI was utilized. There are several reasons which could account for these performance differences. For instance, the formats of the ADI and HSI are very different from the CRT formats. The airspeed, altitude, and heading information was integrated onto one display in the VSF arrangements, while, in the arrangement utilizing the ADI and HSI, this information was presented on separate instruments. It is also thought that the integrated flight director on the VSF served as a better command indicator than the separate pitch and bank steering bars on the ADI. In addition, even though the flight control information was positioned above the navigation information, the conventional displays were smaller and were located on the left front panel. This location, which was only examined for the conventional instruments, may have degraded performance.

Pilot flight performance was found to be better with arrangements utilizing the VSF or conventional ADI than with arrangements utilizing the HUD. One reason for this may be that the flight path angle parameter on the HUD was slightly more

sensitive than the pitch angle parameter on the VSF due to the nature of the software implementation. Another reason may be that the crosscheck distance to the groundspeed readout was further in the HUD configurations than the others. The fact that performance was worse in Arrangement 2 where the groundspeed readout was on the bottom center CRT compared to Arrangement 1 where the groundspeed was on the top center CRT supports this explanation. The report of these findings should not be construed as evidence for the use of the VSF instead of the HUD since the purposes of these flight display formats and implementation are very different.

5.2 MFK LOGIC

Keyboard operation time was faster and more accurate with the Tailored Logic compared to the Branching Logic, regardless of MFK task type. Thus, tailoring the logic to the flight phase does affect pilot performance. The fact that significant time savings can be realized on this sample of tasks implies that a considerable reduction in overall workload can be achieved. The pilots were also quite enthusiastic about the MFK concept and indicated a preference for the Tailored Logic in their informal reactions. It is suggested that the Tailored Logic should be used as the primary logic in actual aircraft applications. The Branching Logic should also be implemented concurrently so that the pilot can access infrequently used functions not available in the Tailored Logic.

With respect to each type of MFK task, the amount of performance difference between the logics varies. Detailed examination of the switch hits required by the logic for each task type suggests an explanation for why significant performance differences were only observed in some tasks and stresses the importance of several design criteria to the optimization of control logic. An attempt will be made to show that the performance differences between logic types are more apparent in the tasks which had additional visual search and hand motion due to the following conditions:

- (1) Several different subtasks were required under one task type (IFF MODE/CODE, IN/OUT, etc.) and the subtasks were randomly assigned throughout the flight.*
- (2) Task completion required selection of different MFK multifunction switches, rather than repeated selection of the same switch.
- (3) Task completion required selection of switches in nonideal locations (other than top and bottom switches of columns).

Completion of the IFF tasks involved several of these conditions. First, the pilot's choice of switches depended upon which of the programmed functions the experimenter specified. Second, the required switch was in a nonideal location (i.e., third switch on left column). The Tailored Logic required one less multifunction switch hit than the Branching Logic, thus reducing the visual search and hand motion required.

*See Sections 3.4.2.1 and 3.4.2.2 for description of tasks and procedures used in establishing task order, etc.

In the Branching Logic, the altimeter set task also required a visual search of the MFK in order to locate two different switches, one of which was in a nonideal location (i.e., fifth switch on left column and third switch on right column). The altimeter task in the Tailored Logic, however, required only one switch that was in a nonideal location.

Although the ILS change task required repeated selection of the same switch in the Branching Logic, the switch was located in a nonideal location (third switch on left column) and it was also required for elevation tasks. Since two of the required task types involved the same ILS switch, some additional thought, and consequently time, may have been required for its activation. In the Tailored Logic, however, only one switch in an ideal location (first key on right column) was required and that switch was only required for ILS change tasks.

Performance differences were also observed between Branching and Tailored Logics for the elevation set tasks. The task in the Branching Logic required selection of two different switches in nonideal locations (i.e., third and fourth switch on left side). In addition the first switch hit, ILS, was also required for ILS change tasks. Once again, more time may have been required for its activation since the same switch was required for two types of tasks. In fact, operation did take less time in the Tailored Logic (24.62) compared to the Branching Logic (31.90). While the elevation could be set more rapidly using the Tailored Logic, there were also significant errors in control of the vertical steering command. It is believed that the difficulty in maintaining vertical steering stems from the fact that the elevation task in the Tailored Logic is a short task -- selection of only one multifunction switch was required. It may be that the pilots rushed through this short task without reference to vertical control while on the longer task, i.e. using Branching Logic, they were more likely to pause between switch activations to check flight parameters.

The absence of performance differences due to logic type in FLY TO, UHF, TACAN, and weapon tasks was most likely due to the fact that these tasks required less visual search and hand motion. Completion of the FLY TO, UHF, and TACAN tasks in the Branching Logic all required two successive pushes of the same multifunction switch. In addition, the required switch hits for these tasks remained the same throughout the flights. The stores tasks did, though, require selection of more multifunction switches, as many as all five switches of the left column. Most of the subject pilots accomplished the task by hitting the top left column switch first and then the second left switch and so on. This left column switch selection method may have lessened the visual search requirements for this particular task.

As can be seen in the foregoing, performance differences between logic types were more apparent when task completion involved additional visual search and hand motion. Performance differences were found in tasks where the subtasks varied throughout the flight (e.g. subtasks within IFF), where task completion required selection of different MFK switches in nonideal locations (e.g., IFF and altimeter tasks), and where the same switch was required for different task types (ILS and elevation tasks). For these tasks with additional visual search and hand motion in the Branching Logic, performance was much improved in the Tailored Logic by requiring fewer switch hits.

The Tailored Logic, however, was not as much of a savings for those tasks which required minimal visual search and hand motion in the branching logic (e.g.,

tasks requiring repeated selection of the same switch). These findings suggest that when logic is programmed such that the required switches are in ideal locations and switch actions involve repeated selection of the same switch, MFK operation is more efficient. Factors like these must be considered, especially for tasks not available in the Tailored Logic.

6. CONCLUSIONS AND RECOMMENDATIONS

As a result of this evaluation on format arrangements and MFK logic, the following conclusions and recommendations can be made.

6.1 FORMAT ARRANGEMENTS

Any of the format arrangements examined in this study are useable as a backup in the event of CRT failure. However, some arrangements were found slightly better than others — arrangements in which the flight control information was placed over the navigation information and arrangements utilizing the VSF and HSF formats. It is recommended that the ability to switch formats among displays be implemented in computerized avionics systems. First, however, an evaluation should be made which addresses whether the format arrangements should automatically be relocated when a failure occurs (with a pilot override function) or whether only the pilot should determine how the formats are relocated. More detailed investigation should also be conducted to determine the best arrangement of formats in terms of: 1) the current flight phase and the corresponding information required (e.g., flight control, navigation, sensors, weapons, engines, etc.), and 2) the type of failure (e.g., complete or partial, single device or several, etc.).

6.2 MFK LOGIC

Tailoring the logic to the flight phase does affect pilot performance -- multifunction keyboard operation was more efficient with the Tailored Logic than with the Branching Logic. The acceptability of using the Tailored Logic as the primary logic and using the Branching Logic to access infrequently needed functions not available in the Tailored Logic has not yet been determined. Evaluation should be conducted which examines the concurrent implementation of Branching and Tailored Logics during simulated flight.

APPENDIX A

COCKPIT SIMULATOR

1. ELECTRO-OPTICAL FORMATS

Four electro-optical formats were used in the present study to provide information for utilization by the pilot. The following describes each display in detail:

1.1 Head Up Display (HUD) (See Figure 7)

The horizon and flight path angle lines of the flight path scale represented the horizon and each five degrees of flight path angle (FPA) between plus and minus 90 degrees. Positive FPA was presented as solid lines and appeared above the horizon line. Negative FPA was presented as dashed lines and appeared below the horizon line. The five degree increments were numbered on either end of the FPA lines. A minus sign preceded the numbers for negative angles.

The aircraft velocity vector was represented by a flight path marker (FPM) which denoted the point toward which the aircraft was flying at all times. The FPM moved horizontally and vertically, but was not roll stabilized to show bank angle. Rather, the flight path scales and their associated numbers were roll-stabilized and rotated to the appropriate bank angle.

The airspeed, heading, and altitude scales were not roll-stabilized. The airspeed and altitude scales were vertical and appeared on the left and right sides of the display, respectively. The heading scale was horizontal and appeared at the top of the display. The airspeed scale was graduated in 25 knot increments and numbered each 50 knots. At least three sets of numbers were visible at all times. An exact readout of current airspeed was presented in the window in the center of the scale. The readout changed whenever the airspeed changed by one knot. The scale numerics were not superimposed over the window display, but were removed in that area from the CRT.

Calibrated airspeed was displayed in the TAKEOFF/CLIMB and PRECISION APPROACH segments and true airspeed was displayed in the CRUISE and NAV BOMB segments. The abbreviations CAS or TAS, respectively, appeared below the airspeed scale.

Barometric altitude was displayed on the altitude scale on the right side of the HUD. The scale was graduated in 250-foot increments numbered each 500 feet and at least 3 sets of numbers were visible at all times. The total range of the altitude scale was from minus 1,000 feet to plus 99,999 feet with 1,500 feet in view at all times. An exact readout of the altitude was provided in the window in the center of the scale. The readout changed whenever the altitude changed by 1 foot. The scale numerics were not superimposed over the window, but were removed in that area from the CRT. When a 500-foot scale mark moved off the scale, the numerics were removed at that end. Numerical digits were added to the scale when a 500-foot mark was added to the scale as it moved.

The heading scale was displayed at the top of the HUD. Forty scale degrees were in view at all times, graduated in five-degree increments, two digit

numbers every ten degrees. Total heading scale range was 360 degrees. The aircraft magnetic heading was displayed to the nearest degree in the window. The scale numerics were not superimposed over the window, but were removed in that area from the CRT. When a 10-degree mark moved out of the field-of-view, two digits were removed at that end. Two digits were added to the scale when a ten degree mark was added to the scale.

The flight director symbol indicated horizontal and vertical steering error information with respect to the flight path marker. The X, Y commands to position the flight director symbol were such that the pilot flew the flight path marker to the flight director by steering the aircraft in pitch and/or bank angle, i.e., the flight director was moved by the software to the flight path marker when it received the proper control signals.

Alphanumeric readouts were provided in the corners of the HUD. The vertical velocity was displayed (above altitude scale) in digital form with the readout changing in 1-foot-per-minute increments over a range of 0 to 9,999 feet per minute. A caret indicated vertical velocity direction, i.e., up or down. An abbreviation designating the current flight segment appeared below the altitude scale. The abbreviations T.O., CRUS, NBOMB and PA were displayed during the TAKEOFF/CLIMB, CRUISE, NAV BOMB, and PRECISION APPROACH segments, respectively. The mach number was displayed in numerical form in the upper left corner of the HUD. The digital readout changed each .01 increment of mach up to mach 2. During the PRECISION APPROACH segment, the flight path angle was displayed as a numerical value in the location previously used to display mach number. The numerals were preceded by the letter FP indicating flight path angle. The digital readout of flight path angle changed each tenth of a degree for a range of ± 90 degrees. A caret was used to indicate whether the flight path angle was positive (up) or negative (down). The current UHF radio frequency was displayed below the airspeed scale. When any digit changed on the format faster than two times per second (i.e., vertical velocity) that digit was displayed as zero.

1.2 Vertical Situation Format (VSF) (See Figure 8)

The horizon was indicated by the sky/ground texture. The range of the pitch scale was ± 180 degrees. Each 5-degree segment was indicated by lines. Each 10-degree line was numbered, with a minus sign preceding the number for negative pitch angles. Not less than four, nor more than five lines, were displayed in the total field-of-view. Positive pitch angles were depicted in solid lines and negative angles were indicated by dashed lines. The pitch scales were roll stabilized. If the pitch scales coincided with any other symbol or readout, that portion of the pitch scale which interfered was blanked out.

The airspeed scale was graduated in 25-knot increments numbered each fifty knots. At least three sets of numbers were visible at all times. An exact readout of current airspeed was presented in the window in the center of the scale. The readout changed whenever the airspeed changed by 1 knot. The scale moved every 1 knot. The scale numerics were not superimposed over the window display, but were removed in that area from the CRT. Calibrated airspeed (CAS) was displayed during all the flight segments except during the CRUISE segment in which true airspeed (TAS) was displayed. The appropriate abbreviation CAS or TAS was displayed below the airspeed scale to denote airspeed type.

Barometric altitude was displayed on the altitude scale on the right side of the VSF. The scale was graduated in 250-foot increments numbered each 500 feet. At least three sets of numbers were visible at all times. The total range of the altitude scale was from minus 1000 feet to plus 99,999 feet with 1500 feet in view at all times. An exact readout of the altitude was provided in the window in the center of the scale. The readout changed whenever the altitude changed by a foot. The scale numerics were not superimposed over the window, but were removed in that area from the CRT. When a 500-foot scale mark moved off the scale, the numerics were removed at that end. Numerical digits were added to the scale when a 500-foot mark was added to the scale as it moved. The altitude scale and associated symbols and numerics were not roll stabilized.

The heading scale consisted of a moving scale. A digital readout of the present heading, to the nearest degree, was displayed in a box. Twenty degrees either side of the index were visible at all times (40 degrees total). The scale was graduated in 5-degree increments and numbered each 10 degrees. Total heading scale range was 0-359 degrees. When a ten degree mark moved out of the field-of-view, the digits were removed at that end. Digits were added to the scale when a ten degree mark was added to the scale. As a scale number moved into the digital readout area, it was blanked and reappeared as it moved out of the digital readout area. The heading scale and associated numerals were not roll stabilized.

The bank angle scale was a fixed position scale with a variable-position pointer at the bottom of the screen. The bank pointer rotated 360 degrees around the VSF but was blanked to prevent interference with other information. The scale ranged to 60 degrees either side of 0.

The slip indicator was displayed at the bottom center of the format above the bank-angle scale. It indicated coordinated flight. During coordinated turns, the ball remained centered since the gravity and centrifugal forces were balanced. When the forces were unbalanced, the ball moved away from the center, indicating a slip or skid.

The flight director symbol indicated horizontal and vertical steering error information with respect to the aircraft symbol. The X, Y commands to position the flight director symbol were such that the pilot flew the aircraft symbol to the flight director by steering the aircraft in pitch and/or bank angle.

The vertical velocity was displayed in numerical form in a fixed location in the upper right corner of the display. A caret indicated vertical velocity direction; i.e., up or down. The digital readout changed with each one foot/minute change with a range of +9999 feet/minute.

The mach number was displayed in numerical form in a fixed location of the VSF. The digital readout changed each .01 increment of mach up to mach 2.

During the PRECISION APPROACH segment, the flight path angle was displayed as a numerical value in the location previously used to display mach number. The numerals were preceded by the letter FP indicating flight path angle. The digital readout of flight path angle changed each tenth of a degree for a range of +90 degrees. A caret was used to indicate whether the flight path angle was positive (up) or negative (down).

When any digit changed on the format faster than two times/second (i.e., vertical velocity) that digit was displayed as 0.

1.3 Horizontal Situation Format (HSF) (See Figure 9)

Simplified navigation information was presented in a track-up format. A map corresponding to a vertical distance on the HSF of approximately 80 miles was used. The aircraft's track was displayed at a fixed location centered at the top of the HSF. The value displayed ranged from 0-359 degrees.

The true track to the next waypoint, following the one currently being flown to, was displayed in the lower left corner as indicated in the figure with an "N" preceding the value of the track.

The fuel quantity was displayed in a fixed location below the next track angle in the lower left corner of the HSF. Fuel quantity was displayed with an "F" preceding the digital readout of the remaining fuel in pounds, e.g., F 17500.

The range scale was displayed in the lower left corner of the HSF and indicated the range covered by the map in nautical miles.

The distance to go to the next waypoint and the time to go to the next waypoint were displayed in the upper left corner of the HSF. The waypoint identifier was given, followed by the distance in nautical miles and the time to go to the nearest tenth of a minute.

The distance and time to the next target were displayed in the upper right hand corner. The course, distance, and time to fly direct to the next target were presented in the lower right-hand corner.

The groundspeed was displayed below the distance and time to the next target. Display of groundspeed was to the nearest knot and was preceded by the alphabetical characters GS, e.g., GS 461.

The crosstrack deviation was displayed on the HSF by the relative displacement of the track line on the map from the aircraft symbol. The aircraft was positioned laterally in the center of the display, but only about 1/5 of the way up from the bottom. The map moved under the aircraft symbol and was positioned to show the actual aircraft position in relation to the desired track.

The waypoint symbol and its identification (ID) was displayed anytime that waypoint was on the map. The letter "W" with a number identified waypoints and the letter "T" with a number identified targets.

1.4 Status Format (SF)

The status formats displayed mission related data to the pilot. In the TAKEOFF/CLIMB, CRUISE, and APPROACH segments, the SF displayed communications and navigation data (Figure 10) and the same information plus stores data during the NAV BOMB flight segment (Figure 11).

2. DEDICATED DISPLAYS AND CONTROLS

Most of the backup flight instruments in the cockpit simulator were inoperable in Arrangements 1-7 so that the pilot was forced to use the information displayed on the HUD or VSF and HSF to maintain control of the cockpit simulator. However, the following instruments, switches and indicators were operable and available for use by the pilot during all eight arrangements:

a) Angle of Attack (AOA). The AOA indicator operated through a range from 0 through 30 units.

b) Pitch Trim Knob (left console). Adjusted the alignment of the horizon line with the aircraft symbol on the VSF.

c) Master Arm Switch. Had to be in the arm position in order to deliver weapons.

d) Stick Switches. Trim button adjusted stick to neutral position. Bomb release button enabled a weapon option to be released.

e) Flight Phase Switches (upper center front panel; Figure A1). Only the T.O. CLIMB, CRUISE, NAV BOMB and PREC APPR flight phase switches were operable. The selected flight phase switch (lighted) determined the information displayed on the SF.

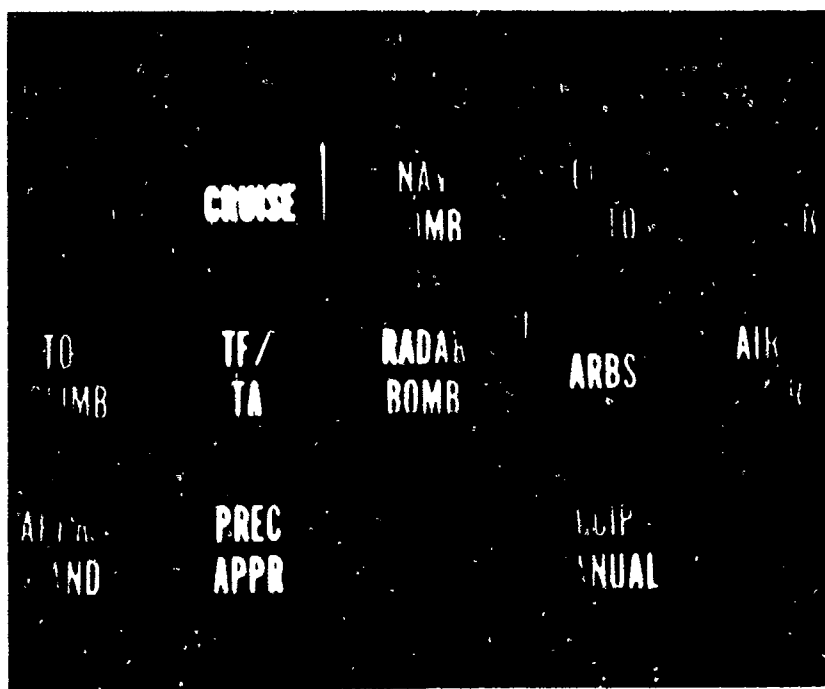


Figure A1. Flight Segment Switches

Engine instrumentation was provided during all format arrangements.

f) RPM. Indicated engine speed in percent RPM. The instrument was calibrated from 0 - 100%. The operating range was 52 - 100%.

g) Turbine Outlet Pressure (TOP). TOP was used as an indication of engine performance. Calibrated in inches of mercury, the operating range was 25 - 45 in. Hg.

h) Fuel Quantity. Indicated total usable internal fuel, ranging from 0 - 9,000 lb.

i) Turbine Outlet Temperature (TOT). Indicated TOT in degrees C (pointer and digital readout). The usable range was 0 - 1000 degrees C.

j) Oil Pressure. Indicated engine oil system pressure in psi. The instrument was calibrated 0 - 60 psi with a normal operating range of 27 - 53 psi.

APPENDIX B

EXPERIMENTERS' CONSOLE AND SIMULATOR FACILITIES

1. EXPERIMENTERS' CONSOLE

The console was equipped with CRT displays and status light matrices which provided the experimenters with the capability of monitoring the displays in the simulator and the actual switch actions (Figure 14). (During Arrangement 3 in which each pilot used dedicated instruments rather than electro-optical flight displays, the VSF and HSF were presented on the console to show flight performance.) A layout of the experimenters' console is shown in Figure B1. The following list specifies the functions allocated to each piece of equipment on the console that were used in the present study. Each letter refers to the notations used on the layout.

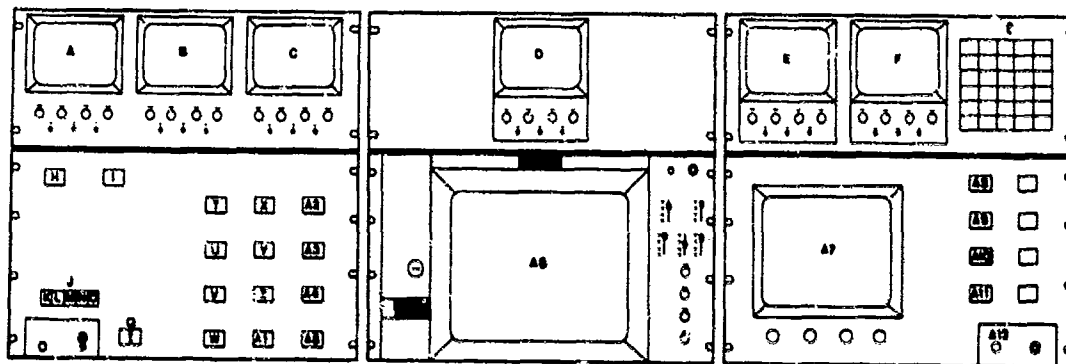


Figure B1. Layout of the Experimenters' Console

A = Status display (Figure B2); presented flight and task event information

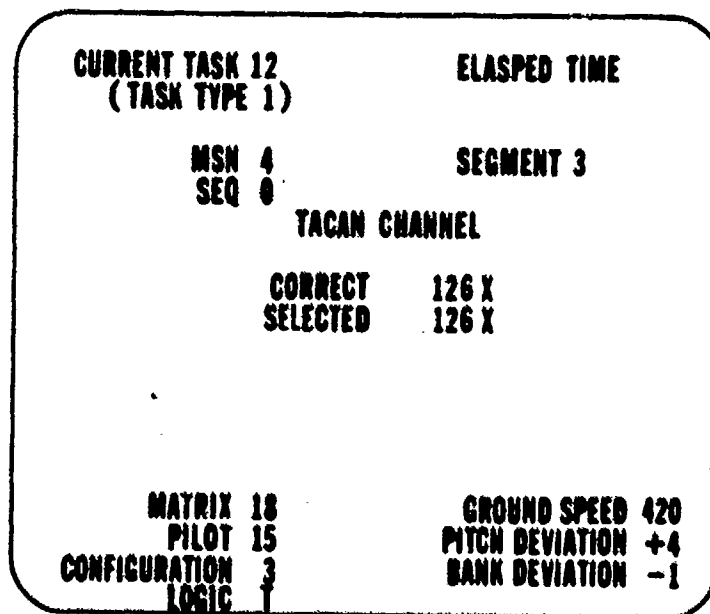


Figure B2. Status Display on the Experimenters' Console

B = Repeater display of multifunction switch legends on the MFK

C = Repeater display of the top right CRT

D = Repeater display of HUD

E = Repeater display of the bottom right CRT

F = Repeater display of the lower center CRT

G = Status panel lights; each status light stayed lit as long as the corresponding switch in the cockpit was activated.

H = Master power switch for facility

I = Abort switch for McFadden flight control systems

J = Interphone options (Note: the pilot's mike was always hot.)

K = On/off switch for interphone system

L = Switch enabled communication between two experimenters

M = Switch enabled experimenter/pilot communication

N = Switch enabled experimenter/computer personnel communication

O = Switch enabled communication between experimenters, pilot and computer personnel

P = Volume control for headset

Q = Voice recorder options

R = Run switch for voice recorder

S = Pause switch for voice recorder

T = Reset switch for McFadden system

U = Pre-event switch; activation initiated thirty seconds of flight data recording

V = Event marker switch; activation started recording of task event data and unlocked MFK

W = Mission complete switch (guarded); activation initiated the computerized data reduction procedures

X = Run switch for simulation

Z = Keyboard unlock switch; activation unlocked MFK in those task events where recording terminated after the pilot entered incorrect legal digits

A1 = Indicated whether tape recording was continual or voice activated

A2 = Hold switch for simulation

A4 = Segment complete switch (guarded); activation terminated test flight and automatically updated the controls/displays configuration to that specified by the next higher matrix number. The automatic sequencing could be overridden via input on the terminal.

A5 = Task abort switch (guarded); activation terminated recording of task event data and initialized system for next task event.

A6 = Repeater display of upper center CRT

A12 = Volume control for headset

2. SIMULATION FACILITIES

The simulator consisted of interconnected facilities as shown in Figure B3. A functional description of each system element is provided below.

a. PDP 11/50

Configuration Control - used to set up the cockpit controls/ displays configuration prior to each flight.

Display Assembly - generated image listings to be further processed by the Ramtek raster symbol generator. Data from the simulation models was used for the HUD, VSF and SF formats.

Map Driver - provided output control of map data to the Ramtek symbol generator.

Keyboard Logic - processed incoming switch data and determined the display state of all the keyboards.

Flight Control Sampling and Scaling - buffered and scaled flight control data to be used by simulation models.

Simulation Models - provided all necessary aircraft parameters to be used in display processing.

Data Recording - recorded cockpit display parameter data on magnetic tape.

Data Reduction - an off-line program reduced the raw real-time recorded data into meaningful data that could be analyzed.

b. Ramtek

Display Generation - processed image lists to display HUD, VSF, HSF, and SF on 480 line raster monitors.

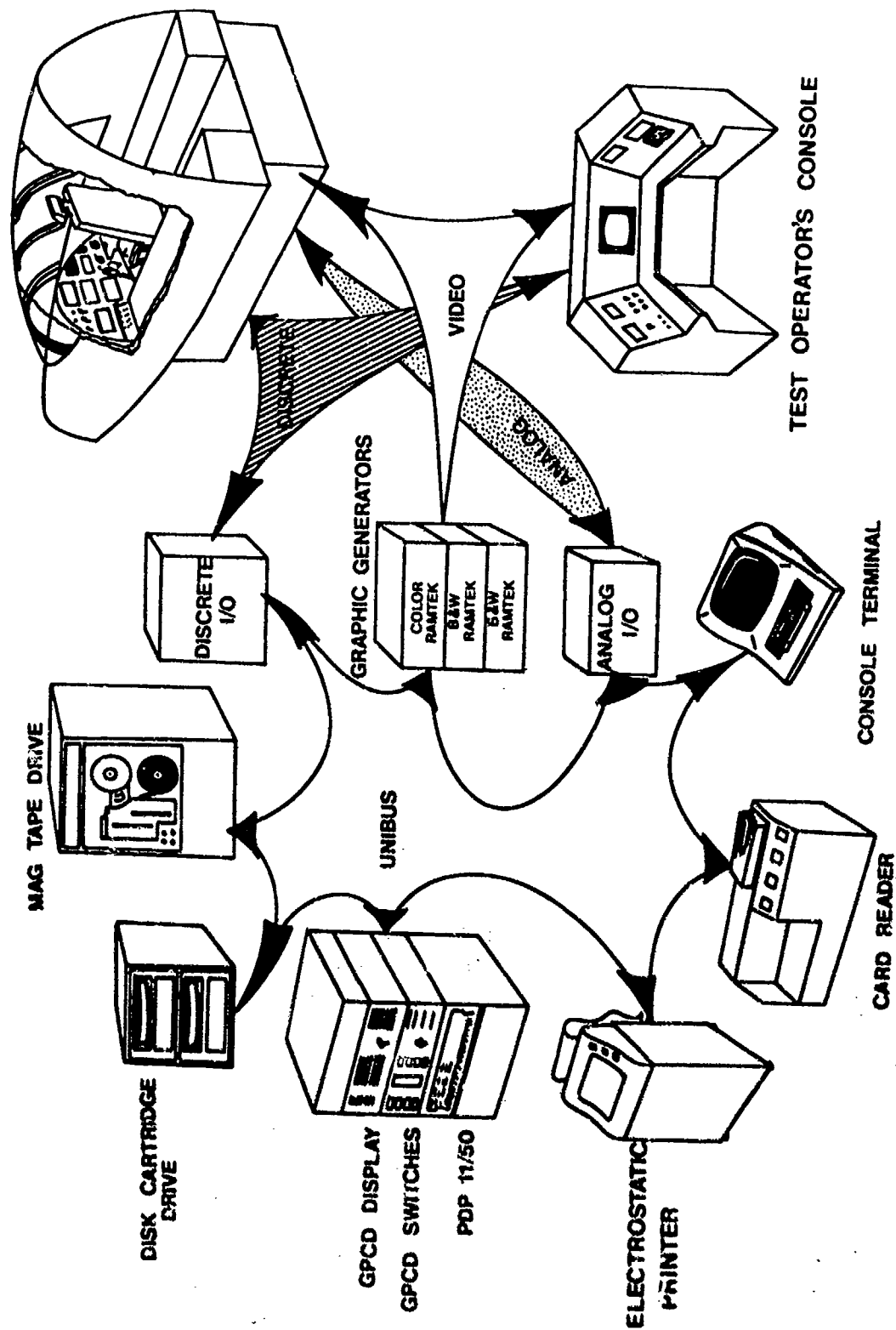


Figure B3. Simulator Facility Configuration

c. Cockpit

Keyboard Input/Output - provided a switch image buffer of all cockpit switch states to be sampled by the 11/50. Also decoded keyboard display data being sent from the 11/50.

Flight Control - Digitized analog stick, rudder, and thrust control inputs and buffered the resultant data for transmission to the 11/50.

d. Support Equipment

Console Terminal - system operators input/output device to the 11/50.

Printer and Card Reader - hard copy input/output to the 11/50.

Disk Drive - mass storage device for the operating system.

Magnetic Tape Drive - mass storage device for data collection.

Discrete and Analog Input/Output - input/output port from the 11/50 to all cockpit and experimenter consoles' subsystems.

APPENDIX C

DAILY TEST SCHEDULES

The daily test schedule (Table C1) indicates the time and activity to train, test, and debrief one pilot during one day of the experiment. Times for controls/displays familiarization, training flights, test flights, simulator reconfigurations, data verification, and debriefing are indicated in the schedule provided. Table C2 shows the schedule of flight segments for one data flight. As was mentioned in Paragraph 3.4.1, each pilot participated in a three hour briefing at his home base prior to the on-site testing.

TABLE C1
DAILY TEST SCHEDULE

TIME	ACTIVITY *
0900 - 1000	Cockpit Briefing
1000 - 1030	Training Flight 1
1030 - 1045	Break Simulator Reconfiguration
1045 - 1145	Data Flight 1
1145 - 1300	Lunch
1300 - 1330	Training Flight 2
1330 - 1345	Break Simulator Reconfiguration
1345 - 1445	Data Flight 2
1445 - 1500	Break
1500 - 1630	Pilot Completion of Final Debriefing Questionnaire

* See Paragraph 3.4 for description of each activity

TABLE C2

DATA FLIGHT SCHEDULE

0 - 12 minutes	TAKEOFF/CLIMB Flight Segment
12 - 15 minutes	Completion of Questionnaire * Simulator Reconfiguration
15 - 27 minutes	CRUISE Flight Segment
27 - 30 minutes	Completion of Questionnaire * Simulator Reconfiguration
30 - 42 minutes	NAV BOMB Flight Segment
42 - 45 minutes	Completion of Questionnaire * Simulator Reconfiguration
45 - 57 minutes	PRECISION APPROACH Flight Segment
57 - 60 minutes	Completion of Questionnaire *
60 - 75 minutes	Data Verification Simulator Reconfiguration

* Post flight segment questionnaire (see Paragraph 3.4.2.3.6 and Appendix F).

APPENDIX D

FLIGHT INFORMATION

A total of four missions, two for data flights and two for training flights were used in the experiment. Initial conditions for all the missions are specified in Table D1. The task order and data entry information for each mission are provided in Table D2. A sample symbolic map (Figure D1), Flight Plan (modified AF Form 70; Figure D2), and script excerpts (Table D3) are included.

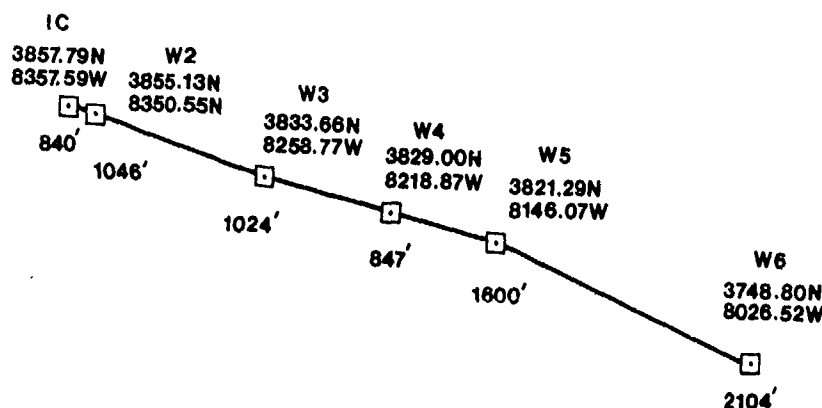


Figure D1. Sample Symbolic Map

The cockpit was in the following configuration at the initialization of each flight segment:

- a) Flight phase switches - either T.O. CLIMB, CRUISE, NAV BOMB, or PREC APPR flight phase switches activated.
- b) HUD or VSF - Flight parameters appropriate to that of level flight with an altitude of 2,000 feet in the climb and approach segments, and 17,000 feet in the cruise and weapon delivery segments. Calibrated airspeed of 383 knots.
- c) HSF - Aircraft position on track, approximately fifteen miles short of the first waypoint. Heading same as that for the first leg. Groundspeed of 420 knots and fuel amount of 7093 pounds.
- d) SF - Communications and navigation status information in all segments except the bombing segment where weapons information was presented as well.
- e) MFK - inoperative.

TABLE DL. INITIAL CONDITIONS FOR EACH MISSION

INITIAL CONDITIONS	DATA FLIGHT				TRAINING FLIGHT			
	CLIMB	CRUISE	NAV BOMB	PREC APP	CLIMB	CRUISE	NAV BOMB	PREC APP
MISSION 1 LOCATION HEADING UHF IFF TACAN MODE 1/2 MODE 3 FLY TO ALTIMETER SET ILS ELEV/DH WEAPON OPTION (Quantity, Interval, Mode, Fuze)	3640.25N	3855.13N	3640.25N	3855.13N	3242.10N	3242.10N	3242.10N	3242.10N
	8342.00W	8350.55W	8342.00W	8350.55W	8324.05W	8324.05W	8324.05W	8324.05W
	2000'	17000'	17000'	17000'	2000'	17000'	17000'	17000'
	033°	108°	033°	108°	254°	254°	254°	254°
	255.4	255.4	12386.3	344.1	250.1	250.1	13323.0	348.0
	11/2112	11/2112	11/2112	11/2112	24/2343	24/2343	24/2343	24/2343
	5445-OUT	5706	3336-OUT	3336-OUT	5462	5462	4041	4041
	111Y	110Y	121Y	121Y	101X	101X	101X	101X
	3	4	3620.95N	3620.95N	3619.50N	3619.50N	3608.07N	3608.07N
	28.99	29.83	7835.67W	7835.67W	8002.41W	8002.41W	8247.75W	8247.75W
MISSION 2 LOCATION HEADING UHF IFF TACAN MODE 1/2 MODE 3 FLY TO ALTIMETER SET ILS ELEV/DH WEAPON OPTION (Quantity, Interval, Mode, Fuze)	109.5/254	109.5/254	109.5/254	109.5/254	1083/312	1083/312	1083/312	1083/312
	945/300	945/300	945/300	945/300	964/300	964/300	964/300	964/300
	18.75,P,NT	18.75,P,NT	18.75,P,NT	18.75,P,NT	16.90,P,NT	16.90,P,NT	16.90,P,NT	12.75,P,NT
	10.90,P,NT	10.90,P,NT	10.90,P,NT	12.90,P,NT	18.70,P,NT	18.70,P,NT	18.70,P,NT	18.70,P,NT
	14.90,S,N	14.90,S,N	14.90,S,N	16.70,P,NT	14.70,P,NT	14.70,P,NT	14.70,P,NT	14.70,P,NT
	16.50,P,NT	16.50,P,NT	16.50,P,NT	14.80,P,NT	12.60,S,N	12.60,S,N	12.60,S,N	16.40,P,NT
	3932.35N	3847.00N	3932.35N	3847.00N	3222.07N	3222.07N	3222.07N	3222.07N
	7921.96W	7934.02W	7921.96W	7934.02W	8633.50W	8633.50W	8633.50W	8633.50W
	2000'	17000'	17000'	17000'	17000'	17000'	17000'	17000'
	254°	291°	254°	291°	088°	088°	088°	088°
MISSION 3 LOCATION HEADING UHF IFF TACAN MODE 1/2 MODE 3 FLY TO ALTIMETER SET ILS ELEV/DH WEAPON OPTION (Quantity, Interval, Mode, Fuze)	303.0	303.0	15390.9	262.5	348.0	348.0	16264.8	325.3
	12/2121	12/2121	12/2121	12/2121	21/3234	21/3234	21/3234	21/3234
	4343-OUT	4634	5210-OUT	5210-OUT	6436-OUT	4366	3649	3649
	104Y	116X	103Y	103Y	117X	105Y	105Y	105Y
	4	5	3619.50N	3619.50N	3620.95N	3620.95N	3745.00N	3745.00N
	29.99	30.24	8002.41W	8002.41W	7835.67W	7835.67W	8313.05W	8313.05W
	107.9/286	107.9/286	107.9/286	107.9/286	109.5/247	109.5/247	109.5/247	109.5/247
	567/250	567/250	567/250	567/250	1121/200	1121/200	1121/200	1121/200
	12.75,P,NT	12.75,P,NT	12.75,P,NT	10.75,P,NT	18.75,P,NT	18.75,P,NT	18.75,P,NT	14.65,P,NT
	16.60,P,NT	16.60,P,NT	16.60,P,NT	16.60,P,NT	16.90,S,N	16.90,S,N	16.90,S,N	18.45,P,NT
MISSION 4 LOCATION HEADING UHF IFF TACAN MODE 1/2 MODE 3 FLY TO ALTIMETER SET ILS ELEV/DH WEAPON OPTION (Quantity, Interval, Mode, Fuze)	18.80,S,N	18.80,S,N	18.80,S,N	14.50,P,NT	12.75,P,NT	12.75,P,NT	12.75,P,NT	12.75,P,NT
	14.100,P,NT	14.100,P,NT	14.100,P,NT	18.90,P,NT	16.40,P,NT	16.40,P,NT	16.40,P,NT	16.40,P,NT
	3932.35N	3847.00N	3932.35N	3847.00N	3222.07N	3222.07N	3222.07N	3222.07N
	7921.96W	7934.02W	7921.96W	7934.02W	8633.50W	8633.50W	8633.50W	8633.50W
	2000'	17000'	17000'	17000'	17000'	17000'	17000'	17000'
	254°	291°	254°	291°	088°	088°	088°	088°
	303.0	303.0	15390.9	262.5	348.0	348.0	16264.8	325.3
	12/2121	12/2121	12/2121	12/2121	21/3234	21/3234	21/3234	21/3234
	4343-OUT	4634	5210-OUT	5210-OUT	6436-OUT	4366	3649	3649
	104Y	116X	103Y	103Y	117X	105Y	105Y	105Y

TABLE D2. TASK ORDER AND DATA ENTRY INFORMATION*

SEG	TRAINING		TRAINING		DATA		DATA	
	MSN	TASKS	MSN	TASKS	MSN 1	TASKS	MSN 2	TASKS
C	1	ALT 28.98	1	ALT 30.12	1	IFF 3 IN, 6063	1	ALT 30.24
L	2	IFF 3 IN, 5462	2	IFF 3 IN, 4366	2	ALT 29.83	2	FLYTO 5
I	3	TCN 101X	3	TCN 105Y	3	FLYTO 4	3	IFF 3 IN, 6072
M	4		4		4	TCN 106X	4	TCN 124X
B	5		5		5	TCN 110Y	5	IFF 4634
	6		6		6	IFF 5706	6	TCN 116X
C	1	IFF 4041	1	IFF 3649	1	IFF 3336	1	TCN 113Y
R	2	UHF 13323.0	2	UHF 16264.8	2	TCN 112Y	2	UHF 15390.9
U	3	FLYTO 3608.07H/8247.75W	3	FLYTO 370045N/8313.05W	3	FLYTO 3620.95N/7835.67W	3	FLYTO 3619.50N/8002.41W
I	4		4		4	IFF 3 OUT	4	IFF 5210
S	5		5		5	TCN 121Y	5	IFF 3 OUT
E	6		6		6	UHF 12386.3	6	TCN 103Y
N	1	WPN OPT1, Q12, I75	1	WPN OPT1, Q14, I65	1	UHF 285.6	1	UHF 250.1
A	2	UHF 348.0	2	UHF 325.3	2	WPN OPT2, Q12	2	UHF 262.5
V	3	WPN OPT4, Q16, I40, P, T	3	WPN OPT2, Q18, I45, P, T	3	UHF 344.1	3	WPN OPT1, Q10
B	4		4		4	WPN OPT3, Q16, I70, P, T	4	ALT 29.72
O	5		5		5	WPN OPT4, Q14, I80	5	WPN OPT3, Q14, I50
M	6		6		6	ALT 30.16	6	WPN OPT4, Q18, I90, P, T
B								
P	1	ILS 109.7/254	1	ILS 110.1/342	1	TCN 119X	1	IFF 3 IN, 4021
R	2	ELEV 1123/200	2	ELEV 1012/250	2	IFF 3 IN, 5650	2	TCN 118X
E	3	UHF 14	3	UHF 13	3	ELEV 1860/250	3	ELEV 1765/200
C	4		4		4	UHF 17	4	UHF 10
A	5		5		5	ILS 108.3/312	5	ILS 109.5/268
P	6		6		6	UHF 19	6	UHF 18

*See Section 3.4.2.1 for additional information.

A 29.83	E 1860/250	I 108.3/312	P 3336	T 5650				
B 12386.3	F 285.6	J 17	Q 4021	U 5706				
C 30.16	G 344.1	K 12	R 109.5/282	V 6063				
D 29.92	H 262.5	L 19	S 1260/200	W 6072				
AIRCRAFT IDENT		TAKE-OFF TIME	TOTAL DISTANCE	TOTAL ETL	TOTAL AMT FUEL			
IDENT		MAG	DISTANCE	GROUND	ETE	ETA	LEG	ACTUAL FUEL REMAIN
FREQ		CRS	REMAIN	SPEED	REMAIN	ATA	REMAIN	
3716.72N	#3	033	47	420	07:00			
8312.87W			167		24:00			
3745.00N	#4	043	39	420	06:00			
8246.65W			128		18:00			
3822.35N	#5	062	80	420	11:00			
8136.10W			48		07:00			
3851.89N	#6	051	48	420	07:00			
8059.00W			--		--			
OPTION 1		OPTION 2		OPTION 3		OPTION 4		
18MK82 PAIRS ALL 75 FT NT		12MK82 PAIRS ALL 90 FT NT		16MK82 PAIRS ALL 70 FT NT		14MK82 PAIRS ALL 80 FT NT		
NOVEMBER DATA								
1. 9		4. 4		7. AVN 112Y		10. WIN 121Y		
2. 6		5. 3619.50N 8002.41W		8. NBG 119X		11. WHP 106X		
3. 3620.95N 7835.67W		6. 3629.98N 8120.35W		9. ORT 110Y		12. NIW 121X		

Figure D2. Sample Flight Plan

TABLE D3

EXCERPTS FROM MISSION SCRIPT (EXAMPLE OF EACH TASK TYPE)¹

CLIMB SEGMENT

DRAGON 10, CINCINNATI CENTER, WE HAVE RADAR CONTACT,
CONTINUE CLIMB ON COURSE.

TASK 1 (IFF 3IN, CODE 6063)²

DRAGON 10, CINCINNATI, REQUEST YOU SQUAWK MODE 3 CODE
VICTOR.

DRAGON 10, CENTER READS YOUR SQUAWK.

TASK 2 (ALT SET 29.83)

DRAGON 10, CINCINNATI, ALTIMETER IS NOW ALPHA.

DRAGON 10, TRAFFIC 1 O'CLOCK 30 MILES, CROSSING.

TASK 3 (FLY TO 4)

DRAGON 10, CENTER CLEARS YOU PRESENT POSITION DIRECT
TO WAYPOINT NOVEMBER 4, THEN FLIGHT PLANNED
ROUTE.

DRAGON 10, CENTER, TRAFFIC PASSING OFF YOUR PORT WING,
5 MILES, HIGH.

TASK 4 (TACAN 106X)

DRAGON 10, CENTER, REQUEST YOU TUNE WHIPPLE TACAN,
NOVEMBER 11.

DRAGON 10, CINCINNATI, YOU ARE CLEAR OF TRAFFIC.

DRAGON 10, CENTER, WHAT'S YOUR ALTITUDE?

. . .

TASK 6 (IFF 3/5706)

DRAGON 10, CINCINNATI, SQUAWK MODE 3 CODE UNIFORM.

¹ See Paragraph 3.4.2.1 for description of script use.

² Indicates task number and correct digits for task. This information from the scripts was not read to the subject pilots.

CRUISE SEGMENT

DRAGON 10, ARE YOU ON TOP?

TASK 1 (IFF 3/3336)

DRAGON 10, CINCINNATI, SQUAWK MODE 3 CODE PAPA.

DRAGON 10, CENTER IS RECEIVING YOUR SQUAWK.

. . .

TASK 3 (FLY TO 3620.95N, 7835.67W)

DRAGON 10, CINCINNATI, YOU ARE CLEARED PRESENT
POSITION DIRECT TO WAYPOINT NOVEMBER 3,
FLIGHT PLANNED ROUTE, MAINTAIN 17,000'.

TASK 4 (IFF, 3 OUT)

DRAGON 10, YOU'RE GETTING CLOSE TO OUR LOCATION,
PLEASE STRANGLE MODE 3.

DRAGON 10, CENTER OBSERVES YOUR LAZY PARROT.

. . .

TASK 6 (UHF 123863)

DRAGON 10, CINCINNATI CENTER, CONTACT BOX CAR ON
BRAVO FREQUENCY.

DRAGON 10, BOX CAR YOU ARE LOUD AND CLEAR.

NAV BOMB SEGMENT

HAVE YOU BEEN BRIEFED ON THE POSSIBLE
DIVERT?

TASK 1 (UHF 285.6)

DRAGON 10, BOX CAR, CONTACT STAIRCASE ON FOXTROT
FREQUENCY.

DRAGON 10, STAIRCASE HERE, READ YOU LOUD AND CLEAR,
HOW ME?

TASK 2 (WPN 2, Q 12)

DRAGON 10, STAIRCASE, CHANGE WEAPON OPTION 2.

DRAGON 10, ARE YOU IN THE CLEAR AT PRESENT?

. . .

TASK 4 (WPN 3, Q16, PRS, I70,T)

DRAGON 10, OWL HAS A WEAPON OPTION CHANGE. CHANGE
OPTION 3.

DRAGON 10, THERE IS FOG FORMING AROUND THE PRIMARY
TARGET AREA. STAND BY FOR A POSSIBLE
DIVERT.

TASK 5 (WPN 4, Q14, 180)

DRAGON 10, OWL, CHANGE WEAPON OPTION 4.

DRAGON 10, THE WEATHER STILL LOOKS GOOD IN THE TARGET
AREA.

. . .

PRECISION APPROACH SEGMENT

. . .

TASK 3 (ELEV/DH 1862/250)

DRAGON 10, CENTER, SET FIELD ELEVATION AND DECISION
HEIGHT FROM ECHO DATA

DRAGON 10, CINCINNATI, ARE MY TRANSMISSIONS BREAKING
UP?

TASK 4 (UHF 17)

DRAGON 10, CINCINNATI, CENTER, CONTACT GREENSBORO
APPROACH ON JULIET FREQUENCY.

DRAGON 10, GREENSBORO APPROACH, READ YOU LOUD AND
CLEAR. CONTINUE DESCENT, EXPECT RADAR
VECTORS.

TASK 5 (ILS 108.3/312).

DRAGON 10, GREENSBORO, SET ILS FREQUENCY AND THE
INBOUND COURSE FROM INDIA DATA.

DRAGON 10, EXPECT FULL-STOP RUNWAY 31.

. . .

APPENDIX E

KEYBOARD LOGIC AND DISPLAY FORMAT FOR TASKS

1. OPERATING SEQUENCE FOR EACH TASK TYPE

A brief description of each operating sequence used in the present study is shown below by task type for the Branching Control Logic (B) and for the Tailored Control Logic (T).

Set UHF Channel

- B. Pilot selected the COMM system select switch, UHF and UHF CHNG multifunction switches, two digits and ENTER on the DEK.
- T. Pilot selected the UHF CHNG multifunction switch, two digits and ENTER on the DEK.

Set UHF Frequency

- B. Pilot selected the COMM system select switch, UHF and UHF CHNG multifunction switches, four digits and ENTER on the DEK.
- T. Pilot selected the UHF CHNG multifunction switch, four digits and ENTER on the DEK.

Set UHF Channel and Frequency (The first two digits selected designated the channel.)

- B. Pilot selected the COMM system select switch, UHF and UHF CHNG multifunction switches, six digits and ENTER on the DEK.
- T. Pilot selected the UHF CHNG multifunction switch, six digits and ENTER on the DEK.

Change IFF Code

- B. Pilot selected the COMM system select switch, IFF and MODE 3 multifunction switches, four digits and ENTER on the DEK.
- T. Pilot selected the MODE 3 multifunction switch, four digits and ENTER on the DEK.

Change IFF Mode In/Out Status

- B. Pilot selected the COMM system select switch, the IFF and MODE 3 multifunction switches, and ENTER on the DEK.
- T. Pilot selected the MODE 3 multifunction switch and ENTER on the DEK.

Change IFF Code and In/Out Status

- B. First, the pilot selected the COMM system select switch and the IFF multifunction switch. To change an IFF code, the pilot selected the MODE 3 multifunction switch, four digits and ENTER on the DEK. To change the mode in/out status, he selected the MODE 3 multifunction switch and ENTER on the DEK. The pilot could complete the two subtasks (changing code and changing mode in/out status) in either order.
- T. To change an IFF code, the pilot selected the MODE 3 multifunction switch, four digits and ENTER on the DEK. To change the mode in/out status, he selected the MODE 3 multifunction switch and ENTER on the DEK. The pilot could complete the two subtasks (changing code and changing mode in/out status) in either order.

Change TACAN Channel

- B. Pilot selected the NAV system select switch, TCN and TCN CHNG multifunction switches, three digits, the letter X or Y and ENTER on the DEK.
- T. Pilot selected the TCN CHNG multifunction switch, three digits, the letter X or Y and ENTER on the DEK.

Set FLY TO Waypoint Number

- B. Pilot selected the NAV system select switch, STEER SELECT and FLY TO multifunction switches, two digits and ENTER on the DEK.
- T. Pilot selected the FLY TO multifunction switch, two digits and ENTER on the DEK.

Set FLY TO Latitude/Longitude

- B. Pilot selected the NAV system select switch, STEER SELECT and FLY TO multifunction switches, and on the DEK: six digits, one letter, ENTER, six digits, one letter, ENTER.
- T. Pilot selected the FLY TO multifunction switch and on the DEK: six digits, one letter, ENTER, six digits, one letter, ENTER.

Change Altimeter Setting

- B. Pilot selected the NAV system select switch, DATA ENTRY and ALT SET multifunction switches, four digits and ENTER on the DEK.
- T. Pilot selected the ALT SET multifunction switch, four digits and ENTER on the DEK.

Set Field Elevation and Decision Height

- B. Pilot selected the NAV system select switch, ILS and ELEV/DH multifunction switches, seven digits and ENTER on the DEK.

- T. Pilot selected the ELEV/DH multifunction switch, seven digits and ENTER on the DEK.

Set ILS Frequency and Course

- B. Pilot selected the NAV system select switch, ILS and ILS CHNG multifunction switches, seven digits and ENTER on the DEK.
- T. Pilot selected the ILS CHNG multifunction switch, seven digits and ENTER on the DEK.

Change Weapon Quantity Parameter

- B. Pilot selected the STORES system select switch, DISPLAY OPTION multifunction switch, one digit and ENTER on the DEK, QUANTITY multifunction switch, two digits and ENTER on the DEK and SAVE multifunction switch.
- T. Pilot selected the desired WEAPON OPTION and QUANTITY multifunction switches, two digits and ENTER on the DEK and SAVE multifunction switch.

Change Weapon Quantity and Interval Parameters

- B. First, the pilot selected the STORES system select switch, DISPLAY OPTION multifunction switch, one digit and ENTER on the DEK. Next, the pilot changed the following parameters, in either order:

Quantity - Pilot selected the QUANTITY multifunction switch, two digits and ENTER on the DEK.

Interval - Pilot selected the INTERVAL multifunction switch, two digits and ENTER on the DEK.

After the pilot completed these parameter changes, he selected the SAVE multifunction switch.

- T. First, the pilot selected the desired WEAPON OPTION multifunction switch. Next, the pilot changed the following parameters, in either order:

Quantity - Pilot selected the QUANTITY multifunction switch, two digits and ENTER on the DEK.

Interval - Pilot selected the INTERVAL multifunction switch, two digits, and ENTER on the DEK.

After the pilot completed these parameter changes, he selected the SAVE multifunction switch.

Change Weapon Quantity, Drop Mode, Interval and Fuzing Parameters

- B. Pilot selected the STORES system select switch, DISPLAY OPTION multifunction switch, one digit and ENTER on the DEK. Next, in any order, the pilot changed the following parameters:

Quantity - Pilot selected the QUANTITY multifunction switch, two digits and ENTER on the DEK.

Drop Mode - Pilot pushed the SINGLES multifunction switch to select PAIRS.

Interval - Pilot selected the INTERVAL multifunction switch, two digits and ENTER on the DEK.

Fuze Selection - Pilot selected the FUZE TAIL multifunction switch.

After selection of these parameters, the pilot selected the SAVE multifunction switch.

T. Pilot selected the desired WEAPON OPTION multifunction switch. Next, the pilot completed the following parameter changes in any order:

Quantity - Pilot selected the QUANTITY multifunction switch, two digits and ENTER on the DEK.

Drop Mode - Pilot pushed the SINGLES multifunction switch to select PAIRS.

Interval - Pilot selected the INTERVAL multifunction switch, two digits and ENTER on the DEK.

Fuze Selection - Pilot selected the FUZE TAIL multifunction switch.

After selection of these parameters, the pilot selected the SAVE multifunction switch.

2. MFK DISPLAY FORMAT

2.1 Mechanization

Today's pilot has access to a multitude of information concerning the status of various aircraft subsystems and associated controls. In most cases, he may look at a particular control head and determine whether the system is on or off, what operating phase is selected and what frequency or code is set. Access to information will not be lost with the advent of multifunction switching and programmable displays. On the contrary, as much or more information will be available to the pilot and it will be centralized in location. The status of most of the systems was displayed on the SF (see Paragraph 2.1.1 for formats). In addition, status and pre-entry information were displayed on the MFK separate from the SF when the pilot proceeded through the logic steps. This information consisted of previous and current frequencies and channels, IFF code data, etc., as well as a pre-entry readout of all digits selected before they were entered into the system.

Two conventions were employed in presenting digital information to the pilot whether it consisted of current or pre-entry data. The differences in conventions were related to the type of task. If a task required only one activation of the DEK ENTER key, e.g., UHF change, the information was presented to the pilot

under the appropriate CRT MFK legend adjacent to the multifunction switch. If two or more activations of the ENTER key were required, e.g., inserting a waypoint, the data was presented in the center column of the MFK with each new piece of data written on a separate line. Current frequencies, channels, IFF squawks, weapon selections, waypoint coordinates, etc. were presented to the pilot according to these guidelines. In addition, the previous frequency/channel for UHF/TACAN was displayed in the center column of the MFK whenever UHF CHNG or TCN CHNG was selected.

When the DEK was activated, the multifunction switch legend which called up the DEK had an asterisk displayed by it. The pilot was presented with a readout of all digits selected on the DEK before pushing the ENTER key. He could use this pre-entry readout to verify that the digits selected were correct and sequenced properly. In the case of a single unit data input, e.g., UHF CHNG, the pre-entry readout was written over the current frequency beneath the appropriate legend on the MFK. This pre-entry readout convention applied to UHF, IFF, TACAN, altimeter, field elevation/decision height and ILS frequency/course changes. When the pilot had to activate the ENTER key two or more times during a task, e.g., inputting a waypoint, the pre-entry readout was written over the corresponding current data located on the MFK center column. This convention applied to FLY TO tasks, and Weapon Option selections.

When the pilot selected the first digit on the DEK, the current data display for that particular subtask was erased. For example, selection of the first digit in a UHF change task completely erased the display of the frequency. During a waypoint load task, each line was erased as the first digit appropriate to that line was selected on the DEK. When the ENTER key was pushed, the data was entered into the system, the digits indicated current status and the previous channel/frequency readouts were erased.

The IFF mode IN/OUT function required special treatment. Though not a digital pre-entry readout, a method was employed which allowed the pilot to verify the mode which was activated or deactivated. To deactivate Mode 3, the pilot selected the desired mode multifunction switch and ENTER on the DEK. Parentheses then appeared around the Mode 3 readout on the MFK and on the SF as a reminder to the pilot that he was not squawking Mode 3. To activate Mode 3, the pilot followed the same sequence described above: selected the desired mode multifunction switch and ENTER on the DEK. The parentheses around the Mode 3 blanked at the selection of ENTER. The absence of parentheses on the MFK and SF indicated that Mode 3 was squawking.

The pilot could switch back to a previous UHF frequency or TACAN channel without selecting any digits. The "previous" information displayed in the MFK center column was saved in the computer memory and the pilot could change to that frequency/channel by selecting COMM, UHF, UHF CHNG and ENTER for the UHF frequency or NAV, TCN, TCN CHNG and ENTER for the TACAN channel in the Branching Logic (UHF CHNG and ENTER or TCN CHNG and ENTER in the Tailored Logic). It is important to note that it was not possible to continue to go back to earlier selected frequencies/channels. Only the current and previous data could be switched back and forth.

The current digits were also displayed when the DEK CLEAR key was pushed twice. This erased all digits selected but not entered and displayed the current digits which had been erased with the first DEK selection.

2.2 Legends and Switch Functions for Each MFK Page

The following pages show the multifunction switch legends for each MFK page (Figure E1) and note how each programmed switch functioned. The selection of a programmed switch either: (1) called up a new MFK page, (2) caused an asterisk to be displayed for a different legend, or (3) in the case where the DEK was activated, caused an asterisk to be displayed, until the ENTER key was pushed, for the multifunction switch legend which called up the DEK. If an unprogrammed switch was selected, the message "OPTION N/A" was displayed for the appropriate switch on the CRT.

2.2.1 Branching MFK Logic

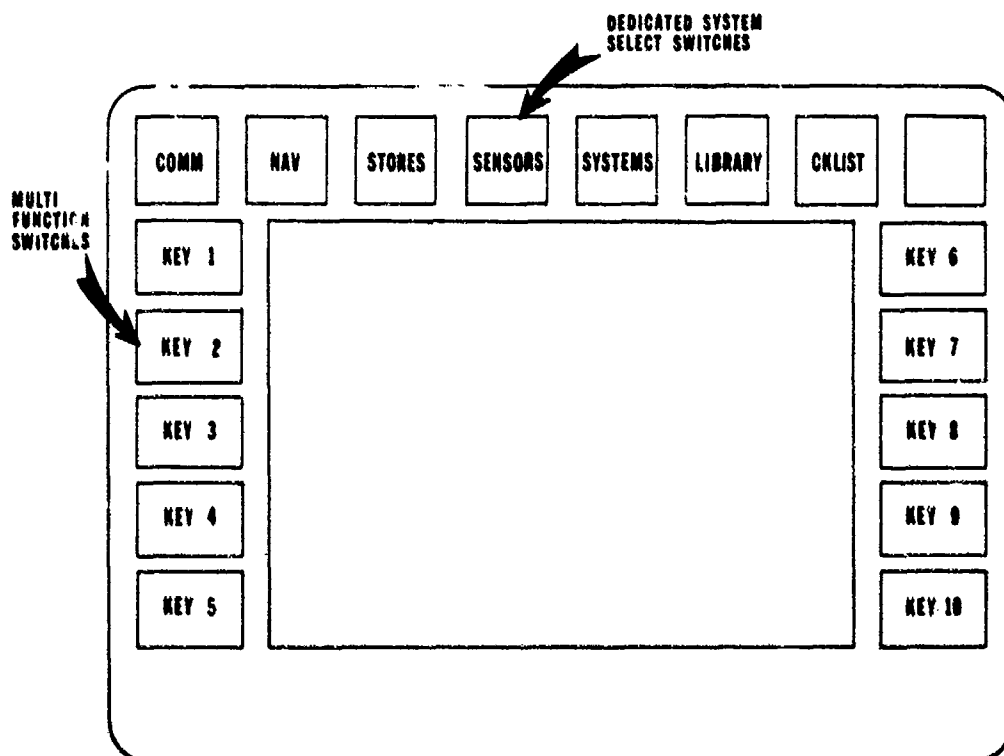


Figure E1. Drawing of MFK with Multifunction Switches Numbered

COMMUNICATION FUNCTIONS

Page 1

- | | |
|-------------------|-----|
| 1. UHF
T/R&G | 6. |
| 2. ADF/AUX
OFF | 7. |
| 3. IFF
3-5500 | 8. |
| 4. VHF/FM
OFF | 9. |
| 5. | 10. |

Key 1 Called up UHF functions, MFK page 2 (Figure E3).

Key 3 Called up IFF functions, MFK page 2 (Figure E4).

Figure E2. Communication Functions, MFK page 1
(Displayed when "COMM" system select switch selected.)

UHF FUNCTIONS

PAGE 2

- | | | |
|----------------------|-------------------|---------------------|
| 1. UHF CHNG
340.3 | UHF
PREV-357.8 | 6. GUARD
XMIT |
| 2. *T/R+G | | 7. SQUELCH
OUT |
| 3. T/R | | 8. BEARING
SAVE |
| 4. ADF | | 9. BEARING
ERASE |
| 5. OFF | | 10. RETURN |

Key 1 Activated DEK for pilot input of UHF channel (2 digits, ENTER), frequency (4 digits, ENTER), or channel and frequency (6 digits, ENTER).

Key 10 Returned MFK to Communications, page 1 (Figure E2).

Figure E3. UHF Communication Functions, MFK page 2.
(Displayed when "UHF" multifunction switch selected.)

IFF FUNCTIONS

PAGE 2

1. MODE 1 21	IFF	6. EMERG
2. MODE 2 1200		7. NORM* LOW STBY
3. MODE 3 3300		8. MODE C
4. MODE 4		9. OUT* TEST MON
5. OFF		10. RETURN

Key 3 Activated DEK for pilot input of code (4 digits, ENTER). If only ENTER was selected (no digits), the IFF was changed to the alternate transmitting status.

Key 7 Activation caused the condition of the receiver/transmitter to be changed in sequence (normal power, reduced power (LOW) warmup (STANDBY)). The current condition was identified by the asterisk and top location of the legend.

Key 10 Returned MFK to Communications, page 1 (Figure E2).

Figure E4. IFF Communication Functions, MFK page 2.
(Displayed when "IFF" multifunction switch selected.)

NAVIGATION FUNCTIONS

PAGE 1

- | | |
|------------------------|---------------------|
| 1. *IMS
NORMAL | 6. NAV
MODE |
| 2. DOPPLER
ON | 7. NAV
UPDATE |
| 3. ILS ON
109.7/254 | 8. STEER
SELECT |
| 4. TCN T/R
107X | 9. MARK |
| 5. DATA
ENTRY | 10. DISPLAY
DATA |

Key 3 Called up ILS functions, page 2 (Figure E6).

Key 4 Called up TACAN functions, page 2 (Figure E7).

Key 5 Called up Data Entry functions, page 2 (Figure E8).

Key 8 Called up Steer Select functions, page 2 (Figure E9).

Figure E5. Navigation Functions, MFK page 1
(Displayed when "NAV" system select switch selected).

ILS FUNCTIONS

PAGE 2

- | | | |
|--------|-----------------------|-------------------|
| 1. | ILS | 6. |
| 2. | | 7. |
| 3. | ILS CHNG
109.7/254 | 8. ILS STEER |
| 4. | ELEV/DH
0769/200 | 9. FLT DIR
OFF |
| 5. OFF | | 10. RETURN |

Key 3 Activated DEK for pilot input of ILS frequency and course (7 digits, ENTER).

Key 4 Activated DEK for pilot input of field elevation and decision height (7 digits, ENTER).

Key 10 Returned MFK to Navigation, page 1 (Figure E5).

Figure E6. ILS Functions, MFK page 2
(Displayed when "ILS" multifunction switch selected.)

TACAN FUNCTIONS

PAGE 2

- | | | |
|---------------------|--------------------|-------------|
| 1. *T/R | TACAN
PREV-104X | 6. REC ONLY |
| 2. TEST | | 7. A/A T/R |
| 3. CRS TO | | 8. A/A REC |
| 4. TCN CHNG
107X | | 9. CRS FROM |
| 5. OFF | | 10. RETURN |

Key 4 Activated DEK for pilot input of TACAN channel (3 digits, X or Y, ENTER).

Key 10 Returned MFK to Navigation, page 1 (Figure E5).

Figure E7. TACAN Navigation Functions, MFK page 2.
(Displayed when "TCN" multifunction switch selected.)

DATA ENTRY FUNCTIONS

PAGE 2

- | | | |
|-----------------------|------------|-----------------------|
| 1. CHANGE
SEQUENCE | DATA ENTRY | 6. TARGET
LOAD |
| 2. HOLDING
FIX | | 7. WIND SET
075/25 |
| 3. DELETE
WAYPOINT | | 8. ALT SET
30.16 |
| 4. HLDNG LFT | | 9. HLDNG RT |
| 5. WAYPOINT
LOAD | | 10. RETURN |

Key 8 Activated DEK for pilot input of altimeter setting (4 digits, ENTER).

Key 10 Returned MFK to Navigation, page 1 (Figure E5).

Figure E8. Data Entry Navigation Functions, MFK page 2.
(Displayed when "DATA ENTRY" multifunction switch selected.)

STEER SELECT FUNCTIONS

PAGE 2

1. *CMD NAV	<u>STEER SELECT</u>	6. OFFSET LF
2. CMD TRACK		7. OFFSET RT
3. CMD HDG 089		8. FLY TO
4. CRS SET 091	11	9. ILS STEER
5. OFF		10. RETURN

Key 8 Activated DEK for pilot input of waypoint number (2 digits, ENTER) or latitude/longitude (6 digits, 1 letter, ENTER, 6 digits, 1 letter, ENTER).

Key 10 Returned MFK to Navigation, page 1 (Figure E5).

Figure E9. Steer Select Functions, MFK page 2.
(Displayed when "STEER SELECT" multifunction switch selected.)

STORES FUNCTIONS

PAGE 1

- | | |
|--------------------|--------------------------|
| 1. 18 MK 82 | 6. LIST
BY STA |
| 2. BLU 27 | 7. DISPLAY
OPTION |
| 3. SUU 25 | 8. STORES
STATUS |
| * 4. FUEL
TANKS | 9. |
| 5. | 10. DISPLAY
JETT PROG |

Key 7 Activated DEK for pilot input of weapon option number (1 digit, ENTER). Called up weapon option parameters, MFK page 2. Figure E11 is an example of such a page. Selection of SAVE switch called page 1 of Stores Functions and the parameters for the selected option were displayed in the MFK center column, e.g.,

16 MK 82
PR
ALL
90 FT
NT

MASTER ARM

Figure E10. Stores Functions, MFK page 1
(Displayed when "STORES" system select switch selected.)

WEAPON OPTION PARAMETERS

PAGE 2

1. QUANTITY	OPTION 1	6. SEL STNS
	12 MK 82	ALL
	SINGLES	
2. *SINGLES	ALL	7.
PAIRS SALVO	75 FT	
	NT	
3. INTERVAL		8. SAVE
4. *FUZE	MASTER	9. ACTIVATE
NOSE	ARM	
5. *FUZE		10. RETURN
TAIL		

Key 1 Activated DEK for pilot input of quantity (2 digits, ENTER).

Key 2 Activation caused the release mode to be changed in sequence (SINGLES, PAIRS, SALVO). The current mode is identified by the asterisk and top location of the legend.

Key 3 Activated DEK for pilot input of interval (feet) between impact points on the ground (2 digits, ENTER).

Key 4 Selected NOSE FUZE.

Key 5 Selected TAIL FUZE.

Key 8 Saves data for display as new parameters for option 1, 2, 3, or 4. Returns to MFK page 1 (STORES functions, Figure E10) with current parameters for the selected weapon option presented in center of CRT.

Key 10 Returned MFK to STORES functions, MFK page 1 (Figure E10).

Figure E11. Weapon Option Parameters, MFK page 2.

2.2.2 Tailored MFK Logic

TAKEOFF/CLIMB FLIGHT PHASE

PAGE 1

- | | |
|----------------------|----------------------|
| 1. UHF CHNG
347.8 | 6. AUTO HDG |
| 2. TCN CHNG
121Y | 7. ATT HOLD |
| 3. CMD HDG | 8. ALT SET
30.16 |
| 4. CMD ALT | 9. IFF M/C
3-6300 |
| 5. FLY TO | 10. CRS SET |

11

Key 1 Activated DEK for pilot input of UHF channel (2 digits, ENTER), frequency (4 digits, ENTER) or channel and frequency (6 digits, ENTER).

Key 2 Activated DEK for pilot input of TACAN channel (3 digits, X or Y, ENTER).

Key 5 Activated DEK for pilot input of waypoint number (2 digits, ENTER) or latitude/longitude (6 digits, 1 letter, ENTER, 6 digits, 1 letter, ENTER).

Key 8 Activated DEK for pilot input of altimeter setting (4 digits, ENTER).

Key 9 Activated DEK for pilot input of code (4 digits, ENTER). If only ENTER was selected (no digits), the IFF was changed to the alternate transmitting status.

Figure E12. TAKEOFF/CLIMB Flight Phase Options, MFK page 1.

CRUISE FLIGHT PHASE

PAGE 1

- | | |
|----------------------|----------------------|
| 1. UHF CHNG
363.1 | 6. AUTO HDG |
| 2. TCN CHNG
100X | 7. ALT HOLD |
| 3. CMD HDG | 8. HDG HOLD |
| 4. CMD ALT | 9. IFF M/C
3-6300 |
| 5. FLY TO | 10. CRS SET |

14

- Key 1 Activated DEK for pilot input of UHF channel (2 digits, ENTER), frequency (4 digits, ENTER), or channel and frequency (6 digits, ENTER).
- Key 2 Activated DEK for pilot input of TACAN channel (3 digits, X or Y, ENTER).
- Key 5 Activated DEK for pilot input of waypoint number (2 digits, ENTER) or latitude/longitude (6 digits, 1 letter, ENTER, 6 digits, 1 letter, ENTER).
- Key 9 Activated DEK for pilot input of code (4 digits, ENTER). If only ENTER was selected (no digits), the IFF was changed to the alternate transmitting status.

Figure E13. CRUISE Flight Phase Options, MFK page 1.

NAV BOMB FLIGHT PHASE

PAGE 1

- | | |
|----------------------|-----------------------|
| 1. UHF CHNG
387.4 | 6. WEAPON
OPTION 1 |
| 2. BOMB TGT | 7. WEAPON
OPTION 2 |
| 3. ALT HOLD | 8. WEAPON
OPTION 3 |
| 4. AUTO HDG | 9. WEAPON
OPTION 4 |
| 5. ALT SET
30.12 | 10. CRS SET |

Key 1 Activated DEK for pilot input of UHF channel (2 digits, ENTER), frequency (4 digits, ENTER), or channel and frequency (6 digits, ENTER).

Key 5 Activated DEK for pilot input of altimeter setting (4 digits, ENTER).

Keys 6, 7, 8, & 9 Permitted selection of programmed weapon options 1, 2, 3 and 4, respectively, which were displayed on the SF. After selection of one of the four options, the Page 2 for the selected weapon option was displayed on the MFK. Figure E15 is an example of such a page. Selection of SAVE switch called page 1 of the NAV BOMB Flight Phase and the parameters for the selected option were displayed in the MFK center column, e.g.,

16 MK 82
PR
ALL
90 FT
NT

ACTIVATE
MASTER ARM

Figure E14. NAV BOMB Flight Phase Options, MFK page 1.

SELECTED WEAPON OPTION PAGE

PAGE 2

1. QUANTITY	OPTION 1	6. SEL STNS ALL
2. *PAIRS SALVO SINGLES	16 MK 82 PAIRS ALL	7.
3. INTERVAL	90 FT NT	8. SAVE
4. *FUZE NOSE		9.
5. *FUZE TAIL	MASTER ARM	10. RETURN

Key 1 Activated DEK for pilot input of quantity (2 digits, ENTER).

Key 2 Activation caused the release mode to be changed in sequence (SINGLES, PAIRS, SALVO). The current mode is identified by the asterisk and top location of the legend.

Key 3 Activated DEK for pilot input of interval (feet) between impact points on the ground (2 digits, ENTER).

Key 4 Selected NOSE FUZE.

Key 5 Selected TAIL FUZE.

Key 8 Saves data for display as new parameters for option 1, 2, 3, or 4. Returns to MFK page 1 (NAV BOMB Flight Phase, Figure E14) with current parameters for selected weapon option presented in center of CRT.

Key 10 Returned MFK to page 1, NAV BOMB Flight Phase options (Figure E14).

Figure E15. Selected Weapon Option Page, MFK page 2.

PRECISION APPROACH FLIGHT PHASE

PAGE 1

- | | |
|-----------------------|--------------------------|
| 1. UHF CHNG
269.2 | 6. ILS CHNG
110.1/223 |
| 2. TCN CHNG
120Y | 7. ELEV/DH
1811/200 |
| 3. DISPLAY
RDR ALT | 8. ILS STEER |
| 4. CMD ALT | 9. IFF M/C
3-3300 |
| 5. CHK LIST | 10. CRS SET |

- Key 1 Activated DEK for pilot input of UHF channel (2 digits, ENTER), frequency (4 digits, ENTER), or channel and frequency (6 digits, ENTER).
- Key 2 Activated DEK for pilot input of TACAN channel (3 digits, X or Y, ENTER).
- Key 6 Activated DEK for pilot input of ILS frequency and course (7 digits, ENTER).
- Key 7 Activated DEK for pilot input of field elevation and decision height (7 digits, ENTER).
- Key 9 Activated DEK for pilot input of code (4 digits, ENTER). If only ENTER was selected (no digits), the IFF was changed to the alternate transmitting status.

Figure E16. PRECISION APPROACH Flight Phase Options, MFK page 1.

APPENDIX F

PILOT QUESTIONNAIRES

Immediately after each flight segment, each pilot was given a questionnaire concerned with the arrangements of the formats. The pilots'¹ responses to these questions as well as the questions in the final debriefing questionnaire which were concerned with the format arrangements appear first in the appendix. Next, are the pilots' responses to the final debriefing questionnaire. This questionnaire was administered following the completion of all data flights and was designed to elicit subjective evaluation of the format arrangements², MFK, keyboard logic, display formats, and simulation quality. (Editorial comments are contained within brackets.)

Nonparametric Kolmogorov-Smirnov tests of significance (Ref. F1) were conducted on the data obtained from the questionnaires. Results are reported where the probability associated with the observed value of the maximum deviation is smaller than $p = .05$.

-
- ¹ Although performance data was collected on only sixteen pilots, seventeen pilots completed the required briefings, test flights, and questionnaires. The responses to all seventeen pilots were tabulated and analyzed.
 - ² During testing and questionnaire administration, the format arrangements were referred to as display arrangements. After the study it was decided to employ the word "format" since flight information was being arranged different ways rather than displays. Similarly, the VSF, HSF, and SF were referred to as VSD-Vertical Situation Display, HSD-Horizontal Situation Display, and MPD-Multipurpose Display, respectively. After the study, it was decided to employ the word "format" since the information could be presented on a number of displays.

1. FORMAT ARRANGEMENT DATA FROM DEBRIEFING QUESTIONNAIRES

POST FLIGHT SEGMENT QUESTIONNAIRE

[Administered immediately after each format arrangement was evaluated.
Comments for each question are recorded by format arrangements starting on
page 84.]

1. We'd like your opinion regarding your ability to use this display arrangement to fly the simulator. Did you find it Unacceptable, Satisfactory, or Optimum?

Display Arrangement	Unsatisfactory	Satisfactory	Optimum
1	3	9	5 ($\underline{D}(17)=0.71$, $p < .01$)
2	1	10	6 ($\underline{D}(17)=0.65$, $p < .01$)
3	0	8	9 ($\underline{D}(17)=0.47$, $p < .01$)
4	1	16	0 ($\underline{D}(17)=1.00$, $p < .01$)
5	3	14	0 ($\underline{D}(17)=1.00$, $p < .01$)
6	3	14	0 ($\underline{D}(17)=1.00$, $p < .01$)
7	0	12	5 ($\underline{D}(17)=0.71$, $p < .01$)
8	3	14	0 ($\underline{D}(17)=1.00$, $p < .01$)

2. Very briefly, what was the main problem and/or advantage, if any, you found in using this display arrangement during the ____* phase of flight?¹
3. Do you anticipate the same or other problems/advantages in using this display arrangement during the ____* phase of flight in an aircraft?¹

* The particular phase in which the format arrangement was evaluated.

¹ Responses are recorded by format arrangement starting on page 84.

4. If this display arrangement was standard and you had extensive experience using it, do you feel it would be Unacceptable, Satisfactory, or Optimum?

Display Arrangement	Unsatisfactory	Satisfactory	Optimum
1	3	8	6 ($\underline{D}(17)=0.65, p < .01$)
2	1	10	6 ($\underline{D}(17)=0.65, p < .01$)
3	0	7	10 ($\underline{D}(17)=0.41, p < .01$)
4	2	13	2 ($\underline{D}(17)=0.88, p < .01$)
5	2	15	0 ($\underline{D}(17)=1.00, p < .01$)
6	4	13	0 ($\underline{D}(17)=1.00, p < .01$)
7	0	11	6 ($\underline{D}(17)=0.65, p < .01$)
8	5	12	0 ($\underline{D}(17)=1.00, p < .01$)

5. Is this display arrangement useable as a backup in the event of failure?

Display Arrangement	Yes, Useable	No, Unuseable
1	16	1 ($\underline{D}(17)=1.07, p < .01$)
2	17	0 ($\underline{D}(17)=1.21, p < .01$)
3	17	0 ($\underline{D}(17)=1.21, p < .01$)
4	17	0 ($\underline{D}(17)=1.21, p < .01$)
5	16	1 ($\underline{D}(17)=1.07, p < .01$)
6	16	1 ($\underline{D}(17)=1.07, p < .01$)
7	17	0 ($\underline{D}(17)=1.21, p < .01$)
8	17	0 ($\underline{D}(17)=1.21, p < .01$)

FINAL DEBRIEFING QUESTIONNAIRE

QUESTIONS CONCERNING FORMAT ARRANGEMENTS

I. Rate your ability to use each of the display arrangements. [Some comments are recorded by format arrangement starting on page 84 .]

Display Arrangement	Very Inefficient	Moderately Inefficient	Satisfactory	Moderately Efficient	Efficient
1	3	2	3	3	6
2	2	1	6	6	2
3 ¹	1	1	2	5	8
4	2	8	5	2	0
5 ²	4	8	5	0	0
6 ³	7	4	6	0	0
7	0	3	8	5	1
8* ⁴	6	5	4	1	0

1 D(17)=0.36, p < .05

2 D(17)=0.40, p < .01

3 D(17)=0.40, p < .01

4 D(16)=0.34, p < .05

*One pilot did not make a response.

II. Was any arrangement BEST? Which arrangement and why?
Was any arrangement WORST? Which arrangement and why?
[Responses are recorded by format arrangement starting on page 84 .]

III. Indicate below where you would like the attitude and map information by putting numbers from Figure 2 [12] in the blanks.

- During departure, cruise, or penetration at night with thunderstorms, I would like my attitude information at _____ and my map at _____.

Attitude Information

9 pilots - top center CRT
5 pilots - HUD and top center CRT
3 pilots - HUD

Map Information

14 pilots - bottom center CRT
2 pilots - top right CRT
1 pilot - top center CRT

- During cruise at night with St. Elmo's fire static electricity , I would like my attitude information at _____ and my map at _____.

Attitude Information

12 pilots - top center CRT
4 pilots - HUD and top center CRT
1 pilot - HUD

Map Information

15 pilots - bottom center CRT
1 pilot - top right CRT
1 pilot - top right or
bottom center CRT

- During final in day weather with fog, I would like my attitude information at _____ and my map at _____.

Attitude Information

10 pilots - HUD
5 pilots - HUD and top center CRT
2 pilots - top center CRT

Map Information

10 pilots - bottom center CRT
4 pilots - top center CRT
2 pilots - top right CRT
1 pilot - top or center
front CRT

- During final on a clear moonless night, I would like my attitude information at _____ and my map at _____.

Attitude Information

5 pilots - HUD and top center CRT
10 pilots - HUD
2 pilots - top center CRT

Map Information

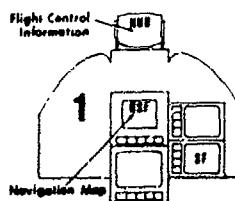
10 pilots - bottom center CRT
4 pilots - top center CRT
2 pilots - top right CRT
1 pilot - top or center
front CRT

COMMENTS:

- Additional attitude information on the HUD would be nice but not essential. Perhaps a redundant display or pilot option would be desirable.
- I would always want my panel in the same configuration, otherwise confusion would result. In fighter aircraft the pilot must often read the flight instruments with a quick glance while maintaining outside visual references. The pilot must know exactly where each instrument is. If the panel is in different configurations the pilot might have to look around to find the instrument he's interested in.
- I primarily use the ADI for instrument approaches with an occasional crosscheck of the HUD.
- During final in day weather with fog, I would like my attitude information on the HUD and my map at the top center location with improved HUD field of view understood.

- It would be optimum to have all information on HUD. Since I do not feel that this is possible, I have used different positions for flight information and navigation information. The first two questions I put 3 [top center CRT] as best position because looking at windscreen is not important at this time. On second two questions you want to be looking for runway so this information is best displayed on HUD while you look for runway.
- I don't consider the map particularly useful as presently mechanized.

FORMAT ARRANGEMENT 1



FINAL DEBRIEFING QUESTIONNAIRE:

Rate your ability to use each of the display arrangements.

Display Arrangement	Very Inefficient	Moderately Inefficient	Satisfactory	Moderately Efficient	Efficient
1	3	2	3	3	6

POST FLIGHT SEGMENT QUESTIONNAIRE:

Question requesting opinion regarding pilots' ability to use arrangement to fly the simulator. The responses were 3 Unacceptable; 9 Satisfactory; 5 Optimum.

Question requesting opinion regarding arrangement if it were standard and pilot had extensive experience using it. Responses: 3 Unacceptable; 6 Satisfactory; 6 Optimum.

Question regarding whether arrangement is useable as a backup in the event of failure. 16 Yes, useable as backup; 1 No, not useable as backup.

FINAL DEBRIEFING QUESTIONNAIRE COMMENTS:

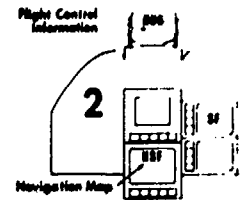
- Display 1 would be very acceptable for weapons delivery.
- Arrangement 1 was best. I like the HUD because you are looking outside the aircraft most of the time.
- Arrangement 1 was best. Found this arrangement easiest to fly the simulator and hold parameters.
- Arrangement 1 was worst. Navigation map data on top (groundspeed heading, etc.) blocked out by switch box below HUD. To position seat to proper location to see HUD, one must duck under to see above mentioned information.
- Arrangement 1 was best. Less crosscheck required. Comfortable head positioning.

- Arrangement 1 was best with flight control information setting on top of map. The HUD is outstanding for any type of aircraft and mission. With this arrangement, you can do most of your flying heads up. When course information is checked, the flight control information is setting on top of the map. The pilot has all the necessary information in a vertical scan line which is superior to any other system.

POST FLIGHT QUESTIONNAIRE COMMENTS:

- Don't like flying HUD. VSD easier to use.
- HUD as primary instrument makes crosscheck to keyboard more difficult. Good as backup, not as primary.
- Would like to have flight director directly in front in case HUD fails. Like to have map at right.
- Easier to maintain flight control (zero pitch display of HUD makes operation easier than VSD). Can look out with HUD.
- Distant crosscheck from HUD to MFK. With HUD, less reason to look down in cockpit. Optimum as backup.
- Arrangement O.K.
- Ability to look out and still see displays is an advantage.
- Found no problems with the displays arrangement.
- Arrangement is optimum for landing and weapon delivery. The HUD control box makes crosscheck between HUD and top CRT difficult.
- Is an advantage to be able to glance down from HUD to see information on map. More symmetrical. Easy to use with MFK.
- Better control of the simulator.
- Pretty comfortable flying it.
- Flew simulator better with HUD. Digital readouts top of map are cut off. Need groundspeed on HUD. Would rather have two sets of altitude information.
- Looking out using HUD is an advantage.
- Arrangement unacceptable because information on map is blocked by control box. Have to keep moving head. Would be O.K. if information not blocked.
- Top data of HSD blocked by "box" below HUD.
- Difficult crosscheck between HUD, groundspeed and MFK. Would be better if needed information located on higher displays.

FORMAT ARRANGEMENT 2



FINAL DEBRIEFING QUESTIONNAIRE:

Rate your ability to use each of the display arrangements.

Display Arrangement	Very Inefficient	Moderately Inefficient	Satisfactory	Moderately Efficient	Very Efficient
2	2	1	6	6	2

POST FLIGHT SEGMENT QUESTIONNAIRE:

Question requesting opinion regarding pilots' ability to use arrangement to fly the simulator. The responses were: 1 Unacceptable; 10 Satisfactory; 6 Optimum.

Question requesting opinion regarding arrangement if it were standard and pilot had extensive experience with it. Responses: 1 Unacceptable; 10 Satisfactory; 6 Optimum.

Question regarding whether arrangement is useable as a backup in the event of failure. 17 Yes, useable as backup; 0 No, not useable as backup.

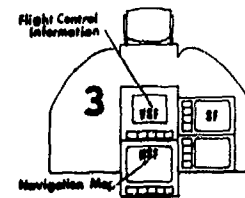
FINAL DEBRIEFING QUESTIONNAIRE COMMENTS:

- Best configuration is with HUD and NAV information on pedestal. Can fly HUD and still look outside.
- Too much eye movement necessary.
- I would rate number 2 best for landing since it would be easy to transition from instruments to visual flying.
- Ideal display is 2 with systems status information on the top right MPD. This approximates the A-7D cockpit display which I feel is ideal by using the flight control information on the HUD. Pilot can keep his head-out of the cockpit for collision avoidance.
- Arrangements 2, 5, 6, 7, and 8 all graded satisfactory. Too much eye movement involved.

POST FLIGHT QUESTIONNAIRE COMMENTS:

- Easier to fly altitude with head-up.
- Too wide crosscheck. Too much eye movement.
- Rather have attitude information right in front. No problem as a backup.
- Seldom use HUD in A-7. With arrangement, have to look straight out. Makes crosscheck to inside difficult. Would rather have VSD display in center.
- Easier to use HUD. Look either side of cockpit displays. Data display on MPD is in better position. Doesn't have to look down as far.
- Location was a problem. Long crosscheck between HUD, MFK and HSD. Outside field of view is an advantage. Good backup.
- Would rather have map on top CRT when HUD is up. Would make crosscheck diagonal (smaller) rather than L shaped.
- Can't think of any advantage or problem.
- Arrangement good. Like it.
- Like HUD, easier to work with. Better for aircraft, because head is out of cockpit.
- Arrangement 2 is better than 1. Would rather have map on lower CRT than on top CRT.
- Pitch, bank information right where you need them.
- Able to look outside. Need groundspeed on HUD.
- HUD comments: Velocity vector and flight director confusing. Hard to determine bank angle. Horizon line needs to be longer. Velocity vector needs to be larger. Display fuzzy, not in focus. Information hard to interpret.
- Less trouble maintaining flight control with HUD compared to CRTs.
- The HUD makes flying easier. Is easier to fly speed when readout is on attitude indicator. Arrangement is a blast to fly in cruise.
- Long crosscheck between HUD and MFK.

FORMAT ARRANGEMENT 3



FINAL DEBRIEFING QUESTIONNAIRE:

Rate your ability to use each of the display arrangements. ($D(17)=0.36$, $p < .05$)

Display Arrangement	Very Inefficient	Moderately Inefficient	Satisfactory	Moderately Efficient	Very Efficient
3	1	1	2	5	8

POST FLIGHT SEGMENT QUESTIONNAIRE:

Question requesting opinion regarding pilots' ability to use arrangement to fly the simulator. The responses were: 0 Unacceptable; 8 Satisfactory; 9 Optimum.

Question requesting opinion regarding arrangement if it were standard and pilot had extensive experience with it. Responses: 0 Unacceptable; 7 Satisfactory; 10 Optimum.

Question regarding whether arrangement is useable as a backup in the event of failure. 17 Yes, useable as a backup; 0 No, not useable as backup.

FINAL DEBRIEFING QUESTIONNAIRE COMMENTS:

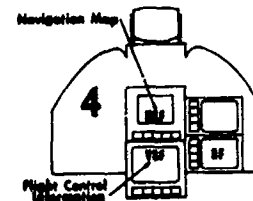
- Less eye movement necessary. Closer to MFK. Easier to control aircraft.
- Central location, ease of associated crosscheck. Size of display.
- Display 3 was the most efficient. Is best for IFR navigation and instrument procedures. Display 3 was best. Flight information ahead is the most important. Had the biggest display and was centered. Navigation information which is also important to a lesser degree was also readily available.
- HUD and navigation information on pedestal. Can fly HUD and still look outside.
- I would rate number 3 best for nav mode (especially in visual conditions) where the instruments require only a frequent crosscheck (not a continuous crosscheck).
- Arrangement 3 was best. Very little head movement required to monitor altitude while using MFK etc.
- Arrangement 3 was best. Flight control information centered and at eye level. Also close to navigation information.

- Arrangement 3 was best by far. Flight control information which is used approximately 90% of the time is centered and in the upper position. And map display just below makes for an efficient crosscheck.
- Arrangement 3 was best. Easier to crosscheck other instruments when the majority of attention is on the center of the panel.

POST FLIGHT QUESTIONNAIRE COMMENTS:

- Rather have map on upper right CRT and status on bottom CRT.
- This arrangement is best we've flown. Liked. Easier to interpret ADI when right in front of your eyeballs.
- This is the way the displays should be arranged.
- Location and size of displays is an advantage.
- Liked this arrangement. Similar to what is familiar with. Like having attitude information located center front.
- Centrally located. Ease of crosscheck.
- Task took too much attention away from flying task.
- Good center front location. Information easier to see. CRT larger. (CRTs on right block heading).
- Arrangement satisfactory for strictly instruments. Don't like to look down all the time. Rather use HUD. Would be disadvantage when flying formation. Have to transition in and out of cockpit.
- Better than having displays on right side CRTs. Would rather have HUD.
- Attitude information centered and in front. Map good below, makes crosscheck easy. With VSD in top location, can easily use in conjunction with HUD. Use of MPD on right CRT optimum.
- Like position of displays.
- Similar to crosscheck distance used in A-7.
- Arrangement optimum. Head not buried deep in cockpit. Liked better than arrangement 4 (VSD on lower CRT).
- Still head-down too much. Better than arrangement 7, worse than 2. Crosscheck easily with VSD center and other displays adjacent.
- VSD in center is an advantage. Most comfortable position. Locating navigation map below VSD is logical.
- Liked crosscheck.

FORMAT ARRANGEMENT 4



FINAL DEBRIEFING QUESTIONNAIRE:

Rate your ability to use each of the display arrangements.

Display Arrangement	Very Inefficient	Moderately Inefficient	Satisfactory	Moderately Efficient	Very Efficient
4	2	8	5	2	0

POST FLIGHT SEGMENT QUESTIONNAIRE:

Question requesting opinion regarding pilots' ability to use arrangement to fly the simulator. The responses were: 1 Unacceptable; 16 Satisfactory; 0 Optimum.

Question requesting opinion regarding arrangement if it were standard and pilot had extensive experience with it. Responses: 2 Unacceptable; 13 Satisfactory; 2 Optimum.

Question regarding whether arrangement is useable as a backup in the event of failure. 17 Yes, useable as a backup; 0 No, not useable as backup.

FINAL DEBRIEFING QUESTIONNAIRE COMMENTS:

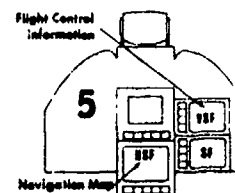
- Display 4 has flight information too low. It would be difficult crosschecking outside and back in.
- Arrangements 4, 5, 6, and 8 were all about the same.

POST FLIGHT QUESTIONNAIRE COMMENTS:

- Stick, kneeboard etc. obstruct view of VSD. Would rather have it on top CRT. Could be worse in aircraft since would have additional equipment.
- Rather have VSD on top. Head down too much.
- Flight director in front center easier than looking to the right and easier to crosscheck with MFK. Would rather have VSD on top CRT, though. Better than arrangement 6.

- Rather have altitude information on top, displays reversed. May be from habit. Advantages include larger displays, more centrally located - don't have to go across cockpit.
- Flight information really buried head down in cockpit. However, could see all information on three CRTs.
- Don't like. Had to lower seat to see top of CRT. Head buried in cockpit too deep. Keep leaning over, looking down in cockpit. Visibility outside down. Would be tough when at minimums. Instrument that is being used is down on lower CRT. Two displays should be flip - flopped.
- Attitude should be on top. Is way too low. Map should be below or to right. Put status information nearer MFK. Would rather have displays reversed, even in lightning conditions.
- Didn't like looking down. Does not lend to optimal arrangement. One advantage is that the crosscheck to the MFK is small. First place VSD format should go in failure.
- No significant difference from standard. When VSD is on the top CRT it is more prominent. When on lower CRT, have to concentrate to look down. More optimal in top position.
- No problems. Pretty good arrangement.
- Would rather have the VSD on top CRT and the map on the bottom CRT.
- Can adjust to this display arrangement as well as the arrangement with the displays on the right. The displays are not optimally located though; the attitude information is too low.
- Would like VSD on top CRT and groundspeed on VSD.
- Rather have attitude information on top. Do not like head down, makes use uncomfortable, hunched over. Probably be easier to use in aircraft.
- Maximum amount of information in center. Is all that you would need to refer too.
- Prefer having ADI on top. What is used too. See no advantages with this arrangement.
- Would like ADI display higher.

FORMAT ARRANGEMENT 5



FINAL DEBRIEFING QUESTIONNAIRE:

Rate your ability to use each of the display arrangements. ($D(17)=0.40$, $p < .01$)

Display Arrangement	Very Inefficient	Moderately Inefficient	Satisfactory	Moderately Efficient	Very Efficient
5	4	8	5	0	0

POST FLIGHT SEGMENT QUESTIONNAIRE:

Question requesting opinion regarding pilots' ability to use arrangement to fly the simulator. The responses were: 3 Unacceptable; 14 Satisfactory; 0 Optimum.

Question requesting opinion regarding arrangement if it were standard and pilot had extensive experience with it. Responses were: 2 Unacceptable; 15 Satisfactory; 0 Optimum.

Question regarding whether arrangement is useable as a backup in the event of failure. 16 Yes, useable as backup; 1 No, not useable as a backup.

FINAL DEBRIEFING QUESTIONNAIRE COMMENTS:

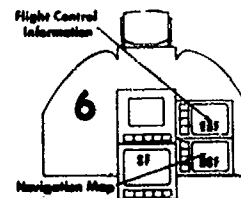
- Arrangements 2, 5, 6, 7, and 8 all graded satisfactory. Too much eye movement involved or off-center in cockpit. Off-center instruments make me feel like I am always in a turn.
- Display 5 is work due to the fact that you have to look cross cockpit.
- Arrangements 5 and 6 were worst. More difficult to monitor flight conditions while using MFK.
- Number 5 worst of CRT displays. Four scan pattern.
- Arrangements 4, 5, 6 and 8 were all about the same.
- Can't read digital readout of heading when map or VSD in top right CRT position.

POST FLIGHT QUESTIONNAIRE COMMENTS:

- Since on left side is more difficult to fly.

- VSD on smaller CRT makes fine adjustments difficult.
- Closer eye contact range. Less eye movement from windscreen to right CRT. Still would rather have VSD in center.
- Position of displays was a problem.
- Crosscheck from one side of cockpit to other side (displays and MFK) is difficult. Would rather have map at top right CRT and VSD at bottom.
- Long crosscheck from top right CRT to MFK. Would rather have VSD in center. (Would rather have pilot be flight director.)
- Felt like I was flying off the side of the panel. Would rather have the displays in the center.
- Having the attitude indicator off to the side was a problem. Was better in the center.
- Prefer attitude information in center.
- Don't like on right side. Definitely optimum for backup.
- Difficult to fly VSD on right and operate the keyboard at the same time on the left.
- Don't like VSD on right.
- Shouldn't have to look down and right for altitude information.
- Didn't like having information on right. Felt unnatural crosscheck between EADI and MFK difficult.
- Didn't like it. Traditionally, oriented to having altitude information in front, centrally located. Felt was flying "cross cockpit". If got used to it, could fly it. But is "against" everything have flown.
- Missing heading information. Flight displays shouldn't be on smaller displays.
- Long distance horizontally for crosscheck.

FORMAT ARRANGEMENT 6



FINAL DEBRIEFING QUESTIONNAIRE:

Rate your ability to use each of the display arrangements. ($D(17)=0.40$, $p < .01$)

Display Arrangement	Very Inefficient	Moderately Inefficient	Satisfactory	Moderately Efficient	Very Efficient
6	7	4	6	0	0

POST FLIGHT SEGMENT QUESTIONNAIRE:

Question requesting opinion regarding pilots' ability to use arrangement to fly the simulator. The responses were: 3 Unacceptable; 14 Satisfactory; 0 Optimum.

Question requesting opinion regarding arrangement if it were standard and pilot had extensive experience with it. Responses were: 4 Unacceptable; 13 Satisfactory; 0 Optimum.

Question regarding whether arrangement is useable as a backup in the event of failure. 16 Yes, useable as backup; 1 No, not useable as backup.

FINAL DEBRIEFING QUESTIONNAIRE COMMENTS:

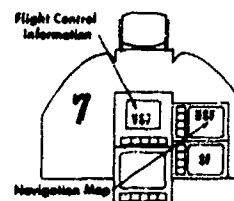
- Arrangements 5 and 6 were worst. More difficult to monitor flight conditions while using MFK.
- Arrangements 4, 5, 6 and 8 were all about the same.
- Can't read digital readout of heading when map or VSD in top right CRT position.
- Display 6 is work due to the fact that you have to look cross cockpit.
- Lower right configuration. Felt like flying cross cockpit and head is buried too much.
- Arrangement 6 was uncomfortable/awkward to look to side for flight information, especially since tasks had to be performed on opposite side of cockpit.
- Arrangement 6 was worst because the flight instruments were farther from the MFK.
- Arrangements 2, 5, 6, 7, and 8 all graded satisfactory. Too much eye movement involved or off-center in cockpit. Off-center instruments make me feel like I am always in a turn.

- Number 6 also bad. Felt unnatural to concentrate attention to one side or to the other.

POST FLIGHT QUESTIONNAIRE COMMENTS:

- Rather have VSD in center than on right side.
- Arrangement 6 not as good as arrangement 3. Having all the information on the right side was a problem.
- Offset to right. Crosscheck between ADI and groundspeed good. Damn good backup.
- Primary flight displays too far from keyboard. Crosscheck difficult. Lose control of flight parameters.
- Looking at side makes it tougher to fly. Is a waste of time to test.
- Length of crosscheck was a problem. Would rather look straight ahead at attitude.
- Afraid sun shining in would prevent use of two right CRTs. Is a disadvantage having all information on right side, especially when flying right wing.
- Long crosscheck from displays to MFK is a problem.
- Located in poor part of cockpit. Heading blocked out on both VSD and HSD by CRT frames. With experience, arrangement satisfactory. But even if had practice with it, wouldn't like it.
- Distant crosscheck between top right CRT (VSD) to left bottom MFK.
- Location on right is a problem. Leaning uncomfortable.
- Easier to fly VSD on right CRT than with HUD. Would rather have VSD in center with HUD. Map location doesn't make a difference and is not that critical. Like to have map on right, either top or bottom right CRT.
- Arrangement unacceptable as primary. Displays off-center. Can't get seat low enough to see heading indicators on VSD. Would have to lean way over to see heading.
- The long crosscheck from the VSD to the MFK was a problem. Had to go across the panel.
- Didn't like it. Would rather have VSD in center. With experience arrangement minimally satisfactory.
- Can't read course on VSD or HSD due to recessed screen.
- Don't like having displays at right. Always leaning to right. Like having VSD over HSD. Would be problem in IFR conditions. May have vertigo problem with leaning to right. Uncomfortable. Would be an outstanding backup.

FORMAT ARRANGEMENT 7



FINAL DEBRIEFING QUESTIONNAIRE:

Rate your ability to use each of the display arrangements.

Display Arrangement	Very Inefficient	Moderately Inefficient	Satisfactory	Moderately Efficient	Very Efficient
7	0	3	8	5	1

POST FLIGHT SEGMENT QUESTIONNAIRE:

Question requesting opinion regarding pilots' ability to use arrangement to fly the simulator. The responses were: 0 Unacceptable; 12 Satisfactory; 5 Optimum.

Question requesting opinion regarding arrangement if it were standard and pilot had extensive experience with it. Responses: 0 Unacceptable; 11 Satisfactory; 6 Optimum.

Question regarding whether arrangement is useable as a backup in the event of failure. 17 Yes, useable as a backup; 0 No, not useable as backup.

FINAL DEBRIEFING QUESTIONNAIRE COMMENTS:

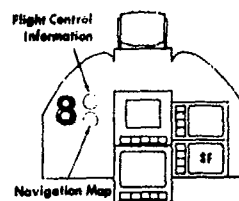
- Can't read digital readout when map or VSD in top right CRT position.
- 7 may be close to moderately efficient.
- Arrangement 7 was best. Best crosscheck. Allows better use of remaining space.
- Arrangements 2, 5, 6, 7, and 8 all graded satisfactory. Too much eye movement involved or off-center in cockpit. Off-center instruments make me feel like I am always in a turn.

POST FLIGHT QUESTIONNAIRE COMMENTS:

- Liked using VSD format on CRT rather than HUD for head down applications.
- Liked crosscheck better than other arrangements.
- Arrangement would be easier to fly in an aircraft. Arrangement could be optimum in transport applications.

- Arrangement satisfactory for VFR conditions and optimum for IFR conditions. For VFR conditions, want arrangement with HUD. Arrangement not bad for instrument flying. Arrangement very useable for those conditions in comparison.
- Having HSD in central position is an advantage.
- Where the navigation information is located does not make any difference because don't use it for reference often.
- Arrangement minimally satisfactory. Difficulty in operating keyboard while flying displays. Can't pay enough attention to flight displays.
- Would rather have map below VSD. Had some problems with crosschecking VSD and HSD. Arrangement pretty good.
- Status on bottom right CRT hard to look at while flying the flight display. Crosscheck problem. Having displays "centered" is an advantage. Head inside alot. More mid air collision potential. Use of HUD is better. Against "grain" to keep head inside so much.
- VSD on larger CRT and centrally located. Could handle crosscheck between VSD and MFK.
- Would rather have the HSD on the bottom CRT.
- Attitude information on upper display. Better to look outside. Groundspeed should be on VSD.
- Having attitude indicator center front is an advantage. Easier crosscheck.
- Didn't like where the HSD was located. Deleted it from crosscheck.
- Like it better than anything else have seen. Would put stuff on MPD nearer to MFK. Attitude information in middle is good. Navigation information is in good location.
- Having VSD format right in front was an advantage. Groundspeed readout should be center too.
- Less eye movement from VSD in center to MFK. Briefer crosscheck.

FORMAT ARRANGEMENT 8



FINAL DEBRIEFING QUESTIONNAIRE:

Rate your ability to use each of the display arrangements. ($D(16)=0.34$, $p < .05$)

Display Arrangement	Very Inefficient	Moderately Inefficient	Satisfactory	Moderately Efficient	Very Efficient
8*	6	5	4	1	0

* 1 pilot did not make a response

POST FLIGHT SEGMENT QUESTIONNAIRE:

Question requesting opinion regarding pilots' ability to use arrangement to fly simulator. The responses were: 3 Unacceptable; 14 Satisfactory; 0 Optimum.

Question requesting opinion regarding arrangement if it were standard and pilot had extensive experience with it. Responses: 5 Unacceptable; 12 Satisfactory; 0 Optimum.

Question regarding whether arrangement is useable as a backup in the event of failure. 17 Yes, useable as backup; 0 No, not useable as backup.

FINAL DEBRIEFING QUESTIONNAIRE COMMENTS:

- Manual instruments were the crudest information. Corrections and indications were not as precise as other CRT displays.
- Arrangement 8 was worst. The instrumentation is arcaic.
- Arrangements 2, 5, 6, 7, and 8 all graded satisfactory. Too much eye movement involved or off-center in cockpit. Off-center instruments make me feel like I am always in a turn.
- Arrangement 8 was worst. Small instruments. Stone age compared to the magic stuff.
- Arrangement 8, although backup in nature put flight information directly above task area. This was a very handy arrangement. Didn't have to move head to complete tasks.
- Arrangement 8 was worst. More comfortable head positioning.

- 8 would only be acceptable for an emergency backup. 8 was worst. Gauges were small and hard to see. Had to lean left to see attitudes and then lean to the right to see performance instruments (engine).
- Arrangements 4, 5, 6 and 8 were all about the same. Number 8 would be the worst if the problem has been compounded (i.e., requiring more round dials).
- Arrangement 8 was worst. Felt unnatural to concentrate attention to one side or the other.
- Arrangement 8 was worst. Old style. Inefficient.
- Arrangement 8 was worst. Did not have the CRT to provide larger display, which gives closer control on pitch and azimuth.

POST FLIGHT QUESTIONNAIRE COMMENTS:

- Having attitude indicator off-center was a problem. There were no advantages.
- Difficult to retrieve information from small instruments.
- Would rather have ILS switch on left side of MFK.
- Instruments cruder, not as sophisticated. All standby instruments above and close to the MFK. Crosscheck easy and quick. With experience, arrangement unacceptable for today's state-of-the-art technology.
- Location disrupts scan. Rest of status information on right side. Nice to have attitude information above keyboard so can monitor flight control while working with radios etc. Would be good backup arrangement.
- Would like ADI larger, bigger gauge. Very useable as backup.
- Crosscheck is less between displays (electromechanical) and MFK. Line of sight doesn't change.
- Problem getting used to different set of instruments after flying CRT. Had to figure out how to interpret information. MPD should be in center. Useable as backup. About all one would use it for.
- Small attitude indicator is a problem. Groundspeed readout should be closer to attitude indicator.
- All the instruments in one area is an advantage. Easier to operate keyboard while looking at flight displays. Instruments antique.
- Arrangement satisfactory since not given any more information. Needles are sensitive so can see things happen quicker. Tended to forget about groundspeed. Out of crosscheck. Like flying F100. Certainly not optimum.
- Small crosscheck between flight displays and MFK.

- Once used to CRTs hard to go back to electromechanical instruments.
- Instrumentation was problem.
- Looking at left side of cockpit for flight displays makes crosscheck to engine instruments on right difficult. (HUD control box is too big and in the way.)
Operation of MFK on left side no problem.
- Instruments were too small and off-center.
- Scan and crosscheck are advantages.

General Comments on Format Arrangements

- Best were arrangements that allow both a "heads up" crosscheck and allowed the crosscheck to be concentrated over a smaller area of eye movement so the crosscheck was more systematic and organized. Worse were arrangements that require head to be down extensively and eye and head movements over large sector to obtain desired information.
- I do not care to have flight control information off-center or too high. Optimum position is at eye level centered. Also best to have flight control information and navigation information in close proximity to each other.
- I would always want my panel in the same configuration, otherwise confusion would result. In fighter aircraft the pilot must often read the flight instruments with a quick glance while maintaining outside visual references. The pilot must know exactly where each instrument is. If the panel is in different configurations; the pilot might have to look around to find the instrument he's interested in.

2. FINAL DEBRIEFING QUESTIONNAIRE DATA

The purpose of this questionnaire is twofold. First, we would like your opinion regarding the best location/arrangement of displays for Vertical Situation (attitude information), Horizontal Situation (map) and Systems Status Information on five electro-optical displays and the backup or electromechanical displays. Second, we are interested in your thoughts regarding the use of a multifunction keyboard, specifically the logic implementation or steps required to complete a task. The extent to which this questionnaire can contribute to our data analysis will depend largely upon your candid opinion. Most of the questions can be answered with a check (✓) but you are encouraged to make further comments. Please be specific as possible.

PERSONAL DATA

Mean Age: 36 years
Mean Total Flying Time: 2962 hours (n = 17)
Mean Total Jet Time: 2719 hours
Current Aircraft: A7D
Mean Hours in A7D: 565 hours
Civilian Job: 11 Pilots: None
 2 Pilots: Engineer
 1 Pilot: Airline Pilot
 1 Pilot: Charter Pilot
 1 Pilot: Real Estate Agent
 1 Pilot: Student
Mean Year Earned Wings: 1965

DISPLAY ARRANGEMENTS

- I. Rate your ability to use each of the display arrangements.*
- II. Was any arrangement BEST? Which arrangement and why?
Was any arrangement WORST? Which arrangement and why?*
- III. Indicate below where you would like the attitude and map information by putting numbers from Figure 2 [12] in the blanks.*

*S . Format Arrangement Data (Appendix F1).

KEYBOARD LOGIC IMPLEMENTATION

- I. Considering all of the tasks completed in this test, compare the standard control head with the logic implemented on the multifunction keyboard (MFK). Check (✓) the appropriate box.

	Standard Much Better Than MFK	Standard Slightly Better Than MFK	Equal	MFK Slightly Better Than Standard	MFK Much Better Than Standard
Brute ¹ Force Logic	1	2		4	1
Tailored Logic				2	7
TOTAL ²	1	2		6	8

¹During testing and questionnaire administration, the systems logic was referred to as brute force logic. After the study, it was decided to employ the word "branching" since it describes the process of progressing through the levels of indenture better.

²D=.65, p < .05

COMMENTS:

BRANCHING LOGIC PILOTS:

- Obvious drawbacks include: second aircraft in flight of 2 or 3 or 4 needs certain functions in a single function control head, i.e., UHF radio. For a single aircraft only a few switches should be single function. Suggest UHF, weapons selection (not fusing etc., just mere selection), IFF, RHAW, ALTIMETER SETTING. Advantage of CRT presentation is movement of display at pilot option, plus elimination of unneeded switches.
- UHF recall on last frequency is good. Master Arm Switch reminder is good.
- I'm used to standard.
- [MFK Slightly Better Than Standard]. Very nice to have capability to change various components from MFK. But having to go to "COMM", "UHF", "UHF CHNG" to do so makes it more time consuming.
- The MFK was easy to use and status display was excellent. A few functions (i.e., UHF change) could be done by a limited amount of feel selection without looking, but most processes required visual cues to accomplish the tasks. The use of a status display board is excellent.

- [MFK Slightly Better Than Standard]. Corrections were easier. On typing in latitude/longitude on A-7D computer if you make a mistake you have to do it all over. Like not having to do that with the MFK.

TAILORED LOGIC PILOTS:

- Location could be improved. Like center top.
- [MFK Slightly Better Than Standard]. Would have rated MFK much better had I not had deep rooted habit patterns established. With practice, I feel MFK could become better.
- [MFK Much Better Than Standard]. This applies to certain types of flying only. I don't think the keyboard will work around formation flying.
- Not nearly as much distraction from flying as conventional controls, especially at night.

II. For each function (i.e., UHF, IFF, etc.) compare the standard control head with the logic implemented on the MFK. Check (✓) the appropriate box.
(B = Branching Logic, T = Tailored Logic)

	Std. Control Head Much Better Than MFK		Std. Control Head Slightly Better Than MFK		Equal		MFK Slightly Better Than Std.		MFK Much Better Than Std.	
	Total		Total		Total		Total		Total	
UHF ¹	B-3	3	B-2	3	B-0	0	B-2	5	B-1	6
	T-0		T-1		T-0		T-3		T-5	
IFF ²	B-0	0	B-3	3	T-2	2	B-1	3	B-1	8
	T-0		T-0		T-0		T-2		T-7	
TACAN ³	B-1	1	B-5	5	B-1	1	B-0	2	B-1	8
	T-0		T-0		T-0		T-2		T-7	
FLY TO ⁴	B-3	4	B-1	1	B-1	2	B-2	3	B-1	7
	T-1		T-0		T-1		T-1		T-6	
ALTIMETER ⁵	B-4	5	B-1	3	B-1	3	B-1	3	B-1	3
	T-1		T-2		T-2		T-2		T-2	
ILS ⁶	B-0	0	B-2	2	B-1	1	B-3	5	B-2	9
	T-0		T-0		T-0		T-2		T-7	
STORES ⁷	B-3	3	B-1	2	B-1	1	B-0	4	B-3	7
	T-0		B-1		T-0		T-4		T-4	
TOTAL	B-14	16	B-15	19	B-7	10	B-9	25	B-10	48
	T-2		T-4		B-3		T-16		T-38	

Logic responses collapsed (one-sample test):

¹D(17)=0.65, p < .01

²D(16)=0.61, p < .01

³D(17)=0.68, p < .01

(Logic responses not collapsed (two-sample test):

D=0.72, p < .05)

⁴D(17)=0.62, p < .01

⁵D(17)=0.82, p < .01

⁶D(17)=0.80, p < .01

⁷D(17)=0.59, p < .01

COMMENTS:

BRANCHING LOGIC PILOTS:

- UHF, IFF, and TACAN can all be changed by feel on the standard head. FLY TO on the standard head is a rotary wheel which is very easy to use. Stores option selection is very good. Setting an altimeter value for navigation is a little

harder than turning a standard baro-counter altimeter but entering target area setting is easier. ILS was o.k. Since it is usually only used once in flight it would be o.k. to put all the necessary information into the system at one time.

- Again, only because its what I'm used to. Some confusion on communication/navigation using squawk/altimeter.
- In general, the MFK requires too much time and attention. The standard control heads can be operated without looking at them. This is not possible with the MFK. In single place fighter aircraft the pilot often must operate the various systems without looking at the control panels.
- Need to be able to change UHF frequencies and set weapons switches by brail. Our FLY TO thumbwheel switch is easy to work and simple.
- [Stores - Std. Control Head Much Better Than MFK]. Under the pressure of battle, one could not operate the MFK to change stores info at last minute. A7D system is much better and easier to operate.

TAILORED LOGIC PILOTS:

- Altimeter and Stores [Std. Control Head Much Better Than MFK]. It is easier and quicker in A7 to perform these functions. UHF and TACAN [MFK Slightly Better than Std.] -- in A-7 you have to look down and to your far left to perform these functions. The other 3 [(IFF, FLY TO, ILS (MFK Much Better Than Std.))] -- much better in your simulator because you do not have to look way down and to the far right. Another advantage is being able to use left hand for function changes.
- The stores SAVE function is unnecessary.
- The MFK is a significant improvement.

III. Is there any function that is so critical or frequently used that it should not be on a multifunction keyboard, but should be on a dedicated, single-purpose control? If so, which?

COMMENTS:

BRANCHING LOGIC PILOTS:

- IDENT, altimeter setting, UHF
- UHF radio, altimeter setting
- Maybe certain weapon selections, i.e., sidewinders/gun should be quickly available
- The radio. A radio which can be changed by feel with audio feedback (side tone)
- Stores information, altimeter
- UHF, weapons switches
- No
- Altimeter setting, UHF frequency change, FLY TO, course select, IFF, critical weapons functions

TAILORED LOGIC PILOTS:

- UHF radio channel
- No
- IFF IDENT, manual weapons release
- Possibly UHF and IFF
- Pilot should have indicator light on over master arm switch to indicate system armed
- Not that I can think of
- No
- UHF radio
- UHF radio

IV. To change IFF mode in/out status, you were required to hit the multifunction switch for the mode to activate the digit entry keyboard. Then a push of the ENTER key changed the mode to the opposite in/out. Did you find the mechanization of IFF mode in/out:

	Unacceptable	Very Bad	Satisfactory	Very Good	Optimum
Brute Force Logic		1	6	1	
Tailored Logic			6	3	
TOTAL		1	12	4	

COMMENTS:

BRANCHING LOGIC PILOTS:

- Takes too much time and attention.
- None of these with the exception of radio frequency changes (manual) was any faster/easier than is presently in use. They work fine, but seem somehow to require more attention focused toward task completion than current systems.
- Is time consuming. Most often pilot would be required to turn it off and on a few seconds later by the controlling agency as a position check. Perhaps an off/on switch as in Nose/Tail fuzing.
- [Satisfactory]. OK, once I understood the logic.

TAILORED LOGIC PILOTS:

- [Satisfactory]. If used to this type of operation, would be satisfactory.
- In/Out should only require one motion.
- Very seldom used in normal operations. IN prior to takeoff and OUT after landing.
- It's okay, but easier now when all we do is hit a switch.

- V. Two types of three-way "rotary" switches were demonstrated. One was in the IFF logic and changed the system status: STANDBY, NORMAL, LOW. The other was used in the STORES logic to indicate delivery mode: SINGLES, PAIRS, SALVO.

Was this type of mechanization:

	Unacceptable	Very Bad	Satisfactory	Very Good	Optimum
Brute Force Logic			2	4	2
Tailored Logic			5	3	1
TOTAL			7	7	3

COMMENTS:

- [Satisfactory]. The rotary switches are good, but for stores, I do not like the other processes one had to go through for the other changes.
- [Satisfactory]. I didn't know these were three-way switches.
- Easy to change.
- [Optimum]. If time is critical in dropping ordnance, a quick change to singles, pairs, or all is primary and easily accomplished with the logic shown on MFK in stores mode.
- [Satisfactory]. An improvement over the old system.
- [Optimum]. Very quick--speed is important.

VI. Are there any functions which should be added to or deleted from the options presented during each flight mode?

COMMENTS:

- None that I can think of at this time.
- No
- No
- Need more time in simulator during mission profile to adequately evaluate.
- Don't know
- [No response]
- Indicated airspeed in cruise and all other phases of flight. True airspeed and calibrated airspeed should be indicated also but I always want to know my indicated airspeed.
- Delete Stores SAVE.
- Add the groundspeed readout to the flight control information display.

VII. During the NAV BOMB flight mode [Tailored Logic only], the ALTIMETER SET function was on Key 5 of the MFK and during the CLIMB flight mode, it was on Key 8. How did the different locations affect your ability to change the altimeter setting?

	Very Detrimental	Slightly Detrimental	No effect
TOTAL	1	5	3

COMMENTS:

- [Slightly Detrimental]. It was confusing. With more experience it may not be a problem.
- [Slightly Detrimental]. Should be kept at same relative location if possible.
- Actually I did not notice the change, but then I am not very familiar with this setup anyway. In real life it would seem to be easier if it did not change.

MFK AND FLIGHT DISPLAYS

I. Rate each of the following aspects of the MFK. Check (✓) the appropriate box.

	Unacceptable	Very Bad	Satisfactory	Very Good	Optimum
a. Readability ¹		1	5	8	3
b. Legend Arrangement ²			7	9	1
c. Pre-entry Readout		2	5	8	2
d. Legibility ³		1	6	7	3
TOTAL		4	23	32	9

¹ $\bar{D}(17)=0.34, p < .05$

² $\bar{D}(17)=0.40, p < .01$

³ $\bar{D}(17)=0.34, p < .05$

COMMENTS:

BRANCHING LOGIC PILOTS:

- Readability [Satisfactory]. Wonder what bright sunlight will do to the screen? Pre-entry Readout [Very Good]. Blinking is great but should be at fewer cycles per second.
- Pre-entry Readout [Very Good]. When the entry flashed, it sometimes took an extra couple of seconds to verify the correct entry. Maybe a flashing box around the entry and keep the entry steady.
- Several times I had a hard time getting to the altimeter entry just because the generalized DATA ENTRY to get me to altimeter didn't register as the right button to press. During a flight, the altimeter is changed at least 8 to 10 times. Why not have it appear as an entry right after you push the NAV button.
- This system would be fine for a navigator or WSO [weapons system operator] who could devote his full attention to the display. The pilot of a single seat fighter can only devote a fraction of his attention to the tasks performed on the MFK. The MFK requires too much attention and too much thinking. In its present configuration I don't think it will work in a single seat fighter.
- IFF - comm or nav?
- Pre-entry Readout [Very Bad]. Flashes too fast.

TAILORED LOGIC PILOTS:

- The buttons should be separated on the keypunch so that only one will be hit at a time.
- Might be better if other data on display was blanked out and data being changed was larger.
- The function switches seemed a bit small to me. I had to be very careful not to hit two at once. I like the flashing feature used for pre-entry but the time sequence made it hard to read for crosscheck before entering. You might consider a flashing bracket which would flash all the time a change was being made and would direct attention to the change location throughout the "typing" process.
- Pre-entry Readout [Satisfactory]. Think that having the digits flash prior to entry is not the way to go. Makes them difficult to check just prior to entry.

II. Rate each of the following aspects of the HUD. (See Figure 3 [7]).

	Very Bad	Bad	No Opinion	Good	Very Good
a. Amount of Information ^{1*}		1		12	3
b. Information Retrieval ²		1	1	13	2
c. Legibility	1	5	1	9	1
d. Shape of Symbols	1	5	4	6	1
e. Jitter	3	4	3	6	1
TOTAL	5	16	9	46	8

* 1 pilot did not make a response.

¹D(16)=0.54, p < .01

²D(17)=0.48, p < .01

COMMENTS:

- Shape of symbols [Bad]. I would prefer flying the little airplane to a flight director dot, rather than flying a "dot" to the airplane.
- Amount of information [Good]. Should be pilot selectable. Information easily understood. Flight path marker should be more predominant than the flight director symbol  and not  Shape of symbols [Bad]. Don't like the lines becoming broken in other than straight and level flight (Jitter-Bad). Overall, the HUD was good to very good. I'm a little undecided on whether or not I like the printout of airspeed and altitude etc. to the exact foot or knot.
- Would like groundspeed readout where vertical velocity indicator is now (upper right). Put vertical velocity indicator lower right. Velocity vector symbol could be bigger, i.e.



-5-----5

- Jitter [Very Bad]. Probably just a function of this simulator because ours is much better. Amount of information was very good, but I would like the option of removing some of it when not needed--similar to what we have now.
- HUD--most people use altitude information only. Altitude/airspeed information clutters up the windscreen. A good number of pilots including myself turn the HUD off except for weapons delivery because it destroys the interior crosscheck and proficiency of flying off interior gauges. As previously mentioned, this HUD uses  as the aircraft, as does the A-7. This system is much easier to fly from than the  method. System of blocking airspeed and altitude is an excellent idea.

- Add groundspeed. We don't really need the precise reading on aircraft's heading and altitude. The boxes clutter up the displays.
- Legibility [Bad]. Poor focus. Shape of symbols [Bad]. I don't like the symbols. I have a tendency to fly the aircraft symbol rather than vice versa.
- HUD had a lot of information but is hard to read. Was out of focus and lines were too thick. Flight path marker should be larger and steering symbol smaller.

Following notes made on HUD format figure:

Delete boxed present heading readout (not needed) and replace with lubber line. Add a vertical velocity scale to the right of the altitude scale. Move boxed altitude readout to the right slightly and boxed airspeed readout to the left slightly. Add pointers, from the altitude and airspeed boxes to the scales. Make flight director smaller and flight path marker larger. Weapons information and UHF frequency readout are good. Need G readout.

- Shape of symbols [Bad]. The flight director should be a dot so as not to be confused with the aircraft symbol.
- Enclosing altitude/speed/heading in box is great. You are able to spot these values quickly/easily.
- Shape of symbols [Bad]. Biggest objection: should have aircraft symbol be the one to fly to a target symbol and not the other way around.
- I like the flight path marker in the HUD much better than the VSD. Not necessary to have altitude and airspeed reflected to the last digit. These displays are changing constantly and is distracting. To the nearest 100' for altimeter and 10 knots for airspeed is enough.
- Amount of information [Bad]. Too much information. Will interfere with out-of-cockpit view. Parameters displayed are o.k., just too cluttered.

III. Rate each of the following aspects of the VSD (attitude information). (See Figure 4 [8]).

	Very Bad	Bad	No Opinion	Good	Very Good
a. Amount of Information ¹		1	1	9	6
b. Information Retrieval ²		2		13	2
c. Legibility ³		1	2	11	3
d. Shape of Symbols ⁴		8	3	5	1
d. Jitter		6	2	9	
TOTAL		18	8	47	12

¹D(17)=0.48, p < .01

²D(17)=0.48, p < .01

³D(17)=0.42, p < .01

⁴D(17)=0.37, p < .05

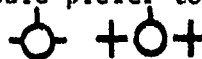
COMMENTS:

- Add groundspeed. The color one was better.
- Aircraft symbol should be more like flight path marker on HUD. Flight director resembles aircraft symbol but does not bank in direction required for making correction. Confusing.
- Shape of symbols [Bad]. Flight director looks like an airplane.
- Good information but needs a lot of refinement. Following notes made on VSD format figure:

Delete boxed present heading. Present 4 more degrees of heading scale. Add vertical velocity scale to left of altitude scale. Add points to boxed altitude and airspeed readouts. Extend pitch ladder beyond aircraft symbol. Use different shape for flight director. Looks too much like Flight Path Marker. Aircraft symbol should be more like this with larger dot. Make the bank pointer larger.



- Shape of symbols [Bad]. Again, I would prefer to fly the little airplane, not the dot. An aircraft symbol may be



The circle makes it easy to center the flight director dot.

- Aircraft symbol is too large. It looks like a pitch line. Flight director is too large. Clutters the display. Maybe I like the A-7 tadpole.



- I personally feel the  symbol for the aircraft is not good. The flight director system using  aircraft symbol works better. This system results in confusion as it is different from other existing systems. Aircraft symbol is the better method. Again boxing altimeter/airspeed works well.
- Flight director and aircraft symbol, if reversed, would be easier to fly.
- Flight path marker needs to be bigger.
- Recommend groundspeed rather than true or calibrated airspeed.
- Amount of information displayed [Bad]. Gets to the point of excessive and then is ignored and therefore not of value. Shape of symbols [Bad]. Think 0 pitch line display and aircraft symbol are really bad.

Fl. Siegel, S., "Nonparametric Statistics for the Behavioral Sciences." McGraw Hill Book Company, New York, 1956.

APPENDIX G

STATISTICAL PROCEDURES USED IN DATA ANALYSES

Amplitude distributions (Reference G1) of the time-history recordings of each parameter were constructed to evaluate the relative effects of the experimental conditions. Summary statistics descriptive of the error amplitude distribution of a sample of tracking performance were computed using the following formulae:

AE (average error) =

$$\frac{1}{T} \int_0^T e(t) dt$$

AAE (average absolute error) =

$$\frac{1}{T} \int_0^T |e(t)| dt$$

RMS (root-mean-square error) =

$$\sqrt{\frac{1}{T} \int_0^T e^2(t) dt}$$

SD (standard deviation) =

$$\sqrt{(RMS)^2 - (AE)^2}$$

where T = time over which the parameter was
integrated

e = amplitude of the parameter at time t

dt = sampling interval

The AE is a numerical index of the central tendency of the amplitude distribution, while the SD reflects the variability of dispersion of the measures around this central tendency. RMS error is also an index of performance variability, but relative to the null point rather than the AE. AAE is the mean of the amplitude distribution replotted with all error amplitudes positive and is indicative of the variability when interpreted in conjunction with the other performance indices.

These summary statistics (AE, AAE, RMS, SD) were computed on the flight parameters groundspeed, vertical steering error, and horizontal steering error for the time period specified by the event and for the immediate thirty seconds prior to the event. Summary statistics for the thirty second pre-event time for each parameter were subtracted from the corresponding values computed for the event in order to measure only the affect of the keyboard operations on the pilot's performance. An example calculation can be illustrated as follows:

Speed Error RMS (Time Period for Correct Entry: Total try)	-	Speed Error RMS (Pre-event Period)	=	Delta Speed Error RMS (Summary Statistic used in Statistical Analyses)
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Keyboard task performance was evaluated by measuring the time required for the task event and the number of switch hits. The number of switch hit errors was derived by subtracting the actual number of switch hits required to accomplish the particular task without error from the total number of switch hits made.

Statistical analyses were conducted on the following dependent variables:

- delta groundspeed RMS
- delta horizontal steering error RMS
- delta vertical steering error RMS
- keyboard operation time
- switch hit errors

These variables were initially analyzed by the use of the Statistical Package for the Social Sciences (SPSS) (Ref. G2) which performs multivariate analysis of variance (MANOVA). In those cases where the MANOVA revealed significant effects, discriminant function analyses were conducted in order to determine which of the dependent variables were most sensitive to changes in independent variables.

Data obtained from the debriefing questionnaire were compiled to be presented in tabular form (Appendix F). Nonparametric Kolmogorov-Smirnov tests of significance (Ref. G3) were conducted.

- G1. Obermayer, R.W., and Muckler, F.A., "Performance Measurement in Flight Simulation Studies." NASA-CR-82, July, 1964.
- G2. Nie, N.H., Hull, C.H., Jenkins, J.G., Steinbrenner, K., and Bent, D.H., "Statistical Package for the Social Sciences" (2nd ed.). McGraw-Hill Book Company, New York, 1975.
- G3. Siegel, S., "Nonparametric Statistics for the Behavioral Sciences." McGraw-Hill Book Company, New York, 1956.

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1. Gemin, G.S., "F-16." USAF Fighter Weapons Review, Spring 1976, 1-8.
2. "The Venomous F-18." Air International, December 1978, 258-266.
3. Reising, J.M., "Total Cockpit Implications of Electro-optical Displays." AGARD-LS-76, May 1975.
4. Bateman, R.P., Reising, J.M., Herron, E.L., and Calhoun, G.L., "Multifunction Keyboard Implementation Study." AFDL-TR-78-197, December 1978.
5. Nie, N.H., Hull, C.H., Jenkins, J.G., Steinbrenner, K., and Bent, D.H., "Statistical Package for the Social Sciences" (2nd ed.). McGraw-Hill Book Company, New York, 1975.