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EVALUATION OF PROPOSED C-141  
ELECTRONIC DISPLAY FORMATS AND MENUS

VOL 2 - FULL MISSION SIMULATION



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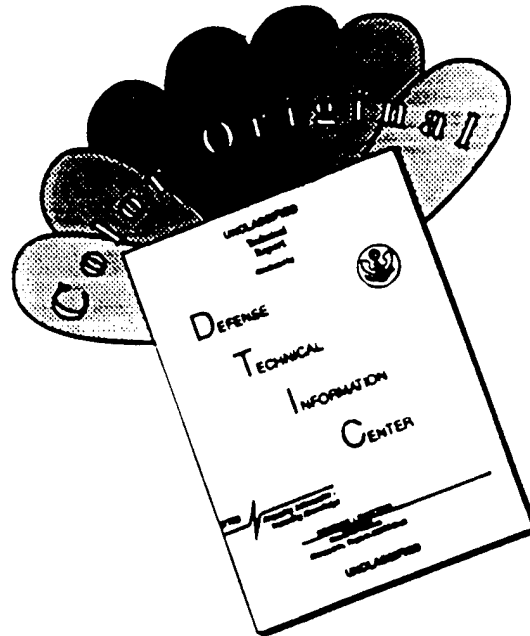


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# TABLE OF CONTENTS

|   |           |
|---|-----------|
| <b>INTRODUCTION .....</b>                                   | <b>1</b>  |
| <b>ANALYSIS AND DESIGN EFFORT .....</b>                     | <b>1</b>  |
| <b>FULL MISSION SIMULATION OBJECTIVES.....</b>              | <b>5</b>  |
| <b>APPROACH.....</b>  | <b>5</b>  |
| <b>METHOD .....</b>   | <b>6</b>  |
| SUBJECTS .....  | 6         |
| APPARATUS .....   | 6         |
| <i>Transport Aircraft Cockpit Simulator .....</i>           | <i>6</i>  |
| <i>C-141 Configuration.....</i>                             | <i>10</i> |
| <i>Control/Display SubSystem Cockpit Configuration.....</i> | <i>10</i> |
| <i>Experimenter's Console .....</i>                         | <i>11</i> |
| PROCEDURE.....  | 11        |
| <i>Training .....</i>                                       | <i>11</i> |
| <i>Data Collection Sessions .....</i>                       | <i>12</i> |
| <i>Mission Descriptions.....</i>                            | <i>12</i> |
| <i>Experimental Design.....</i>                             | <i>14</i> |
| <i>Data Recording and Reduction.....</i>                    | <i>15</i> |
| <b>RESULTS .....</b>  | <b>17</b> |
| PERFORMANCE .....   | 17        |
| WORKLOAD.....   | 19        |
| <i>Subjective Workload Assessment Technique.....</i>        | <i>19</i> |
| <i>Subjective Workload Dominance .....</i>                  | <i>20</i> |
| QUESTIONNAIRES .....  | 20        |
| <i>Function Questionnaire .....</i>                         | <i>21</i> |
| <i>Control/Display SubSystem Element Questionnaire.....</i> | <i>22</i> |
| <i>Final Questionnaire.....</i>                             | <i>26</i> |
| <b>DISCUSSION.....</b>                                      | <b>27</b> |
| INSTRUMENT FLIGHT.....                                      | 28        |
| NAVIGATION .....  | 29        |
| STATION KEEPING EQUIPMENT FORMATION FLIGHT.....             | 29        |
| OPERATIONAL IMPLICATIONS.....                               | 30        |
| RELATION TO PART-TASK EVALUATION RESULTS.....               | 30        |
| IMPLICATIONS FOR THE HEAD-DOWN STANDARD .....               | 31        |
| STUDY OBSERVATIONS / LIMITATIONS.....                       | 32        |
| DESIGN IMPROVEMENTS.....                                    | 32        |
| <i>Primary Flight Display .....</i>                         | <i>32</i> |
| <i>Secondary Flight Display .....</i>                       | <i>33</i> |
| <i>Display Avionics Management Unit.....</i>                | <i>34</i> |
| <b>PROJECT SUMMARY &amp; CONCLUSION .....</b>               | <b>37</b> |

## TABLE OF CONTENTS (CONT'D)

|  |     |
|--|-----|
| REFERENCES.....  | 38  |
| APPENDIX A: PFD, SFD, AND C-141 ELECTROMECHANICAL DISPLAY ELEMENTS ..... | 39  |
| APPENDIX B: DAMU HIERARCHICAL STRUCTURE .....                            | 60  |
| APPENDIX C: QUESTIONNAIRE AND SWORD FORMS .....                          | 65  |
| APPENDIX D: QUESTIONNAIRE RESPONSE RATINGS AND COMMENTS.....             | 85  |
| APPENDIX E: MISSION PROFILES AND SCRIPTS.....                            | 103 |
| APPENDIX F: FUNCTIONAL SPECIFICATION.....                                | 157 |

## LIST OF FIGURES

|  |    |
|--|----|
| FIGURE 1. CURRENT AND PLANNED UPGRADE C-141 COCKPITS. ....                         | 2  |
| FIGURE 2. SIMULATED C-141 ELECTROMECHANICAL AND CDS PFD / SFD FORMATS.....         | 3  |
| FIGURE 3. EXAMPLE OF NAV SELECT AND PFD DAMU MENU PAGES. ....                      | 4  |
| FIGURE 4. TRAC COCKPIT IN THE C-141 CONFIGURATION.....                             | 8  |
| FIGURE 5. TRAC COCKPIT IN THE CDS CONFIGURATION.....                               | 9  |
| FIGURE 6. DAMU SCREEN LAYOUT .....   | 11 |
| FIGURE 7. SICILY AIRDROP MISSION PROFILE.....                                      | 13 |
| FIGURE 8. LUZON AIRDROP MISSION PROFILE .....                                      | 13 |
| FIGURE 9. POPE AIRLAND MISSION PROFILE .....                                       | 14 |
| FIGURE 10. FAYETTEVILLE AIRLAND MISSION PROFILE .....                              | 14 |
| FIGURE 11. COMPARISON OF SKE PERFORMANCE MEANS FOR RUN-IN & DROP 1ST PASS .....    | 17 |
| FIGURE 12. INS FAILURE RESPONSE TIMES .....  | 18 |
| FIGURE 13. SWAT RATINGS FOR AIRDROP SEGMENTS.....                                  | 19 |
| FIGURE 14. SWAT RATINGS FOR AIRLAND SEGMENTS.....                                  | 20 |
| FIGURE 15. SWORD WORKLOAD RATINGS AS A FUNCTION OF CONFIGURATION AND FUNCTION..... | 20 |
| FIGURE 16. COMPARISON OF FUNCTION RATINGS BETWEEN CONFIGURATIONS .....             | 21 |
| FIGURE 17. ADI ELEMENT RATINGS .....   | 23 |
| FIGURE 18. HSI ELEMENT RATINGS.....  | 23 |
| FIGURE 19. ALTITUDE INDICATOR ELEMENTS AND VVI RATINGS.....                        | 24 |
| FIGURE 20. AIRSPEED ELEMENT RATINGS .....  | 25 |
| FIGURE 21. OVERALL SFD FORMAT RATINGS .....  | 25 |
| FIGURE 22. DAMU MENU PAGE AND OPTIONS RATINGS .....                                | 25 |
| FIGURE 23. COMPARISON OF PRIMARY FLIGHT PRESENTATION.....                          | 26 |
| FIGURE 24. COMPARISON OF SECONDARY FLIGHT PRESENTATION AND CONTROL DESIGN .....    | 26 |
| FIGURE 25. CDS GENERAL OPERATIONS. ....  | 27 |
| FIGURE 26. PFD DESIGN REFINEMENTS.....   | 35 |
| FIGURE 27. DAMU DESIGN REFINEMENTS.....  | 36 |

## LIST OF TABLES

|  |    |
|--|----|
| TABLE 1. NUMBER OF MISSIONS PER CONFIGURATION .....                          | 15 |
| TABLE 2. SWAT EVENTS FOR THE AIRDROP AND AIRLAND MISSIONS.....               | 16 |
| TABLE 3. PERFORMANCE MEASURES ANALYZED FOR EACH AIRDROP MISSION SEGMENT..... | 18 |
| TABLE 4. PERFORMANCE MEASURES ANALYZED FOR EACH AIRLAND MISSION SEGMENT..... | 18 |

## **GLOSSARY**

|        |                                      |
|--------|--------------------------------------|
| ADI    | Attitude Director Indicator          |
| ADS    | Airdrop System                       |
| AFB    | Air Force Base                       |
| ANOVA  | Analysis of Variance                 |
| ASC    | Aeronautical System Center           |
| ATC    | Air Traffic Control                  |
| AWFCS  | All Weather Flight Control System    |
| AWG    | Autopilot Working Group              |
| BDHI   | Bearing Distance Heading Indicator   |
| BIT    | Built-in Test                        |
| CARP   | Computed Airdrop Release Point       |
| CCT    | Combat Control Team                  |
| CDS    | Control Display Subsystem            |
| CDU    | Control Display Unit                 |
| CONOP  | Concept of Operations                |
| CRT    | Cathode Ray Tube                     |
| CSIL   | Crew Station Integration Laboratory  |
| DAMU   | Display Avionics Management Unit     |
| DICU   | Display Interface Control Unit       |
| FCR    | Flight Command Repeater              |
| FSAS   | Fuel Savings Advisory System         |
| FSDG   | Flight Symbolology Development Group |
| HSI    | Horizontal Situation Indicator       |
| IFR    | Instrument Flight Rule               |
| ILS    | Instrument Landing System            |
| INS    | Inertial Navigation System           |
| JCO    | Joint Cockpit Office                 |
| LCD    | Liquid Crystal Display               |
| LSK    | Line Select Keys                     |
| MANOVA | Multivariate Analysis of Variance    |

## GLOSSARY (CONT'D)

|         |  |
|---------|--|
| MFD     | Multi-Function Display                         |
| NDB     | Non-Directional Beam                           |
| NSP     | Nav Select Panel                               |
| NVGs    | Night Vision Goggles                           |
| PFD     | Primary Flight Display                         |
| PICU    | Pilot's INS Control Unit                       |
| RMS     | Root Mean Square                               |
| RRI     | Relative Range Indicator                       |
| RSP     | Reference Set Panel                            |
| SFD     | Secondary Flight Display                       |
| SKE     | Station Keeping Equipment                      |
| SOLL    | Special Operations Low Level                   |
| SWAT    | Subjective Workload Assessment Technique       |
| SWORD   | Subjective Workload Dominance                  |
| TACAN   | Tactical Air Navigation                        |
| TOT     | Time Over Target                               |
| TRAC    | Transport Aircraft Cockpit                     |
| VDI     | Vertical Deviation Indicator                   |
| VHF     | Very High Frequency                            |
| VOR     | VHF Omni Range                                 |
| VVI     | Vertical Velocity Indicator                    |
| WL/FIGP | Wright Laboratory Cockpit Integration Division |
| WR-ALC  | Warner Robins Air Logistics Center             |
| ZM      | Zone Marker                                    |

## INTRODUCTION

Warner-Robins Air Logistics Center (WR-ALC) has initiated a program to incorporate the All Weather Flight Control System (AWFCS) into the C-141 cockpit. As part of the upgrade, current cockpit flight instruments will be replaced with a new Control/Display Subsystem (CDS) consisting of four Liquid Crystal Display (LCD) units, two Display Avionics Management Unit (DAMU) and a variety of modified control panels. Figure 1 shows a comparison of the current and planned cockpit layouts.

In support of this cockpit upgrade effort, the Wright Laboratory Cockpit Integration Division (WL/FIGP) conducted a pilot-in-the-loop simulation program to develop and evaluate the display format and menu interfaces being implemented on the CDS hardware. The Wright Laboratory effort focused on the three main functional components of the CDS: Primary Flight Display (PFD), Secondary Flight Display (SFD), and the DAMU menu system.

The *Primary Flight Display* format will provide all instrument flying information, including Attitude Director Indicator (ADI), Horizontal Situation Indicator (HSI), Airspeed Scale, Altitude Scale, Heading, and Bank. The PFDs will replace the C-141's electromechanical ADI, HSI, airspeed and barometric altitude indicators. A comparison of the C-141 and CDS formats are presented in Figure 2.

The *Secondary Flight Display* format will provide supplementary flight and route information. The SFD will allow the selection of three modes: Map, Station Keeping Equipment (SKE) or expanded HSI. The MAP mode of this format is presented in the lower left display in Figure 2.

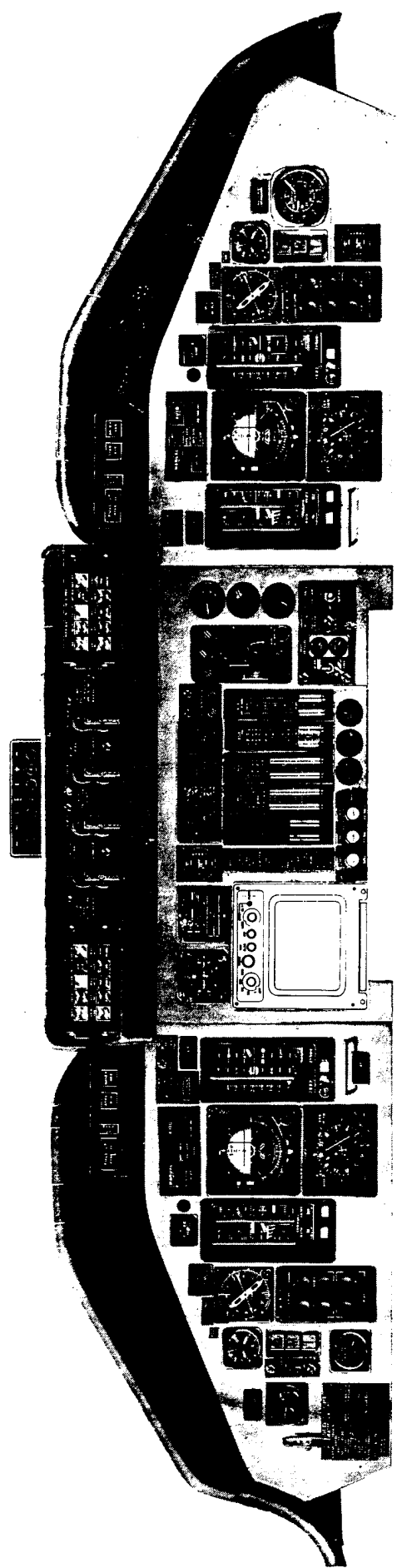
The *Display Avionics Management Unit* menu interface will control the PFD format, SFD formats, and various navigation functions. The Display Avionics Management Unit (DAMU) will replace the C-141's Nav Select Panel (NSP). Figure 3 presents example pages of the DAMU menu structure.

The simulation program was conducted in two phases. In the first phase, the PFD and DAMU were individually evaluated in a part-task context to compare alternative design configurations and to evaluate specific format elements. The method and results of the part-task evaluation can be found in Cone, Toms, Gier, Brown and Patzek (in press). Design changes were made based on the part-task results. In the second phase, the revised CDS components (PFD, SFD and DAMU) were evaluated as an integrated system in a full mission simulation. The purpose of this report is to document the methods and results for the full mission evaluation.

## ANALYSIS AND DESIGN EFFORT

Prior to conducting the simulation evaluations, an analysis and design effort was accomplished. The designs were developed through a cooperative effort between WL/FIGP, the Joint Cockpit Office (JCO), and the C-141 Autopilot Working Group (AWG). The C-141 CDS Concept of Operation (CONOP), Rev A served as a baseline design.

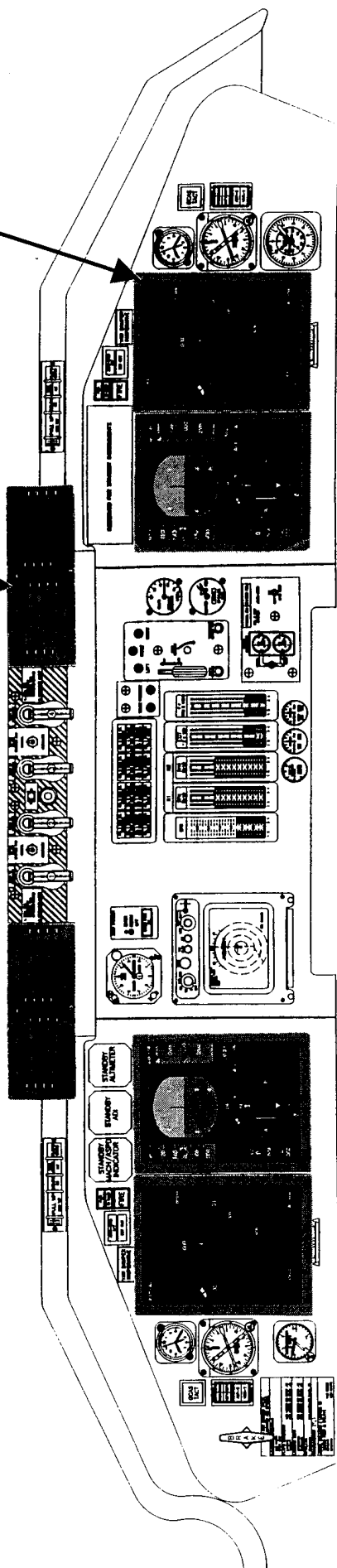
Two design goals drove the design process. The first goal was to insure that the design provided at least the same capability as the current C-141 configuration. A second



**EXISTING INSTRUMENT CONSOLE**

DISPLAY AVIONICS MANAGEMENT UNIT

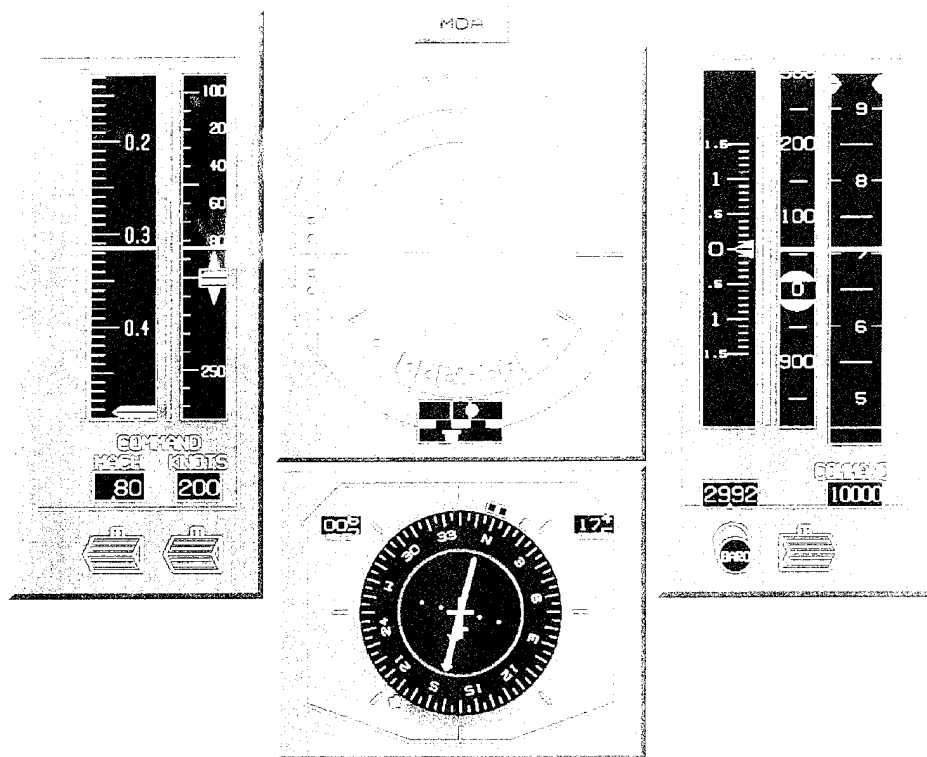
DISPLAY UNIT



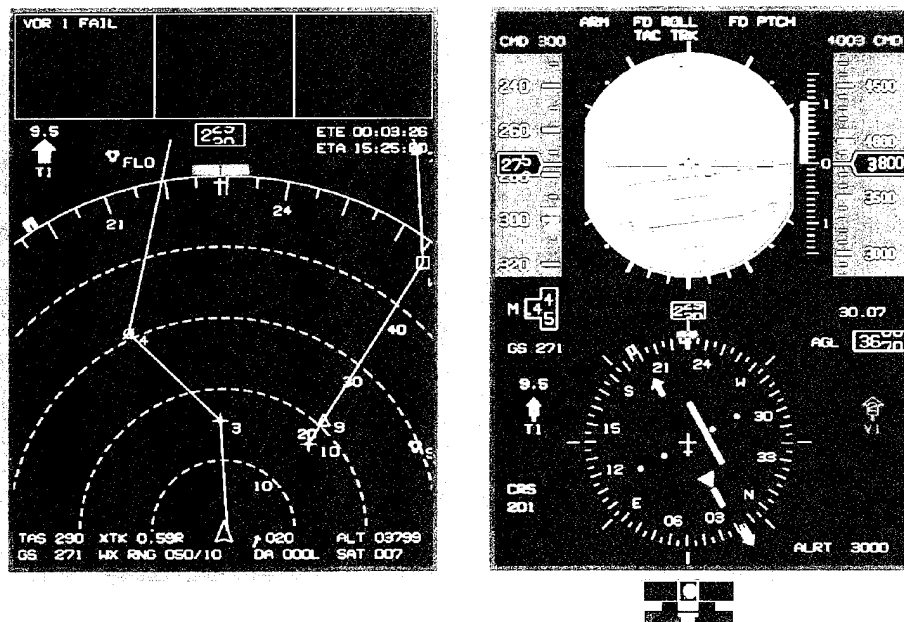
**UPGRADED INSTRUMENT CONSOLE**

*Figure 1. Current and Planned Upgrade C-141 Cockpits.*



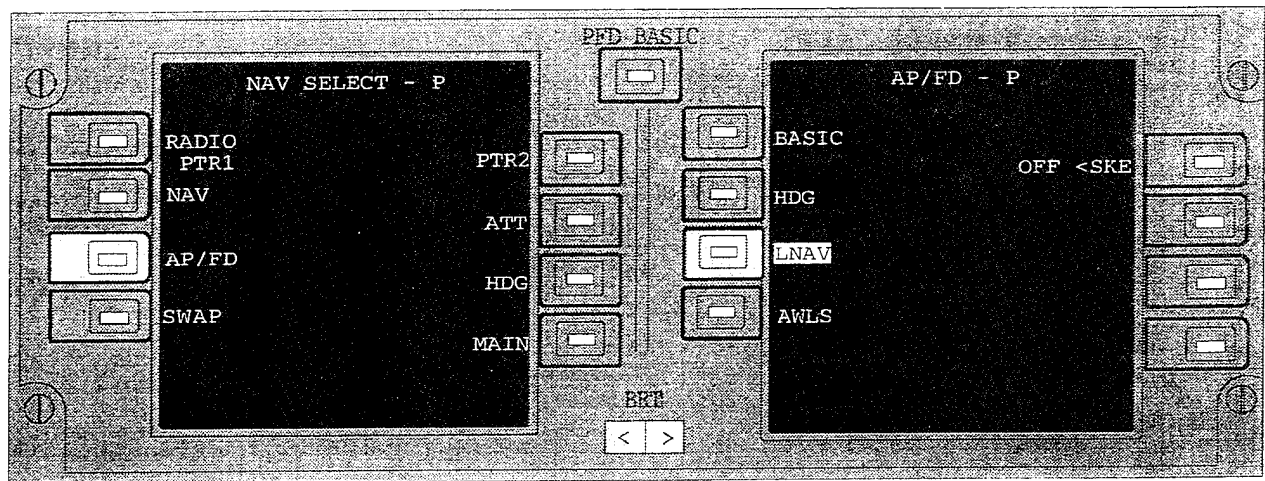


*C-141 Electromechanical Suite*

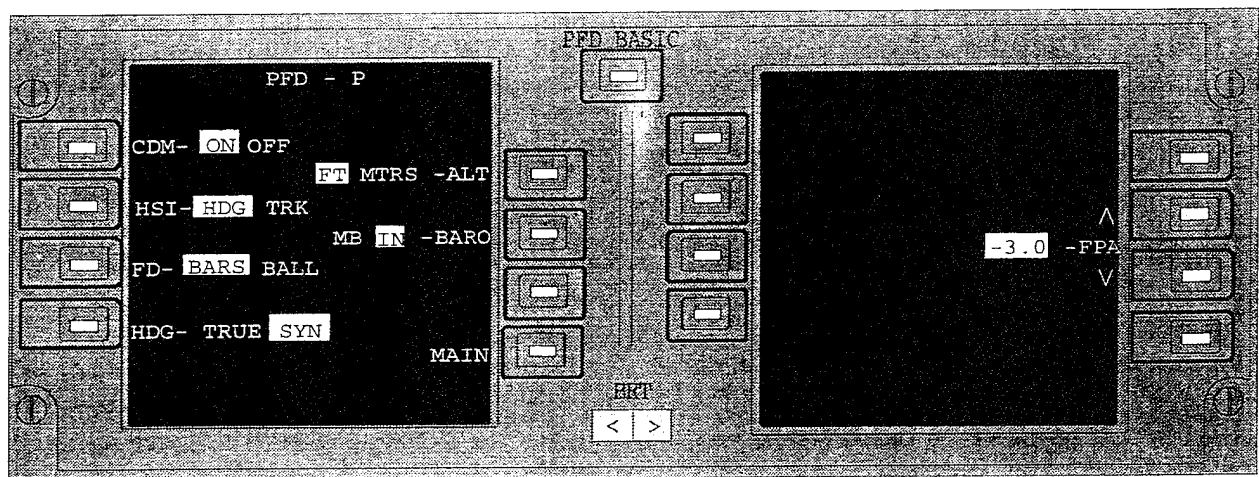


*CDS PFD / SFD Formats*

*Figure 2. Simulated C-141 Electromechanical and CDS PFD / SFD Formats.*



NAV Select Primary Menu Page



PFD Primary Menu Page

Figure 3. Example of NAV Select and PFD DAMU Menu Pages.

design goal applied only to the PFD. This goal required the PFD to be in compliance with the future military standard for electronic head-down primary flight displays format which is being developed by JCO's Flight Symbolology Development Group (FSDG).

To support the design effort, a variety of analysis activities were conducted. First, a mission and functional analysis was performed to identify relevant C-141 missions and functions that needed to be supported by the design, and to aid in the definition of simulation task requirements. This was followed by a control/display analysis to determine if all current C-141 control/display functions were provided by the new design. Technical assessments were then conducted to evaluate operational and human factors issues of the proposed designs. The results of these analyses were then fed back into the design effort, where identified design deficiencies were refined through an iterative process.

The Wright Laboratory analysis and design effort also involved defining detailed symbol designs, dimensions, mechanizations, and interactions for the various elements of the PFD, SFD and DAMU formats. These definitions are documented in a functional specification for the C-141 PFD symbology which is included as Appendix F of this report. The purpose of this document is to serve as a baseline for development of a military standard for a head-down electronic PFD format.

## **FULL MISSION SIMULATION OBJECTIVES**

The purpose of the full mission simulation effort was to evaluate the CDS as an integrated system in a full-mission context. The objectives were to validate that the PFD,

SFD, and DAMU designs would: 1) support C-141 mission functions and 2) provide acceptable crew performance in a full mission context. Acceptable performance was defined as being "as good as or better than" the C-141.

The testing focused on evaluating selected issues associated with the proposed designs, such as the efficiency of information transfer between the system and operator, accurate and timely task completion, workload, and the ability to accomplish C-141 functions and mission objectives using the proposed control and display designs. Specific testing objectives were to:

(1) Evaluate the pilot acceptability of the individual components of the CDS (PFD, SFD, and DAMU), as well as the overall design and interactions of the integrated CDS system with other system components, such as the Multi-function Display (MFD) and Reference Set Panel (RSP).

(2) Evaluate the ability of the proposed C-141 CDS to support C-141 missions.

A secondary objective was to collect performance data and subjective ratings to support the PFD standardization development effort.

## **APPROACH**

To accomplish these objectives, C-141 pilots flew a series of full mission scenarios in WL/FIGP's TRansport Aircraft Cockpit (TRAC) C-141 simulator. The simulator missions were representative of current missions flown in the C-141 and were structured to provide the pilots with the opportunity to fully exercise the functions provided by the proposed CDS design.

The missions were flown with two cockpit configurations: (1) a graphic depiction of the current C-141 cockpit and (2) the CDS design that is being proposed for incorporation into the C-141. The current C-141 configuration was included as a baseline for performance and subjective assessments of the CDS.

Test missions were developed to satisfy two criteria: (1) to demonstrate a variety of C-141 mission functions, and (2) to fully exercise the integrated CDS. A top level analysis showed that C-141 missions fell into two broad categories: Tactical Airdrop and Strategic Airland, with the majority of the missions being Strategic Airland. To provide a comprehensive evaluation that fully exercises the C-141 CDS, both Airdrop and Airland missions were selected for the study. To exercise the SKE symbology, the Airdrop mission utilized SKE formation flight. The use of two missions for simulation testing allowed: 1) for the pilots to be exposed to a wider variety of operational tasks, and 2) provided them with more extensive experience with the CDS.

A list of PFD, SFD and DAMU system capabilities was compiled in order to identify CDS features and functions to be exercised within the selected mission segments. These capabilities included new implementations of existing functions as well as interface controls for the PFD and SFD formats. Most of these capabilities were included in the test or were demonstrated during simulation flying. The following is a brief description of the Airdrop and Airland missions that were used for the full mission evaluation. The Procedures Section and Appendix E discuss these missions in more detail.

The Airdrop missions consisted of SKE formation flight to two airdrop locations.

The SKE system allows for a fixed separation between aircraft to be maintained during formation flight. The following mission segments were represented in the Airdrop missions: formation flight, checklists, take-off and climb, cruise, low-level airdrop, escape, recovery, Instrument Landing System (ILS) approach and landing.

The Airland mission involved point-to-point navigation in transporting crew and cargo from one airfield to another. Although airland missions typically consist of an overseas destination the simulation mission only consisted of stateside flight to avoid the "dead time" associated with transoceanic flight. The following mission segments were represented: take-off and climb, cruise, descent, non-precision approach and landing.

## **METHOD**

### **Subjects**

Twelve C-141 pilots participated in the full mission evaluation. The C-141 pilots represented a range of experience levels: 5 first pilots, 3 aircraft commanders and 4 rated at either instructor or flight examiner. On average, each pilot had a total of 2433 hours of flight experience, 1950 of which were in the C-141. All pilots were required to be at least SKE wing-qualified.

### **Apparatus**

#### ***Transport Aircraft Cockpit Simulator***

The evaluation was conducted in the TRAC simulator located in the Aeronautical Systems Center (ASC) WL/FIGP Crew Station Integration Laboratory (CSIL). The simulator was configured to provide a cockpit geometry similar to the C-141 aircraft.

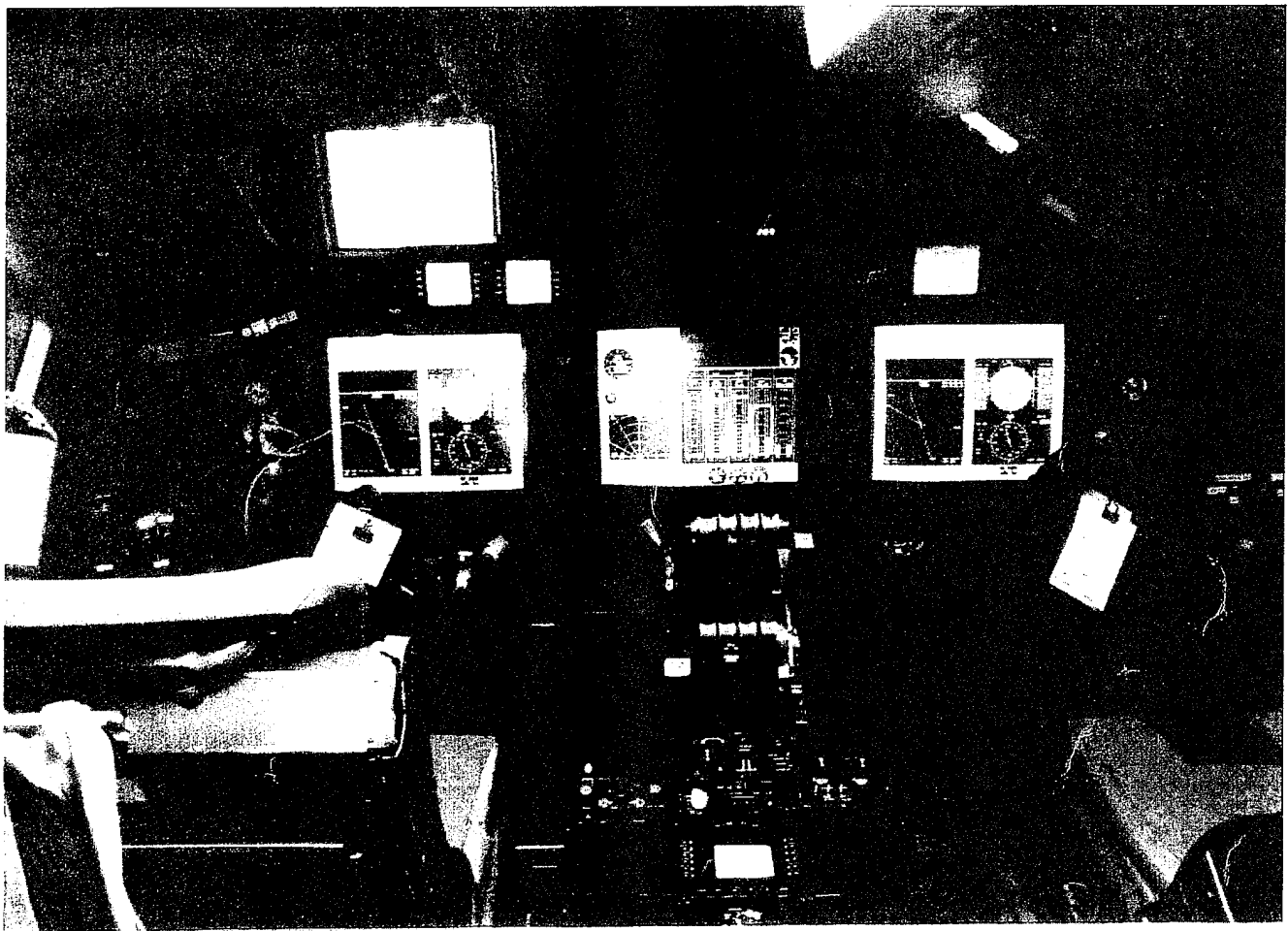
Figure 4 shows a picture of TRAC's simulation of the current C-141 cockpit. A picture of TRAC's simulation of the C-141 CDS cockpit configuration is shown in Figure 5.

The cockpit shell contained three crew stations: pilot, copilot and flight engineer. For purposes of this evaluation, only the pilot's station was configured for flying tasks. The copilot's position had a repeat of the pilot's primary and secondary flight instruments and was occupied by the experimenter pilot. The flight engineer's station was used as an experimenter's station. The simulator was driven by a C-141 aerodynamic model. The displays and aeromodel were driven by four Silicon Graphics IRIS Computers.

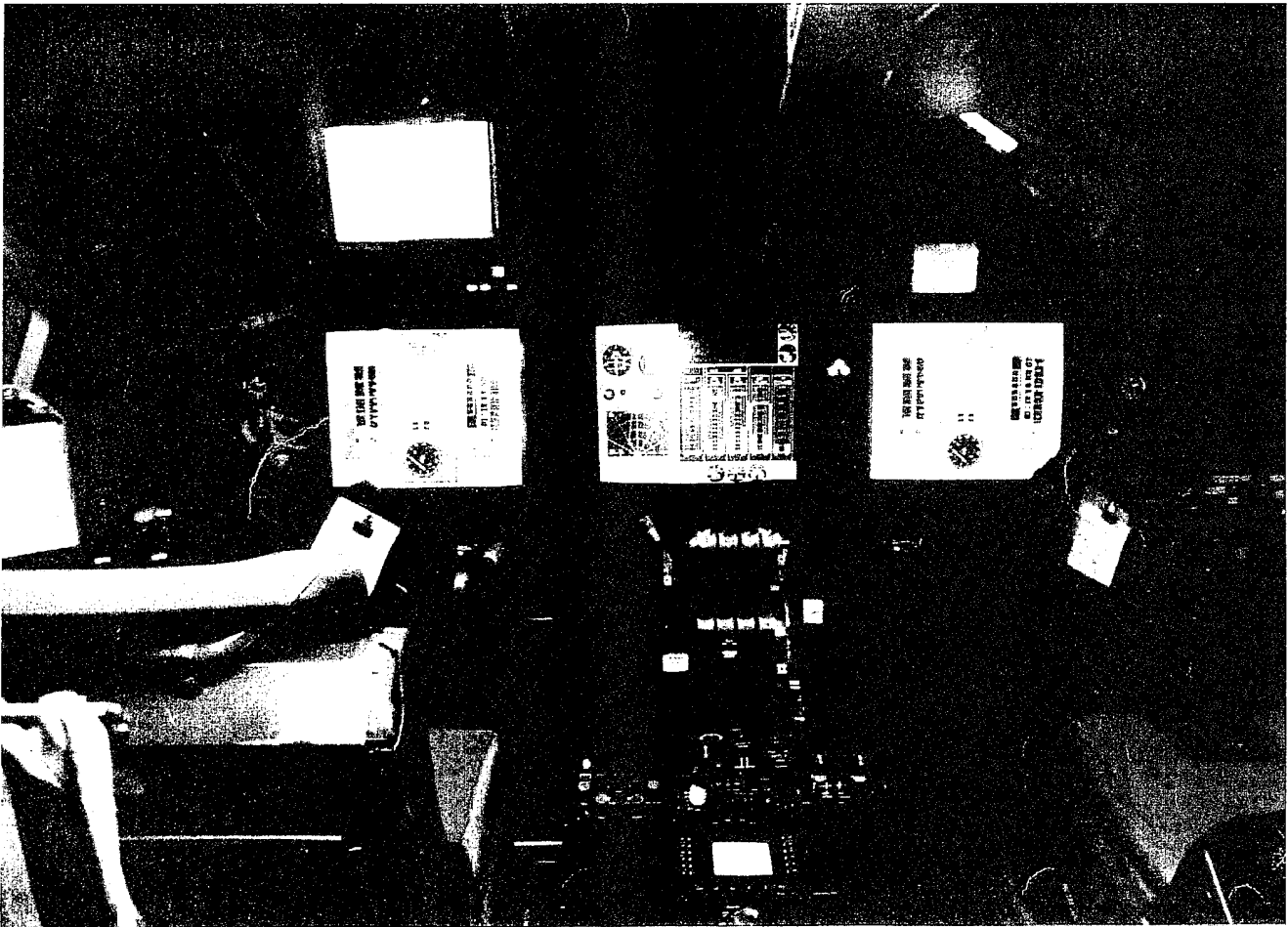
While two cockpit configurations were evaluated, many controls, displays, and panels were used by both configurations. Flight displays and engine instruments were presented on three 21 inch Cathode Ray Tube (CRT) monitors that were placed across the front of the cockpit. One each was mounted in front of the pilot and copilot's seated positions, and used to display the display unit formats being evaluated. The third monitor was placed in the center of the main instrument panel, and displayed graphically drawn engine instruments, C-141 radar altimeter, trim tab position indicators, spoilers and flap indicators, and a weather radar/SKE MFD. An additional 16 inch direct view CRT was used to display an out-the-window visual scene to the pilot position only. This showed a zero visibility condition above 200 feet altitude.

The following additional controls, displays and panels were provided in both configurations:

- MFD for display of SKE or weather radar map.
- Generic yoke, throttle, landing gear handle, and flaps handle for flight control.
- RSP, located on the center console between the pilot and copilot positions, for control of commanded airspeed, commanded altitude, heading marker and course selection, altitude alert, baro setting and altitude alert readout.
- Aural tones for aircraft proximity warning and altitude deviation
- Master Caution Switch
- Approach Plate Holder
- Bearing Distance Heading Indicator (BDHI) for the display of heading, bearing distance information from onboard navigation systems
- Graphically generated Radar altimeter (center CRT) which indicated aircraft altitude above ground in 20 foot increments
- Engine Instruments (center CRT), which showed engine performance and system status information.
- Selected Fuel Savings Advisory System (FSAS) pages interfaced with and controlled the Inertial Navigation System (INS) and provided flight advisories, radar displays, windshear and altitude warnings.
- Flight Command Repeater (FCR) (top center of glareshield), used in conjunction with SKE, and provided information received by the Lead Aircraft Navigator's Flight Command Indicator.
- Pilot's INS Control Unit (PICU) which contained switches and indicator lights and allowed the pilot to select grid mode heading from INS, select which INS unit would be controlled by the Control Display Unit (CDU), and illuminated when INS was receiving Tactical Air Navigation (TACAN) or SKE information or when INS was in Airdrop Mode.



*Figure 4. TRAC Cockpit In The C-141 Configuration.*



*Figure 5. TRAC Cockpit In The CDS Configuration.*

- Display Interface Control Unit (DICU) which controlled information on the MFD.
- Airdrop System (ADS) panel which contained controls for equipment airdrop.
- Mode Select Panel for the control of the Automatic Flight Control Subsystem.
- Clock

### ***C-141 Configuration***

The C-141 electromechanical displays (i.e., the ADI, HSI, Altitude Indicator, Airspeed Scale, and Vertical Velocity Indicator (VVI) and SKE indicators) were graphically emulated on both the pilot and co-pilot CRTs. Refer to Figure 5. Additional detail on the C-141 Configuration is provided in Appendix A.

A NSP, ADI Select Switch, Air Delivery Switch, and Relative Range Indicator (RRI) were also included in this configuration. The NSP was mounted above the glareshield. The NSP was used to select navigation modes for the flight director system. The ADI Select Switch controlled input to the ADI on the pilot/copilot's console and the Air Delivery Switch controlled display of the Zone Marker (ZM) which was used in conjunction with SKE. The RRI showed longitudinal spacing of the aircraft's position relative to lead.

### ***Control/Display SubSystem Cockpit Configuration***

The CDS configuration was that which was planned for incorporation into the C-141 aircraft. The primary components of the CDS configuration were: the Primary Flight Display (PFD), the Secondary Flight Display (SFD) and the Display Avionics Man-

agement Unit (DAMU). The PFDs and SFDs were electronically generated and displayed on 6 by 8 inch areas on large CRTs mounted in front of each pilot position. The DAMU was located in the same glareshield position as the Nav Select Panel in the C-141 configuration. The PFD, SFD and DAMU are described briefly below. Additional detail on the PFD and SFD formats is provided in Appendix A.

### **Primary Flight Display**

The CDS PFD graphically displays primary flight instruments including an ADI, HSI, Airspeed Indicator, Mach Readout, Altitude Indicator, and VVI.

### **Secondary Flight Display**

The CDS SFD graphically displays one of three pages (MAP, HSI, SKE) on a 6 x 8 inch area of the large-screen CRT.

MAP: Displays a weather radar Map (repeated from the MFD radar map) overlaid on the INS route.

HSI: Displays an enlarged format repeat of the HSI from the PFD.

SKE: Displays a repeat of the SKE scope that is located on the MFD.

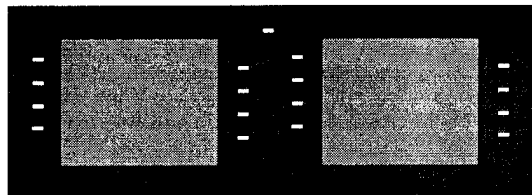
### **Display Avionics Management Unit**

The menu-based DAMU provides the majority of the interface to the CDS and navigational systems. A detailed schematic of the hierarchical structure of the DAMU menu system is provided in Appendix B.

The DAMU display has a right and left display screen with each screen having four Line Select Keys (LSKs) on either side, providing a total of eight LSKs per screen and 16 LSKs per DAMU display. These keys are used for: (1) immediate activation of the line item, (2) the selection of line item



options or (3) displaying options located on the right DAMU screen. Figure 6 illustrates the DAMU dual screen and LSK layout.



*Figure 6. DAMU Screen Layout*

The left DAMU screen displays the Main Menu and the following Primary Menu Pages: Nav Select, PFD, SFD, Display Control, SKE, FSAS / CDU Repeat and BIT (Built-In Test). The BIT page was not evaluated because it can not be accessed in flight. The following briefly describes the functions of the other Primary Menu pages.

Nav Select / Status Menus: Both the Nav Select and Status Menus have the same functions. Both provide the capability to control navigation system input to the Automatic Flight Control System (AFCS).

PFD Menu: The PFD menu provides the capability to independently control the configuration of the PFD.

SFD Menu: SFD menu provides the capability to independently control the configuration of the SFD.

Display Control Menu: The Display Control Menu provides the capability to set display control settings and to select the processor unit, location, and display mode for PFD and SFD displays.

SKE Menu: The SKE Menu provides the capability to access all DAMU SKE related options from one page.

### *Experimenter's Console*

The experimenter's station allowed the test engineer to view status information and select the following test parameters: subject number, session number, mission identifier, and cockpit configuration. Prerecorded radio messages and chatter were automatically triggered by the console at predefined points in each mission. These prerecorded messages supplemented experimenter and copilot communications.

### **Procedure**

Two pilots per week participated in the evaluation. Each pilot was given an initial training session followed by four data collection sessions over the course of the week

### *Training*

Training took place over a period of one and one-half days. Upon arrival, the two pilots were provided with an introductory briefing covering administrative details, a review of the C-141 program, and a review of evaluation objectives and subject responsibilities. Pilots were also given a brief overview of the CDS operations and mission scenarios.

The introductory briefing was followed by an individual hands-on session in the TRAC simulator cockpit. The purpose of the hands-on training was to familiarize the pilot with the various CDS components and display elements. This familiarization process included relevant controls/displays and flying characteristics.

Training tasks were structured to first emphasize the use of the individual components of the CDS (i.e., PFD, SFD, DAMU and RSP, etc.), then to stress the use of those components as an integrated system. Specific topics covered in the training included: differences in scaling between the

C-141 and CDS formats, expanded HSI features, added SKE features, Map features, DAMU menu structure and functionality, and the use of the RSP. Tasks included flying two approaches, one precision and one non-precision. Because the DAMU provided many new functions and its hierarchical menu structure was completely unfamiliar to the pilots, DAMU-specific training was provided. This training exercised all DAMU functions through a series of specified DAMU tasks.

The first-day of training concluded with the Subjective Workload Assessment Technique (SWAT) card sort (Reid, *et al.*, 1989). A set of 27 cards representing all possible combinations of levels of the three dimensions were sorted by each pilot from lowest to highest workload. The resulting orderings were then used during data analysis to develop a baseline workload scale for the group.

The second day of training consisted of each pilot flying one 2 1/2 hour practice mission in the TRAC simulator. The first half of the practice mission was flown with the C-141 configuration to familiarize pilots with the aeromodel and TRAC cockpit anomalies. The second half of the mission was flown with the CDS configuration to give pilots an opportunity to practice various functions in a Full-Mission context. The practice mission incorporated both Airdrop and Airland mission procedures with appropriate verbal feedback. SWAT ratings were also collected to familiarize the pilots with testing procedures. When training was completed, each pilot had experienced all displays, controls and procedures that were used during the data collection missions.

### ***Data Collection Sessions***

Pilots flew two simulation missions (one Airdrop / one Airland) for each cockpit configuration for a total of four test missions. A briefing which described the basic sequence of events was given before each mission. Both missions for one cockpit configuration were completed before the missions for the second cockpit configuration were flown.

During the missions, the pilot was responsible for the aircraft commander tasks. All copilot activities were role-played by an experimenter with C-141 pilot experience. Since the autopilot system was not being tested, the missions were completely hand-flown.

For Airdrop missions, the pilot subject flew the number 2 aircraft in a 3-ship formation, in which the lead aircraft flew a preplanned route. Objective performance data and SWAT ratings were recorded throughout the data collection sessions. Questionnaires were filled out after each mission and Subjective WORKload Dominance (SWORD) forms were completed after all simulation missions were flown.

### ***Mission Descriptions***

To offset training effects, pilots hand-flew (autopilot was not engaged) two similar but different Airdrop and Airland missions (one per configuration) for a total of four separate missions. Both the Airdrop and Airland missions were deemed to be complex enough to induce real-world levels of workload to the pilot. Each mission was approximately two hours in length. Mission profiles and scripts are provided in Appendix E.

Airdrop 1. The Airdrop missions originated and terminated at Pope Air Force Base (AFB), North Carolina, where the subject

pilot commanded the number two aircraft in a three-ship single-file formation. The first mission consisted of a circular training route, flown under Instrument Flight Rule (IFR) conditions, that took the aircraft counter-clockwise to the south and east of Pope before turning back to the north and west for a drop on nearby Sicily Drop Zone. Five minutes prior to Time Over Target (TOT), the Combat Control Team (CCT) transmitted in the blind surface winds and range clearance. After slow-down and release of the heavy equipment load, the formation reconfigured for a short race-track return to the drop zone where they made a second drop before recovering to Pope. Figure 7 depicts the Sicily Airdrop mission profile.

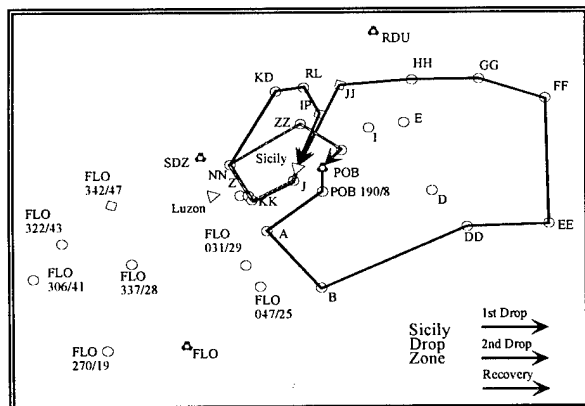


Figure 7. Sicily Airdrop Mission Profile

Pilot general responsibilities were to maintain formation position using the SKE displays and the FCR commands. The experimenter copilot and navigator / flight engineer responsibilities included entering Navaid frequencies, performing checklist procedures, and routine communications. Near Pope, Approach Control picked up the aircraft for an ILS landing. For the ILS approach, the aircraft broke formation and proceeded as a single ship.

**Airdrop 2.** The second airdrop mission originated and terminated at Pope in a route

that circled clockwise on the Luzon Drop Zone. The pilot performed the same duties as the first Airdrop mission for both passes. The recovery route took the formation to the north-east and terminated with a single-ship ILS approach. The second mission was flown with the opposite configuration as the first Airdrop mission. Figure 8 depicts the Luzon Airdrop mission profile.

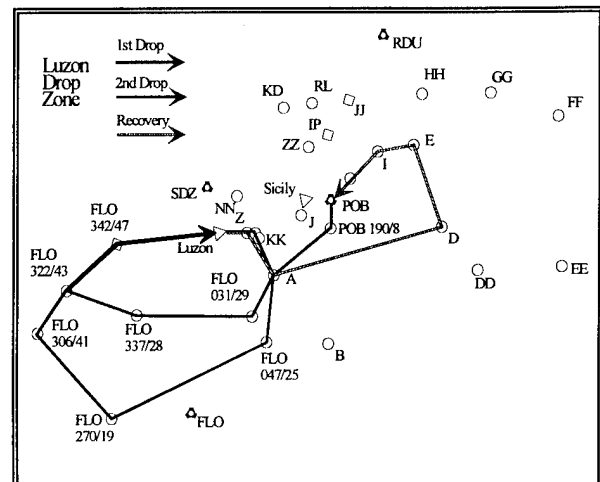


Figure 8. Luzon Airdrop Mission Profile

**Airland 1.** The airland missions were re-supply missions originating at McGuire AFB and terminating with a non-precision approach at either Pope AFB (first airland mission) or Fayetteville AFB (second airland mission). The pilot hand-flew the departure, cross-checking his progress against Very High Frequency (VHF) Omni Range (VOR) and TACAN stations. The experimenter copilot changed VOR and TACAN frequencies upon the pilot's request and maintained contact with Air Traffic Control (ATC). The INS was also available for navigation, if desired.

Upon reaching cruise altitude, a demonstration of DAMU capabilities was conducted during the CDS evaluation. The copilot took control of the simulator to allow the pilot to make observations and exercise the DAMU. These demonstrations consisted

of: TACAN/VOR failure due to signal loss, meter and baro modes, SFD HSI expanded format, heading-up / track-up modes, and SFD MAP options (i.e., TACAN station displays and map radar/range settings). DAMU control functions, which required the pilot to access the copilot's DAMU and repeat the pilot's PFD and SFD at the copilot's station, were also demonstrated.

A band of thunderstorms in the vicinity required the pilot to display weather radar on his Map as well as adjust the range of the weather radar. Airfield conditions restricted the crew to a non-precision approach. The first approach was missed requiring the use of a one turn holding pattern to position for a second approach. During the holding pattern, the number one INS failed, forcing the pilot to select a new attitude source. Figure 9 depicts the Pope Airland mission profile.

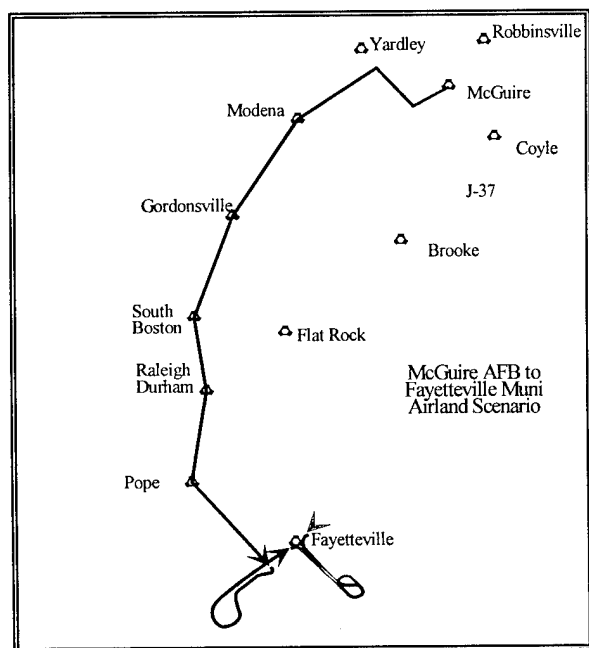


Figure 9. Pope Airland Mission Profile

Airland 2. The second Airland mission took a different route than that of the first Airland mission; however, system faults, demonstrations, and pilot duties remained the same. Airfield conditions restricted the crew

to a non-precision approach (of which the first approach was missed) at Fayetteville. The second mission was flown with the opposite configuration as the first Airland mission. Figure 10 depicts the Fayetteville Airland mission profile.

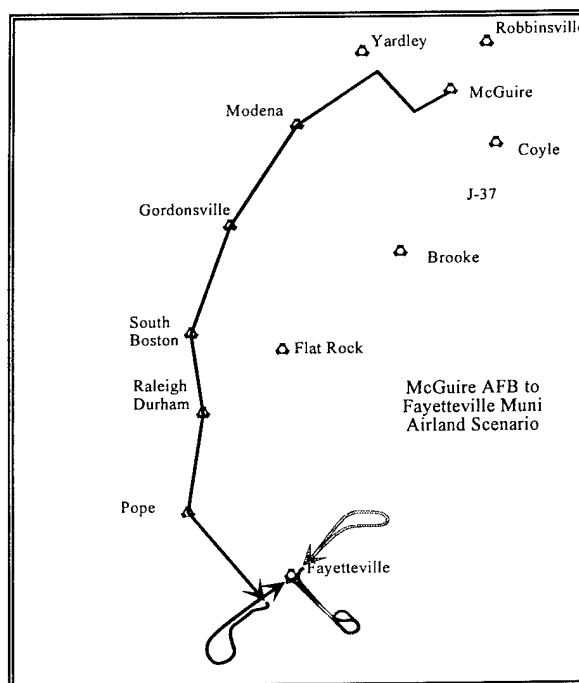


Figure 10. Fayetteville Airland Mission Profile

### Experimental Design

A repeated measures design was used for objective performance evaluation. Each pilot participated in one Airdrop and one Airland data collection session for each configuration, resulting in a total of four data collection sessions, with each session being a different mission profile. The presentation of Cockpit configuration and missions were counterbalanced such that 1) one-half of the pilots flew the CDS configuration first and one-half flew the C-141 configuration first; and 2) each of the four missions was flown three times with each cockpit configuration over the course of the study (Table 1).

**Table 1. Number of Missions per Configuration**

| CDS     |       |         |              |
|---------|-------|---------|--------------|
| AIRDROP |       | AIRLAND |              |
| Sicily  | Luzon | Pope    | Fayetteville |
| 3       | 3     | 3       | 3            |
| C-141   |       |         |              |
| AIRDROP |       | AIRLAND |              |
| Sicily  | Luzon | Pope    | Fayetteville |
| 3       | 3     | 3       | 3            |

The data were combined for both Airdrop missions and for both Airland missions. The Airdrop and Airland missions were then analyzed independently according to mission segment. For the Airdrop missions, the segments were: Cruise, Drop Descent 1st Pass, Run-in & Drop 1st Pass, Drop Descent 2nd Pass, Run-in & Drop 2nd Pass and ILS Approach. For the Airland mission, the segments were: Departure, Cruise, 1st Non-Precision Approach, and 2nd Non-Precision Approach. The independent variable for all mission segments was cockpit Configuration which had two levels - CDS and C-141.

#### **Data Recording and Reduction**

##### **Performance Measures**

The following performance measures were calculated

##### *Airdrop:*

- Root Mean Square (RMS) SKE lateral deviation from Lead
- RMS SKE vertical deviation from Lead
- RMS SKE range deviation from Lead
- Closest point deviation from Computed Airdrop Release Point (CARP)
- RMS deviation from preplanned airspeed
- RMS deviation from altitude restrictions
- RMS ILS glideslope and localizer deviation

##### *Airland:*

- RMS course deviation
- RMS deviation from preplanned airspeed

- RMS pitch and VVI deviation from departure profiles
- RMS deviation from altitude restrictions
- Response time to INS Fail correction
- RMS remain within distance deviation

These performance measures were derived from raw data collected throughout the evaluations at a rate of one sample per second, except for CARP deviation and ILS approach data which were recorded at a rate of five samples per second.

Response time for INS failure correction was also recorded for the attitude INS FAIL event in the Airland Mission.

##### **Workload Data**

Although workload was not the primary emphasis of the evaluation, SWAT and SWORD workload ratings were collected with the intention of identifying interface design deficiencies that may have induced increased workload.

SWAT and SWORD workload metrics were used to complement one another. SWAT was used to provide a global, absolute measure of workload and to identify high-workload mission segments. As a relative workload measure, SWORD was used to pinpoint specific sources of workload. SWAT and SWORD and their applications in the current study are discussed in the following paragraphs.

##### *Subjective Workload Assessment Technique*

SWAT (Reid, *et al*, 1989) is defined on three discrete dimensions: time stress, mental effort load, and psychological stress. When reporting workload ratings, three separate values were given, one for each dimension. For example, the lowest workload task would be reported as a "1, 1, 1" for time stress, mental effort load, and psychological stress, respectively.

Time Stress refers to the amount of task interruption or overlap (1 = often have spare time, 2 = occasionally have spare time, 3 = almost never have spare time).

Mental Effort Load refers to the amount of attention or concentration required to perform a task (1 = very little conscious effort, 2 = moderate mental effort, 3 = extensive mental effort and concentration required).

Psychological Stress refers to the degree of confusion, anxiety or frustration involved in performing a task (1 = little confusion, frustration or anxiety exists, 2 = moderate stress due to confusion, frustration, and or anxiety, 3 = high stress due to confusion, frustration or anxiety).

SWAT ratings were recorded upon the completion of significant mission events. Mission event and configuration were analyzed independently. These events are depicted in Table 2.

**Table 2. SWAT Events For the Airdrop And Air-land Missions**

| AIRDROP MISSIONS         | AIRLAND MISSIONS                            |
|--------------------------|---|
| Cruise                   | Departure                                   |
| Drop Descent 1st Pass    | Cruise                                      |
| Run-In and Drop 1st Pass | DAMU Fail *                                 |
| Escape 1st Pass          | 1st Approach (non precision / NDB)          |
| Drop Descent 2nd Pass    | INS Fail                                    |
| Run-In and Drop 2nd Pass | 2nd Approach (non-precision / TACAN or VOR) |
| Recovery 2nd Pass        |   |
| ILS Approach             |   |

\* Not included in SWAT Analysis of Variance.

An overall mission SWAT rating and a projected SWAT rating for performing the identical mission in real-world conditions were also collected.

### *Subjective WORKload Dominance*

The SWORD (Vidulich, 1989) technique assesses workload by utilizing a series of pairwise comparisons between various system configurations. For this study, SWORD was used to provide relative judgments regarding "task difficulty" between three cockpit configurations with three mission functions. The comparison cockpit configurations were: CDS, Simulator C-141, and C-141. The functions were: Navigation, Instrument Flying, and SKE Formation Flying. Navigation was defined as tasks which involved the assignment of Navaids to Bearing Pointers (DAMU tasks) and use of the HSI. Instrument Flying was defined as tasks which involved use of the primary flight instruments. SKE formation flying was defined as those tasks which involved the use of SKE instruments in the airdrop missions.

Upon the completion of missions with both cockpit configurations, pilots were presented a SWORD rating sheet (Appendix C) which requested comparisons judgments to be made for all possible paired combinations of cockpit Configurations (i.e., CDS, Simulated C-141 and Current C-141) and Functions (Navigation, Instrument Flying, and SKE Formation Flying). A total of 27 paired comparisons were used.

### **Questionnaires**

Four separate questionnaires were administered to all participating pilots at various points throughout mission. These questionnaires addressed such areas as: acceptability of the cockpit configurations, adequacy of the configurations for operational use, adequacy of functions provided, and recommendations for design improvements. Pilots were encourage to elaborate and give any design recommendations in the comments section provided for each questionnaire

item. All questionnaires are included in Appendix C.

(1) A "mission" questionnaire was administered after the completion of each mission. Data collected from these questionnaires were used primarily as a means to assess if any unforeseen or extraneous mission-related variables impacted the study.

(2) A second questionnaire, referred to as the "function" questionnaire, was administered upon the completion both mission types for a given cockpit configuration. The primary purpose of this questionnaire was to address operational issues concerning basic C-141 functions. These data were used to compare C-141 functions across cockpit configurations.

(3) A "CDS element" questionnaire was administered upon completion of the CDS cockpit configuration missions. The primary emphasis of this questionnaire was to address specific display and control elements of the CDS. The CDS questionnaire separately addressed the three major components of the CDS: PFD, SFD, and DAMU. A fourth section of the questionnaire addressed other instrument control panels used in the simulation (e.g., RSP).

(4) A "final" questionnaire was administered upon the completion of all simulator missions with both cockpit configurations. The purpose of the final questionnaire was to obtain subjective comparisons across configurations (i.e., C-141 / CDS) with common instruments. The questionnaire also addressed such miscellaneous issues as: safety of flight, training, and operational concerns of "not-tested" mission events

(e.g., refueling) and types (e.g., Special Operations Low Level (SOLL) II). These questionnaire data were primarily used for diagnostic purposes in identifying specific deficiencies associated with various display/control elements.

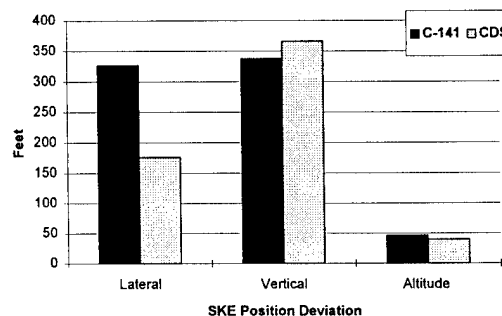
### Video/Audio

Video and audio data were recorded throughout the simulations for reference. Video/audio data collected during the debriefing sessions were transcribed and analyzed with the subjective questionnaire data.

## RESULTS

### Performance

Airdrop Mission. Separate Multivariate Analysis Of VARIances (MANOVA) were conducted on each mission segment. The performance variables for the mission segments are shown in Table 3. For the Run-In and Drop 1st Pass segment, the MANOVA showed a multivariate main effect across cockpit configurations,  $F(3,9) = 3.95, p < 0.05$ . Univariate F-tests revealed this difference to be primarily due to more accurate lateral deviation performance with the CDS,  $F(1,11) = 13.51, p < 0.05$ . Figure 11 illustrates this multivariate effect.



**Figure 11. Comparison of SKE Performance Means for Run-in & Drop 1st Pass**

**Table 3. Performance Measures Analyzed For Each Airdrop Mission Segment.**

| Segment                | Performance Measures   |
|------------------------|--|
| Cruise                 | Lateral Deviation<br>Range Deviation<br>Altitude Deviation   |
| Drop Descent, 1st Pass | Lateral Deviation<br>Range Deviation<br>Altitude Deviation<br>Airspeed Deviation                   |
| Drop Descent, 2nd Pass | Lateral Deviation<br>Range Deviation<br>Altitude Deviation<br>Airspeed Deviation                   |
| Run-In/ Drop, 1st Pass | Lateral Deviation<br>Range Deviation<br>Altitude Deviation<br>Airspeed Deviation<br>CARP Deviation |
| Run-In/ Drop, 2nd Pass | Lateral Deviation<br>Range Deviation<br>Altitude Deviation<br>Airspeed Deviation<br>CARP Deviation |

No multivariate main effects were found for the Cruise, Drop Descent 1, Drop Descent 2, Run-in and Drop (second pass) and ILS Approach segments, indicating that performance with the CDS was “as good as” the C-141 for those segments.

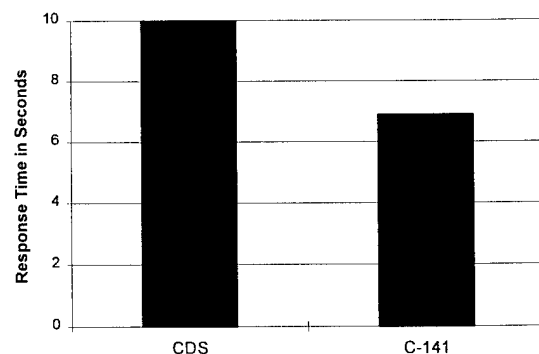
Airland. As with the Airdrop Mission, separate MANOVAs were conducted on each mission segment for the Airland Mission. Performance variables for the mission segments of the Airland Mission are presented in Table 3.

**Table 4. Performance Measures Analyzed For Each Airland Mission Segment.**

| Segment              | Performance Measures   |
|----------------------|--|
| Departure            | Altitude Deviation<br>Airspeed Deviation<br>Course Deviation<br>Pitch Deviation        |
| Cruise               | Altitude Deviation<br>Airspeed Deviation<br>Course Deviation                           |
| First Approach (NDB) | Altitude Deviation<br>Airspeed Deviation<br>Course Deviation<br>Remain-Within Distance |
| Second Approach      | Altitude Deviation<br>Airspeed Deviation   |

For all Airland mission segments, the MANOVAs showed no significant multivariate effects, indicating that performance with the CDS was “as good as” the C-141.

In addition to the MANOVAs, a t-test analysis of the response times with the Airland INS fail event was conducted. No significant differences were found between the C-141 and CDS configuration. However a trend indicated higher response times for the CDS. This trend is illustrated in Figure 12.



**Figure 12. INS Failure Response Times**



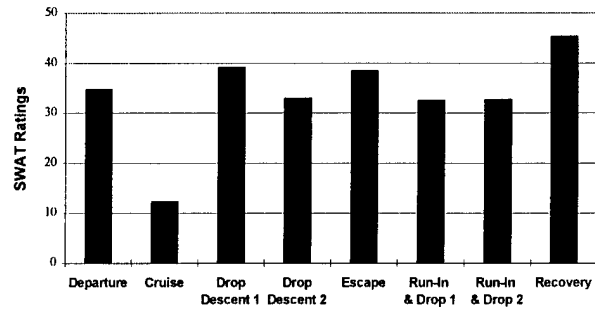
## Workload

### *Subjective Workload Assessment Technique*

The SWAT ratings for the Airdrop and Airland Missions were analyzed independently with 2-factor (Mission Segment x Cockpit Configuration) repeated measures ANalysis Of VAriance (ANOVA). T-tests were used to compare SWAT mission ratings between simulator and projected C-141.

Airdrop. For the Airdrop mission, a significant main effect was found for Mission Segment,  $F(8,88) = 7.80$ ,  $p < 0.05$ . No significant difference between Cockpit Configuration or significant interaction between Cockpit Configuration and Mission Segment was found. Post-hoc analysis using Duncan Multiple Range test showed that the Cruise segment yielded the lowest workload, and the Recovery segment yielded higher workload than the Departure, Run-In and Drop 1st and 2nd Passes, and Drop Descent 2nd Pass segments.

The Recovery and ILS Approach segments had mean SWAT ratings that exceeded 40, which is a level at which performance tends to start to degrade (Reid & Colle, 1988). Also the Descent and Escape segments of the 1st Drop had mean workload ratings that approached 40. Figure 13 illustrates the SWAT ratings for these Airdrop mission segments.



**Figure 13. SWAT Ratings for Airdrop Segments.**

The t-tests did not show any significant differences between projected real-world and simulated Airdrop missions.

Airland. For the Airland missions, a significant main effect was found for Mission Segment,  $F(4,44) = 14.40$ ,  $p < 0.05$ , but no significant difference between Cockpit Configuration or significant interaction between Cockpit Configuration and Mission Segment was found. Post-hoc analysis using the Duncan Multiple Range test showed that the Cruise segment yielded lower workload than all other segments, and showed higher workload for both Approach segments than for the Departure segment. Also both Approaches had SWAT ratings which approached the level where performance tends to degrade (i.e., 40). As with the Airdrop mission, the t-tests did not show any significant differences between projected real-world and simulated Airland missions. Figure 14 illustrates the mean SWAT ratings for the Airland mission segments.

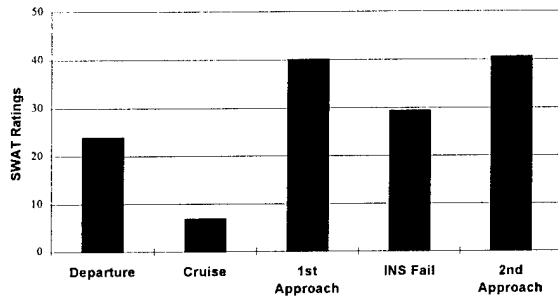


Figure 14. SWAT Ratings for Airland Segments

Because there was not a comparable task in the C-141 configuration, the DAMU Fail event in the Airland mission was not included in the SWAT analysis and data were analyzed separately. The mean workload rating for this event was 36.28. Comments indicated that most of the workload associated with correcting a DAMU failure task was primarily due to pilots being slightly uncomfortable with the new DAMU system.

### Subjective Workload Dominance

The SWORD data were analyzed with a repeated measures factorial ANOVA. Independent variables were Configuration (CDS, Simulator C-141, C-141) and Function (Navigation, Instrument Flight, SKE Formation Flight).

No significant main effects were found; however, a significant interaction was found between Configuration and Function,  $F(4,44) = 6.39$ ,  $p < 0.05$ . Post hoc analysis using the Duncan Multiple Range test ( $p < 0.05$ ) revealed that for Navigation, SWORD workload ratings were significantly higher for the CDS configuration than the Simulator C-141 and C-141 configurations.

This interaction is illustrated in Figure 15. The Simulator C-141 and C-141 configurations showed a similar pattern of results across all tasks. This pattern suggests that

the workload levels induced in the simulator were representative of real-world conditions.

The pattern of results for the CDS configuration, however, differed considerably from the C-141 and Simulator C-141 pattern (Figure 13). The Duncan test showed workload was perceived to be higher than the C-141 and Simulator C-141 for Navigation tasks. Although no significant differences were found across cockpit configurations for SKE tasks, a trend suggests lower workload with the CDS configuration.

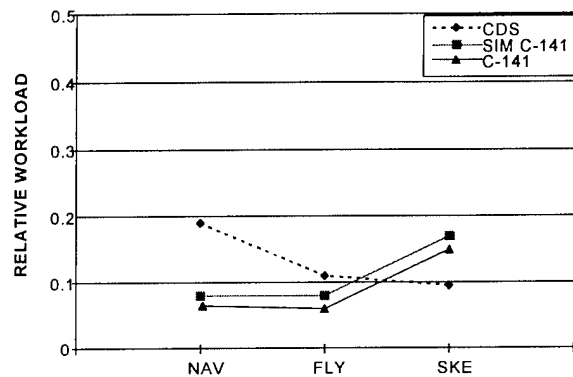


Figure 15. SWORD Workload Ratings as a Function of Configuration and Function

Pilot comments and other study results suggest that higher CDS workload for Navigation was primarily due to the DAMU interface. Navaid/Bearing Pointer assignment was considered to be more cumbersome with the DAMU because of the additional keystrokes that were required. Comments also indicated that CDS workload for the SKE tasks was probably due to the improved SKE cross-check capability provided by the CDS.

### Questionnaires

Frequency distributions and means were generated for all subjective rating scale data collected from the Function, CDS Element and Final Questionnaires.

The five point rating scale shown below was used for the Function Questionnaire and the PFD and SFD sections of the CDS Element Questionnaire.

**1 = Completely Unacceptable.** Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

**2 = Moderately Unacceptable.** Design deficiencies that will degrade pilot performance: changes required.

**3 = Borderline.** Design deficiencies that could impact pilot performance: changes desirable.

**4 = Moderately Acceptable.** Minor design deficiencies that do not impact pilot performance.

**5 = Completely Acceptable.** Good design as is.

Frequencies and mean ratings were calculated for all questionnaire items employing rating scales. Responses from open-ended questions and pilot comments from the questionnaires were summarized and relevant findings reported; as were comments from the transcribed video tapes of the debriefing sessions. Complete responses to all rating scales and summarized comments from the questionnaires are included in Appendix D.

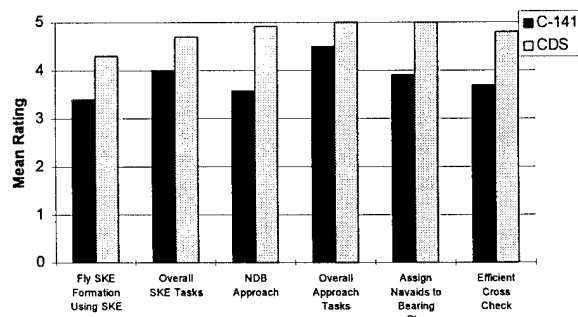
### *Function Questionnaire*

The Function Questionnaire addressed C-141 operational issues at a functional level. Since ratings were obtained on the same functions for both configurations, comparisons were made between CDS and C-141 configurations. For each function, the Wilcoxon Matched Pairs Signed Ranks test was conducted to test significant differ-

ences ( $p < 0.05$ ) between the two configuration rating distributions.

To summarize the data, functions were broken down into the following three functional categories: Instrument Flight, Navigation, and SKE Formation Flight. Instrument Flight was defined as the use of basic flight instruments (e.g., determining vertical velocity, acquiring altitude). Also included in this category were approach-type tasks (e.g., Non-Directional Beacon (NDB), TACAN). Navigation was defined as the use of instruments that indicated position of the aircraft relative to selected navigation points (e.g., acquiring and maintaining course). SKE was defined as the use of instruments associated with formation flight (e.g., selection of SKE instruments).

Across all functional categories, mean ratings for the CDS were shown to be at least "moderately acceptable" (i.e., mean  $> 4.0$ ). Figure 16 shows mean ratings of those tasks which were found to be significantly different with the Wilcoxon Matched Pairs Signed Ranks test. As shown, for those significant differences, the CDS was always rated as more acceptable.



**Figure 16. Comparison of Function Ratings Between Configurations**

Pilot comments generally indicated that CDS ratings were primarily due to: 1) improved cross-check, and / or 2) additional capabilities. The improved CDS cross-check was supported by the Wilcoxon

analysis which found the CDS cross-check to be more efficient than the C-141,  $z = -2.49, p < 0.05$ . The following paragraphs summarize the findings within each functional category.

### **Instrument Flying**

Most instrument flying tasks were highly rated for both configurations with the exception of two tasks: 1) "performing NDB approach" with the C-141 configuration, and "acquiring airspeed trend information" with both the C-141 and CDS configurations. Both tasks had mean ratings of slightly above "moderately acceptable."

The Wilcoxon analysis showed that for "overall approach tasks," pilots rated the CDS configuration higher than the C-141,  $z = -2.02, p < 0.05$ ; particularly with NDB approaches,  $z = -2.67, p < 0.05$ . Pilots generally considered the C-141 cross-check to be especially difficult for NDB approaches because of the peripheral location of BDHI which is needed for non-precision approaches. The CDS, on the other hand, improved cross-check by providing two new capabilities: 1) a second bearing pointer displayed on the HSI and 2) the ability to assign an Automatic Direction Finder to a bearing pointer. With all other Instrument Flying functions, the Wilcoxon analysis showed no significant differences between configurations.

### **Navigation**

Navigation tasks were also highly-rated for both configurations, with the exception of setting command markers which was considered by two pilots to be completely unacceptable. Both of these pilots expressed concern with the RSP's slow rate implementation for the altitude and airspeed command markers (this issue is discussed in detail in

the CDS Element Questionnaire section on Command Marker Setting).

The Wilcoxon analysis showed that the CDS was more rated highly than the C-141 for Navaid Bearing Pointer assignment,  $z = -2.37, p < 0.05$ . Comments indicated this was due to the added capabilities (e.g., two bearing pointers instead of one) provided by the CDS configuration. With all other Navigation functions, the Wilcoxon analysis showed no significant differences between configurations.

### **SKE**

All SKE functions were highly rated for the CDS. As illustrated in Figure 16, the Wilcoxon analysis showed CDS was rated higher than the C-141 for "overall SKE functions,"  $z = -2.52, p < 0.05$ ; and for "flying SKE formation,"  $z = -2.02, p < 0.05$ . Comments indicated that the CDS provided an improved cross-check over the C-141, allowing for information to be more easily integrated to maintain formation position. This improved cross-check was due to the integration of the SKE instruments on the ADI and the display of the SKE map on the SFD. In the C-141 configuration, these instruments and the SKE Map were in separate locations.

### ***Control/Display SubSystem Element Questionnaire***

The CDS Element Questionnaire focused on the design of the display/control elements of the CDS configuration. The primary purpose of this questionnaire was to identify and diagnose design deficiencies within each of the primary CDS components: PFD, SFD and DAMU. The following sections discuss the results obtained for each of these components.

## Primary Flight Display

In general, the overall PFD format was highly rated with mean ratings of very near "completely acceptable." As would be expected, the arrangement of PFD components, color usage, and overall level of clutter were also rated favorably. Specific PFD elements that were highly rated included: pitch and bank steering bars, miniature aircraft symbol (ADI and HSI), ADI field of view, HSI scale design, bearing pointer design and distance presentation on the HSI. Although the VVI did not have as high of a mean rating as the previously mentioned elements, most pilots rated it as "completely acceptable."

The following sections discuss questionnaire results for each of the components located on the PFD.

### Attitude Director Indicator

Figure 17 illustrates mean ratings for ADI elements.

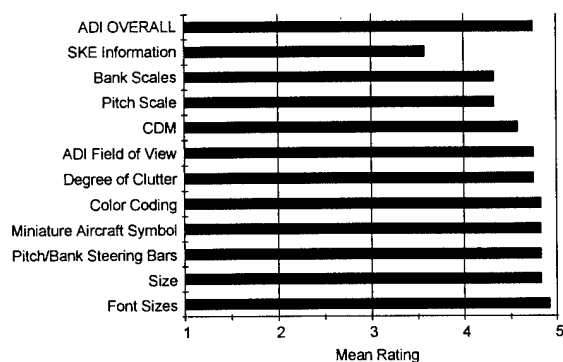


Figure 17. ADI Element Ratings

Overall the ADI was rated highly, with the exception of presentation of SKE information which had a mean rating of less than "moderately acceptable." Two pilots rated the SKE display on the ADI as "completely unacceptable" and three rated it as "borderline." Comments indicated that the low rating was primarily due to the poor readability of the range and vertical deviation

indicators. At least half of the pilots felt that the RRI was difficult to read due to clutter or close placement to other elements. Three felt that the poor contrast of the Vertical Deviation Indicator (VDI) degraded readability.

Although the bank pointer was rated highly, it received consistent negative comments. Over one-half of the pilots stated a preference for a traditional bottom Bank Pointer (triangle). They felt that they could not get a precise indication of bank angle with the CDS implementation. Several pilots also were "uncomfortable" with the CDS expanded pitch scale which appeared to exaggerate the aircraft response to pitch inputs.

### Horizontal Situation Indicator

Figure 18 illustrates mean ratings for HSI elements.

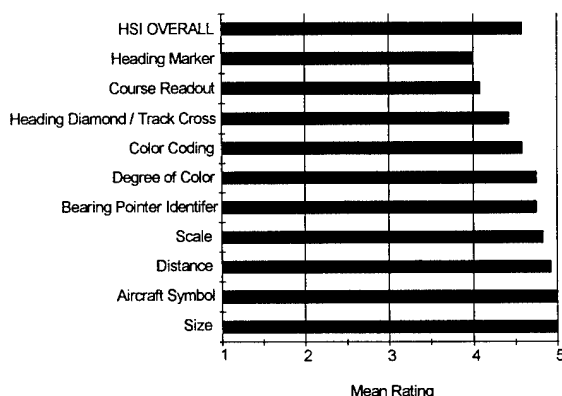


Figure 18. HSI Element Ratings

Overall the HSI was rated highly, with the exception of heading marker design and course readout which were rated "moderately acceptable."

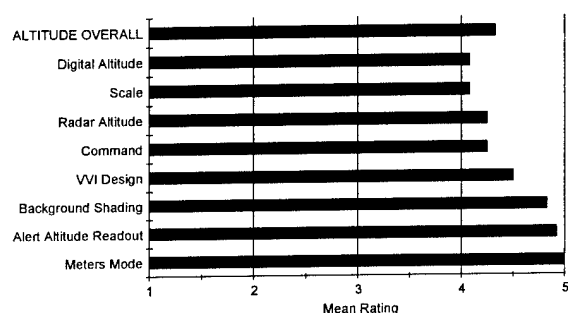
Although the heading marker design and mechanization had an average rating of "moderately acceptable," three pilots rated it as "borderline" and one pilot as "moderately unacceptable." Comments regarding heading marker design were mixed. Two pilots felt that a precise reading could not be ob-

tained because it had a poorly defined center and an indistinguishable lubber line. Two other pilots commented that it was difficult to fly off of when overwritten by bearing pointers.

Several pilots also commented that the course readout was not where they expected it to be and they sometimes mistook it for something else (e.g., distance).

#### Altitude Indicator / Vertical Velocity Indicator

Figure 19 illustrates mean ratings for Altitude Indicator elements and the VVI.



**Figure 19. Altitude Indicator Elements and VVI Ratings.**

Overall the Altitude Indicator was rated highly. The lowest rated elements were altitude scale and digital readout presentation which had average ratings of slightly above "moderately acceptable." Four pilots rated the altitude scale as "borderline." Two pilots rated the digital readout "moderately unacceptable" and one pilot rated it "borderline." Comments regarding these two elements were mixed and are discussed below.

Two pilots commented that trend information acquired from the altimeter could easily be misinterpreted. In the CDS implementation, any digit changing at a rate faster than three Hertz was changed to zero, since it was no longer readable. When this happened, the pilot had to acquire his altitude from the next significant digit. As the rate of change

approached 30 feet per second, the speed at which digits roll over also increased. When the actual rate of altitude change exceeded this threshold, the roll rate of the digits appeared to slow down significantly. In the words of one pilot, the "slow spinning altimeter made it seem like a nominal altitude change when in fact it could be a very significant amount of change." Another pilot felt that the scale moved too slowly to extract trend information.

At least one-third of the pilots felt that the constantly changing digits of the digital readout were distracting. Two pilots rated digital readouts as "moderately unacceptable" and one rated it as "borderline." One pilot commented that the changing digits induced "a constant sense of urgency." Another pilot felt that the digit window display was intrusive because it covered the tape numbers.

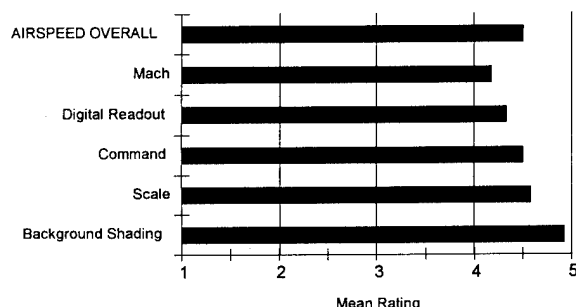
Although, the commanded altitude presentation was rated on the average as above "moderately acceptable," three pilots rated this element as "borderline" and one rated it as "moderately unacceptable." Comments indicated that it was difficult to get a positive indication of set altitude with its bow-tie representation. While this representation was considered to be excellent for determining when the aircraft was on the correct altitude, it was poor for indicating the exact command altitude setting and deriving trend information.

The average rating for radar altimeter presentation and placement was above "moderately acceptable;" however, two pilots rated it as "borderline" and another rated it as "completely unacceptable." Comments regarding the radar altimeter were varied. One pilot felt that the constant movement was distracting. Another pilot commented that the direction of movement was bother-

some because it was opposite of the altitude readout. A third pilot suggested that the radar altimeter be moved to a less prominent location.

### Airspeed Indicator

Figure 20 illustrates mean ratings for Airspeed Indicator elements. Overall the Airspeed Indicator was rated highly, with the exception of the Mach digital readout.



**Figure 20. Airspeed Element Ratings**

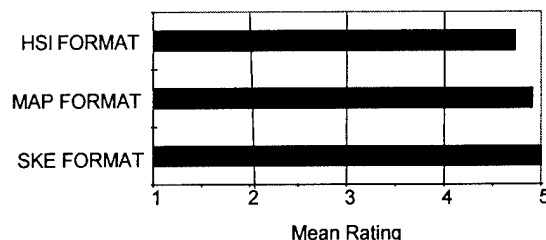
Although the average rating for the display of Mach was “moderately acceptable,” there were two “borderline” ratings. One-fourth of the pilots indicated a preference for a full-time Mach display because certain “rule of thumb” procedures which utilized Mach information at any speed. Also, two pilots expressed a preference for the addition of a Mach command marker.

### Command Markers Setting

Numerous comments were received regarding the setting of command markers which is accomplished at the RSP. Generally, pilots indicated that this action required excessive concentrated, head-down attention for long periods of time. Pilots found it difficult to set a precise altitude and frequently overshoot the desired altitude. They also felt that the slew rate on the airspeed command control was too slow.

## **Secondary Flight Display**

Figure 21 illustrates mean pilot overall ratings for the three SFD formats: Expanded HSI, MAP, and SKE. All elements within each of these three SFD formats were highly rated.

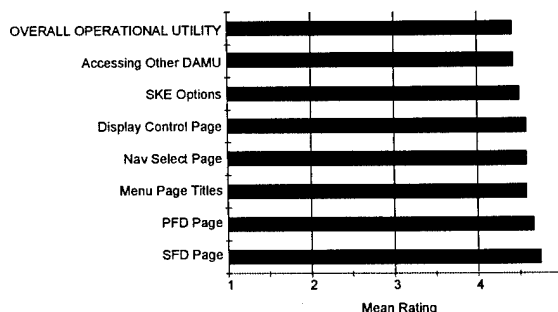


**Figure 21. Overall SFD Format Ratings**

Questionnaire and debriefing comments, however, indicated some minor refinements could be made to the design. Pilots generally indicated a preference for displaying emergency status annunciations at bottom of the screen, rather than on the top. They felt that the primary space given to annunciations could be better used for the display of more important information such as the Map. They also indicated that they would like the capability to turn route on or off; and to display 30°, 60° and 90° spokes on the Map.

## **Display Avionics Management Unit**

Figure 22 illustrates mean ratings on the DAMU menu pages and options. As shown, all pilots generally rated the DAMU to be above “moderately acceptable.”



**Figure 22. DAMU Menu Page and Options Ratings**

Other questionnaire findings indicated that most pilots “sometimes” got lost when navigating through the DAMU menu structure; and that its design “sometimes” degraded their ability to perform certain tasks. Three pilots indicated that changes to the DAMU were “strongly” needed. However, their comments revealed that additional training and experience would most likely offset these effects.

In addition, there were consistent comments regarding “hidden” pages in the DAMU hierarchical menu structure. One instance of “hidden” pages concerns the ZM page on the SFD Menu and the Status Menu page. With these pages, selections could not be easily validated or data entry mistakes corrected because the menu page reverted back to a higher-level menu page. Another instance of “hidden pages” concerns the SFD MAP and WIND (options) selections. When in MAP format, the MAP (options) page could be overwritten by the WIND page with no indication given as to how to re-access the MAP (options) page. An illustration of these concerns (and potential fixes) is shown in Figure 26.

### Final Questionnaire

The final questionnaire (Appendix C) addressed instrument displays, safety, operational and training issues. A major portion of the questionnaire requested pilots to make direct comparisons between the two configurations for various display components. Figures 23 and 24 illustrate the results of these comparison ratings.

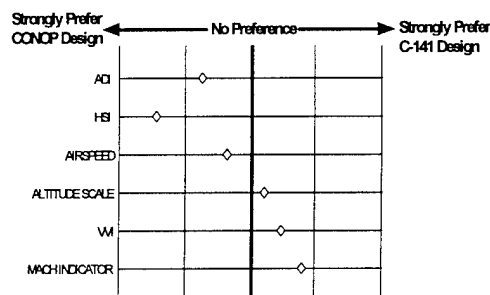


Figure 23. Comparison of Primary Flight Presentation

As shown in Figure , pilots preferred the CDS over the C-141 configuration for the ADI, HSI and airspeed instrument displays, with the strongest preference for the HSI. However, the C-141 configuration was “more preferred” for altitude scale and Mach information, which is consistent with the element questionnaire results. In addition, pilots indicated that they preferred the C-141’s VVI over the CDS VVI. Comments suggested that this preference was primarily due the C-141’s “rolling” digital display which was thought to provide better trend information. On the CDS, the digital readouts were discrete and did not give a rolling appearance.

Figure 24 illustrates comparison ratings for secondary flight information (e.g., SKE, Radar MAP). As shown, pilots indicated an overall preference for the CDS configuration. In particular, pilots indicated a very strong preference for the SKE and MAP formats on the SFD.

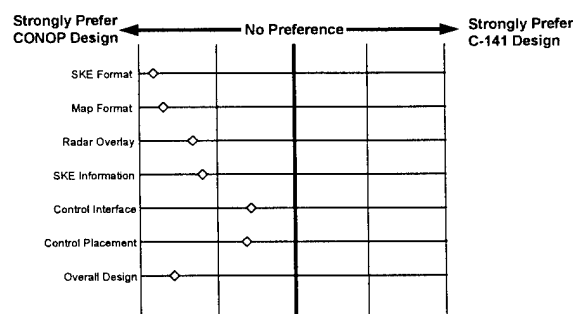


Figure 24. Comparison of Secondary Flight Presentation and Control Design



Several questions on the final questionnaire addressed the feasibility of performing specified missions in real-world conditions. Nearly all pilots felt that the CDS would effectively support the following missions: SOLL 2, Category (CAT) II approach, air refueling, airdrop, airland, low-level tactical, and extended missions. Two pilots expressed concern as to whether the CDS would support missions requiring Night Vision Goggles (NVGs).

Almost all pilots (11 out of 12) felt that the CDS had an acceptable level of safety and most felt (10 out of 12) that the CDS was "as good as the C-141" in meeting operational requirements. Figure 25 illustrates these findings. The distraction and disruption caused by digital readouts was given as the primary reason for concern.

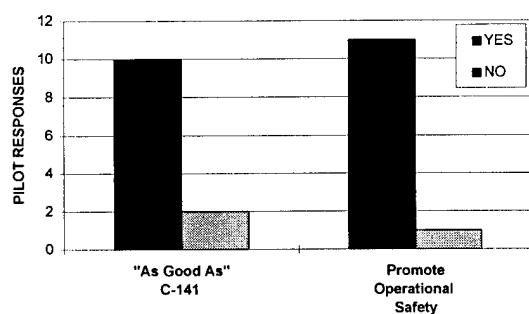


Figure 25. CDS General Operations.

Also, general comments indicated that most pilots felt that the use of Master Caution for the loss of a Navaid signal was inappropriate and could lead to a tendency to ignore a serious caution condition.

Several other questions addressed training requirements for the new CDS. It was generally felt that both classroom and simulation training would be required, especially for DAMU. Their comments also indicated that the length of training time on each would be dependent on the experience level of the pilot.

## DISCUSSION

The overall objectives of the study were to determine if the CDS: 1) will support C-141 operations, and 2) will provide "equal or better" crew performance than the C-141."

These objectives were accomplished through a test and evaluation procedure in which pilots flew two types of missions, Airdrop and Airland, with the current C-141 and the new CDS configurations. Subjective questionnaire, workload, and performance data were collected for both missions to support the evaluation process.

To better assess the test objectives as to whether the CDS will support C-141 operations, results were analyzed along the lines of three major functional areas: Instrument Flight, Navigation, and SKE Formation Flight. Within each of these areas, associated display elements were evaluated to diagnose specific design element deficiencies. Across all functional areas, the results showed that the CDS will support C-141 operations and was equal to and, in some cases, better than the simulated C-141 in providing acceptable crew performance.

One consistent finding throughout the study was the improved instrument cross-check efficiency provided by the CDS over the current C-141 configuration. This improved cross-check capability appeared to be most pronounced in the Airdrop missions. This was due to the CDS integration of the RRI, the MFD, the BDHI and the radar altimeter displays, along with the HSI and ADI into two flat panel displays.

Although the CDS was considered to significantly improve instrument cross-check, several design deficiencies were noted across all functional areas. Most noteworthy were with: the Altitude and Airspeed Indicators, the RRI on the ADI, several DAMU

menu pages, and the RSP. Recommended design refinements are discussed in the section on Design Improvements. Results and related issues within the Instrument Flight, Navigation and SKE Formation Flight functional areas are discussed below.

### **Instrument Flight**

Overall findings of the study showed that the CDS will generally support C-141 instrument flying functions. The performance data showed no differences between the CDS and existing C-141 configuration. This was primarily due to the improved cross-check that was provided on the CDS in which primary flight information was centrally located and integrated in one display.

However, most pilots indicated difficulties, to varying degrees, in extracting altitude trend information from the CDS. The CDS design is intended to provide both precision and trend information with a digital readout and single-moving altitude scale. The scale, however, shows only one-half of the range ( $\pm 1000$  feet range) of the current C-141 scale. This limited range made it difficult for pilots to extract trend information because of its slow rate of movement. Therefore, pilots relied on the digital readout for trend, an approach that violates human factors design principles (MIL-STD 1472D, 1988; Roscoe, 1968) which claim digital readouts to be inferior to analog displays for the presentation of trend information.

The C-141, on the other hand, uses dual moving tapes to display gross altitude ( $\pm 2250$  feet range) and Vernier altitude ( $\pm 225$  feet range). Together, the analog scales provide a good indication of altitude situation awareness. The Vernier altimeter, in particular, provides an excellent source of trend information.

Also there was some concern regarding possible misinterpretation of the true rate of climb or descent on the CDS. This is because the rate of digital rotation changes at a preset rate of climb or descent. During near-level flight, the digital readout shows altitude to the nearest 10 feet. As the rate of climb or descent increases beyond 1800 feet per minute (fpm), the readout rounds the display to the nearest 100 feet. Although the intent was to improve the legibility of the readout by reducing the digital rate of movement, it is possible the display could be misinterpreted especially near the 1800 fpm turn-over point.

Digital readouts, in general, were regarded unfavorably by several pilots. In fact, two pilots stated digital readouts to be the primary reason they considered the CDS to be not "as good as" as the C-141. One of these pilots suggested that digital readouts could introduce a safety risk because their eye-catching movement not only disrupted the cross-check, but created a general sense of urgency.

Pilots also expressed concern with the setting of the attitude and airspeed command controls on the RSP. General comments indicated that an excessive amount of head-down time was needed to get precise settings. In a demonstration of alternative toggle switch mechanizations, pilots expressed a preference for a design that allowed individual column digits of the commanded digital readout to be selected and changed. With this mechanization, column digits (i.e. ones, tens, hundreds) were selected through a lateral movement of the toggle switch. Vertical up-down movements on the toggle switch respectively either increased or decreased the digits within each column. The digit rate of change was dependent upon the time the toggle switch was vertically held in position. This mechaniza-

tion gave pilots the flexibility to manually control slew rates. If switch controls were not a C-141 hardware constraint, all pilots indicated that they would prefer a rotary knob instead. In addition to user-paced control, the rotary knob would provide the pilot with some form of tactile feedback, through "clicks" when rotating the knob.

### **Navigation**

The overall results showed that the CDS supported navigation functions and, in some cases, was superior to the existing C-141. The increased effectiveness of the CDS navigational functions was primarily due to the addition of two capabilities: 1) ADF assignment to Bearing Pointers and 2) the display of two (instead of one) bearing pointers on the HSI. The existing C-141 NSP limits the pilot to one-half of the available radio-based Navaids and does not allow for dual simultaneous representation.

Pilots considered these additional capabilities provided by the CDS to be particularly useful for non-precision approaches, such as NDB approaches. NDB approaches with the C-141 configuration were thought to be especially difficult because of the low precision, low reliability and peripheral placement of the BDHI, which is the only instrument that displays NDB bearing. Consequently, NDB approaches required the pilot to work harder to maintain altitude, airspeed, and course than for any other approach. With the CDS implementation, however, the pilot was able to bring both NDB bearing pointers into the pilot's immediate cross-check. This capability is accomplished by ADF assignment to Bearing Pointer(s) in the DAMU. When flown using ground track information, the desired course can be more easily maintained with the CDS configuration.

The SWORD findings, however, indicated a slight workload penalty associated with the assignment of Bearing Pointers. Although the CDS was considered to be more effective for managing Navaids and Bearing Pointers, the results suggested that the DAMU functions that were required to manage these elements evoked additional workload. Instead of a single keypress off the existing C-141's NSP, the same task required at least two keystrokes on the CDS DAMU menu system. Pilots generally considered this to be a minor drawback in light of the additional capabilities provided by the CDS.

### **Station Keeping Equipment Formation Flight**

The overall results showed that the CDS supported SKE Formation Flight and Airdrop functions, and in some cases, was superior to the existing C-141 configuration. This was supported by better performance with the CDS for the Run-In and Drop segment of the Airdrop mission, a critical portion of an Airdrop mission.

One factor affecting SKE functions was the improved cross-check that was provided by the CDS. This improved cross-check was primarily due to the centralization of the RRI and the MFD on the CDS. On the existing C-141, the RRI and SKE Map displays are located on the periphery of the pilot's cross-check, and are separate from the SKE VDI and primary flight instruments. On the CDS, the RRI was integrated with the ADI, along with other SKE information, such as the SKE bank steering bar and the VDI. Also SKE information on the MFD was repeated in a much larger format on the SFD. Thus, SKE information was more centrally located, allowing for their integration to be more easily accomplished for SKE formation flight.

In addition, by repeating the SKE on the SFD, the MFD was made available for display of the radar map and allowed for the CDS configuration to simultaneously display both SKE and the radar map. In the current C-141, the pilot would have to switch between these formats on the MFD, and would only be able to view one format at a time. Thus, not only was cross-check improved with the centralized location of SKE information in the CDS configuration, but situation awareness could be enhanced with the ability to display more information for immediate viewing in the cockpit.

Digital readouts were also considered by pilots to be a factor contributing to effective CDS SKE performance. This finding was not surprising, given the precision of digital readouts and the precision that is required for Airdrop functions.

Although the results generally showed SKE functions to be more easily performed with the CDS, most pilots suggested minor improvements to RRI. Specifically, the miniature aircraft symbol on the RRI needed to be more discernible. The RRI was considered to be too cluttered and in too close of proximity to other symbol elements, especially the RANGE label. Proposed design refinements to the RRI are presented in the section on Design Improvements.

### **Operational Implications**

A similar pattern of results found in the current study would be expected in real-world conditions. That is, one can expect that the results obtained from simulator flight in the current study should carry-over to operational conditions in the C-141. However, it should be noted that minor design problems could possibly be magnified in extended missions where fatigue may be a factor or in

emergency conditions where stress can be a significant factor.

Although it was not feasible to test the unique requirements of all C-141 missions (i.e. air-refueling, SOLL II, CAT II, extended missions), representative functions were simulated to some degree in both the Airland and Airdrop missions. In response to direct questionnaire items, all pilots commented that they felt the CDS would meet specialized C-141 requirements. A few pilots, however, expressed some concern as to whether NVG compatibility could be obtained with the CDS.

When asked about safety concerns of a mixed fleet (e.g., flying the current C-141 one day and the CDS configuration the next), most pilots indicated that there may be some problems using the DAMU or the transitioning to different ADI pitch scales. Concerns with the DAMU system are consistent with the INS Fail performance results in the Airland Mission that showed a trend suggesting that pilots may have taken longer to correct an INS failure with the CDS configuration. Although study results suggest that the DAMU would adequately support an INS Fail event with consistent use, pilot comments indicate it could be a problem in a mixed fleet environment.

### **Relation To Part-Task Evaluation Results**

Modifications based on the part-task results were implemented for the Full-Mission evaluation. A comparison of the part-task and full mission simulation findings suggest that the most serious deficiencies identified in the part-task evaluation have been corrected.

In particular, many pilots identified the level of clutter on the ADI to be a safety concern during the part-task evaluation. However, no concerns were raised about clutter in the

full mission evaluation. Other safety concerns raised in the part-task evaluation, such as the potential for confusing the primary and secondary flight reference symbols, and the potential for misinterpretation of pitch in the climb-dive mode, have also been eliminated.

Other deficiencies were partially corrected after the part-task evaluation recommendations were incorporated. For example, a problem associated with the part-task design of the heading marker has been resolved, although new concerns were raised in the current design. Similarly, the bow tie command markers are no longer blocked by the digital readout boxes, as was the case with the original command bars. However, the current results suggest additional refinements may optimize the design.

In a few other areas, very little difference is apparent in the full mission and part-task results. Specifically, pilots still found the digital readouts for altitude and airspeed to be distracting.

Some of the results of the current study were unique to the full mission evaluation, and did not show up in the part-task simulation. Other results of the part-task simulation received even greater emphasis by the pilots in the full mission simulation results. Examples include the desire to have Mach displayed full time, and the concern raised by two pilots that the digital readouts may be unsafe. The difference in results or emphasis between the two studies is probably due to the different contexts in which the configurations were used. During precision flying tasks, such as the Precision Instrument Control Tasks (PICT) flown in the part-task simulation, or the SKE portion of the full mission simulation, very precise altitude and airspeed information is helpful, and can lead to improved performance. How-

ever, such precision in a high altitude cruise segment is unnecessary, possibly distracting, and can potentially unnecessarily draw the pilot's attention to the displays. This result was overlooked in the part-task simulation because all of the flying required high precision.

In summary, the current design appears to have resolved the serious safety concerns, such as those associated with clutter, and many of the less serious concerns raised in the part-task simulation. Still, a number of additional concerns have been raised in the current study. In particular, pilots expressed some concern with the following: airspeed and altitude indicators, radar altimeter and Mach display, command markers, heading markers, PFD SKE display, SFD elements and several DAMU menu elements. While these minor deficiencies do not appear to degrade pilot flying performance, they should be corrected in order to optimize the display for use in the C-141, and reduce the risk of an exaggerated effect during demanding conditions.

### **Implications For The Head-Down Standard**

Recall that a secondary objective of both the part-task and full-mission evaluations were to provide data in support of the head-down display military standard being developed by the Joint Cockpit Office. The Part-Task results (Cone, Toms, Gier, Brown and Patzek, in press) highlighted several areas that should be addressed before implementing this design as a head-down standard. A comparison between the part-task and full mission test results show that many of the serious safety concerns were alleviated after the part-task evaluation recommendations were incorporated. However, concerns with some symbology designs and mechanizations (e.g., the design of the digital altitude

readouts) were repeated by pilots in the full mission evaluation results. These areas should be re-addressed in the development of the head-down standard. The current results also point to the need to evaluate any proposed standard formats in all appropriate operational contexts, as well as in generic instrument flying conditions.

### **Study Observations / Limitations**

All pilots indicated that they were able to effectively evaluate the CDS with the simulation testing runs. From the mission questionnaire, most pilots commented that hand-flying the mission increased their workload because normally autopilot is engaged. However they also indicated that other real-world workload sources were not simulated; such as, radio chatter, crew interaction, traffic and intermittent SKE information, which would have mitigated the effects associated with hand-flying the mission.

Also, there was some indication of a “halo effect,” by which pilots were generally inclined to give favorable responses due to the CDS “newness,” not necessarily because it was “better.” This effect appeared to be most prominent in the CDS element questionnaire, where certain elements were rated highly, but also had many unfavorable comments associated with them. For example, the pitch scale and bank pointer were rated highly; however, comments were contradictory to the favorable rating.

### **Design Improvements**

This section presents several design refinements to the PFD, SFD and DAMU based on subjective findings of the study. These refinements have not been tested and are based primarily on pilots comments and inputs from C-141 subject matter experts. It is recommended that these changes be re-

viewed dynamically before incorporating them into the C-141.

### **Primary Flight Display**

Design refinements to the PFD are discussed in the following paragraphs. Some of these refinements are shown in Figure 26.

### **Altitude and Airspeed Indicators**

While space constraints and mission requirements severely limit the available design alternatives to the CDS altitude indicator, the following refinements, taken together, may help improve trend information, and reduce the level of distraction caused by the digital readout.

Altitude Indicator:

- Modify digital readout to move in 20 foot increments.
- Highlight 1000 foot increments with half-circles
- Move altimeter scale numbers to far right and extend line
- Consider changing altitude to Vernier scale

Airspeed Indicator:

- Highlight 200 Knots with arrows

### **Radar Altimeter**

The following recommended changes should help reduce distraction caused by the digital readout.

- Move radar altimeter to lower right corner
- Change direction of rotation to match baro altimeter readout

### **Mach Information**

We suggest displaying Mach Indicator full-time to allow the use of “rule of thumb” procedures.

## **Command Markers**

Suggested refinements to the command markers are based on pilot comments which indicated that too much effort was required to get a precise setting without extensive overshooting. Also command markers lacked a positive indication of set altitude and were not sufficiently prominent (possibly due to lack of contrast).

Recommended Mechanization Improvements:

- Modify the RSP altitude and airspeed command mechanization to allow precise setting to be easily achieved.

Recommended Display Improvements:

- Change command marker to 2-segment magenta and overwrite scale to achieve more contrast

## **Heading Marker Design / Mechanization**

Suggested design refinements to the heading marker are based on low ratings and pilot comments which indicated that the CDS lacked an easily identifiable lubber line, a precise center reference, and the ability to be easily seen when overwritten by bearing pointers.

- Move Heading Digital Read-Out 1/16 inch upward and extend lubber and index lines by 1/16 inch
- Extend top lubber line to compass rose
- Have Heading Marker overwrite Bearing Pointers when in Heading mode.

## **Horizontal Situation Indicator Presentation**

The following suggested design refinements to the HSI are based on pilot comments which indicated that a non-standard placement of digital course read-out disrupted the cross-check:

- Move digital course read-out to upper right side of HSI (standard location)
- Move Baro setting to far right
- Move groundspeed to the lower-left corner

## **Primary Flight Display Station Keeping Equipment Presentation**

These recommended changes to the presentation of SKE information on the PFD are based on low CDS element ratings and pilot comments which stated that clutter and poor contrast degraded the readability of SKE range and VDI. The following changes are strongly recommended:

- Remove "RANGE" label
- Move airplane symbol more to the left, thicken, and color yellow
- Color VDI diamond yellow with black outline

## **Secondary Flight Display**

Questionnaire response ratings indicated that the SFD formats were generally liked. A review of the comments suggested only a few minor improvements. The following are recommended changes based on questionnaire data.

## **Master Caution**

It was generally commented that the Master Caution annunciation was inappropriate for invalid Navaid signals. We suggest not activating Master Caution for invalid signals. Pilot comments indicate instances that Master Caution will go off so frequently that it could possibly be ignored. Pilot comments suggest PFD indications alone should be adequate for showing an invalid Navaid signal.

## **Station Keeping Equipment MAP**

Refinement to the SFD SKE Map was based on several pilot comments.

- Have a selectable DAMU option for route on and off.

## **Display Avionics Management Unit**

Suggested refinements to the DAMU menu pages are discussed in the following paragraphs. These changes are displayed in Figure 27.

## **Station Keeping Equipment Options**


These suggested refinements are based on general pilot comments which indicated that ZM status could not be determined easily.

- Add SKE submenu from SFD DAMU page
- Consider adding an SFD SKE submenu
- Consider placing ZM status on SKE page

## **Hidden or Not Easily Accessed Sub-Menu Pages**

The following refinements are based on pilot comments which indicated a dislike for hidden menu pages (e.g., WIND / ZM pages). This was especially apparent for selecting Bearing Pointer 1 options from the Status or Nav Select Pages.

- Eliminate Wind/Drift Option, just display both on the SFD formats
- Implement preceding ZM changes
- Have only one page for BP#1 selections (make additional page if/when growth occurs) or
- Have an option to get back to previous page

- Possibly change ownership to “” instead of “—” on the SKE Map.
- Display 30°, 60°, 90° spokes on the SFD Map.





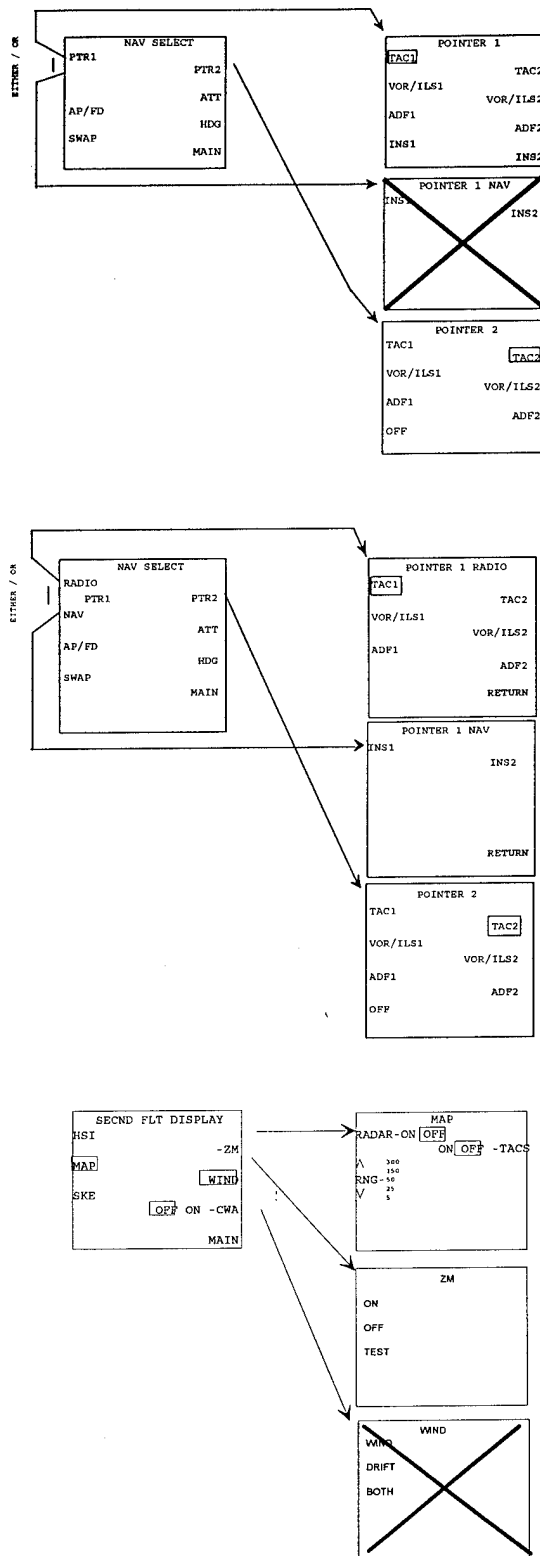


Figure 27. DAMU Design Refinements.

## PROJECT SUMMARY & CONCLUSION

The Full-Mission study concludes the second phase of a two-part evaluation effort conducted by WL/FIGP. The first phase consisted of a part-task evaluation. The primary emphasis of this phase was on the suitability of individual components of the CDS and their ability to provide an efficient crew-vehicle interface as stand-alone units. The second phase was a Full-Mission simulation effort in which the CDS was evaluated as an integrated system. The focus of the full mission effort was to demonstrate that the CDS will support C-141 functions and provide acceptable crew performance.

The primary objectives of the full-mission study were met and results showed that the CDS will: 1) support C-141 functions and 2) was "equal to or better than" the current C-141 in accomplishing C-141 mission functions. However, we recommend modifying the CDS with identified design changes.

The "phased" approach that was used in the current program has shown to be very effective. In particular, it has served to significantly reduce technical risk by critically evaluating the proposed changes prior to their incorporation into software and hardware. Given the success of the C-141 evaluation testing, a phased approach should be considered as a template for future programs. With shrinking budgets, more emphasis will probably be placed on incremental modifications to other Air Mobility Command aircraft in the near future, rather than on major redesigns. This approach should prove to be cost-effective in implementing such modifications.

To better support the development of the head-down standard, a draft functional

specification has been developed throughout the evaluation phase of the current program. It provides high-level functional requirements for all of the PFD symbology, and detailed descriptions of proposed design symbology. In addition, rationale for the designs, and lessons learned during the test phases are included. This specification is included in this report as Appendix F. This document can serve as the basis for a head-down standard, and can be a valuable resource for future cockpit modification programs.

Note that the current effort focused primarily on the components and the integration of the CDS system from a crew-vehicle interface perspective. A number of additional integration issues must still be addressed prior to incorporating the CDS into the C-141. These include:

- 1) Determine the effects of NVG backlighting on the color coding used in these designs. Color coding was found to be critical to aid discrimination of individual symbols, show related information, and to reduce clutter.
- 2) Determine the effects of the new autopilot on crew performance. Significant changes are being proposed to the autopilot system that were beyond the scope of the part-task and full mission evaluations.
- 3) Evaluation of compatibility of the CDS designs with a LCD. All of the evaluation to date were conducted with CRTs. Differences in the two display mediums may significantly affect image quality of the formats when transferred to an LCD.
- 4) Determine the effects of mixed fleet operations and crew qualifications. A ground rule for the current program is that the new CDS will be incorporated

into the C-141 fleet in an incremental fashion. Until all aircraft are modified, pilots will be flying a mixed fleet. Several potential concerns with mixed fleet operations have been identified during testing, including (1) differences in ADI scaling, (2) differences in the DAMU menu approach with the NAV SELECT panel design, and (3) the potential for confusion and errors in emergency or critical conditions.

- 5) Determine the effects on procedures and cockpit resource management. The new CDS provides additional capabilities that may require procedural changes.
- 6) Consider utilizing PCs for some training (e.g., DAMU menu system) to offset some of the costly training that would occur in the aircraft.

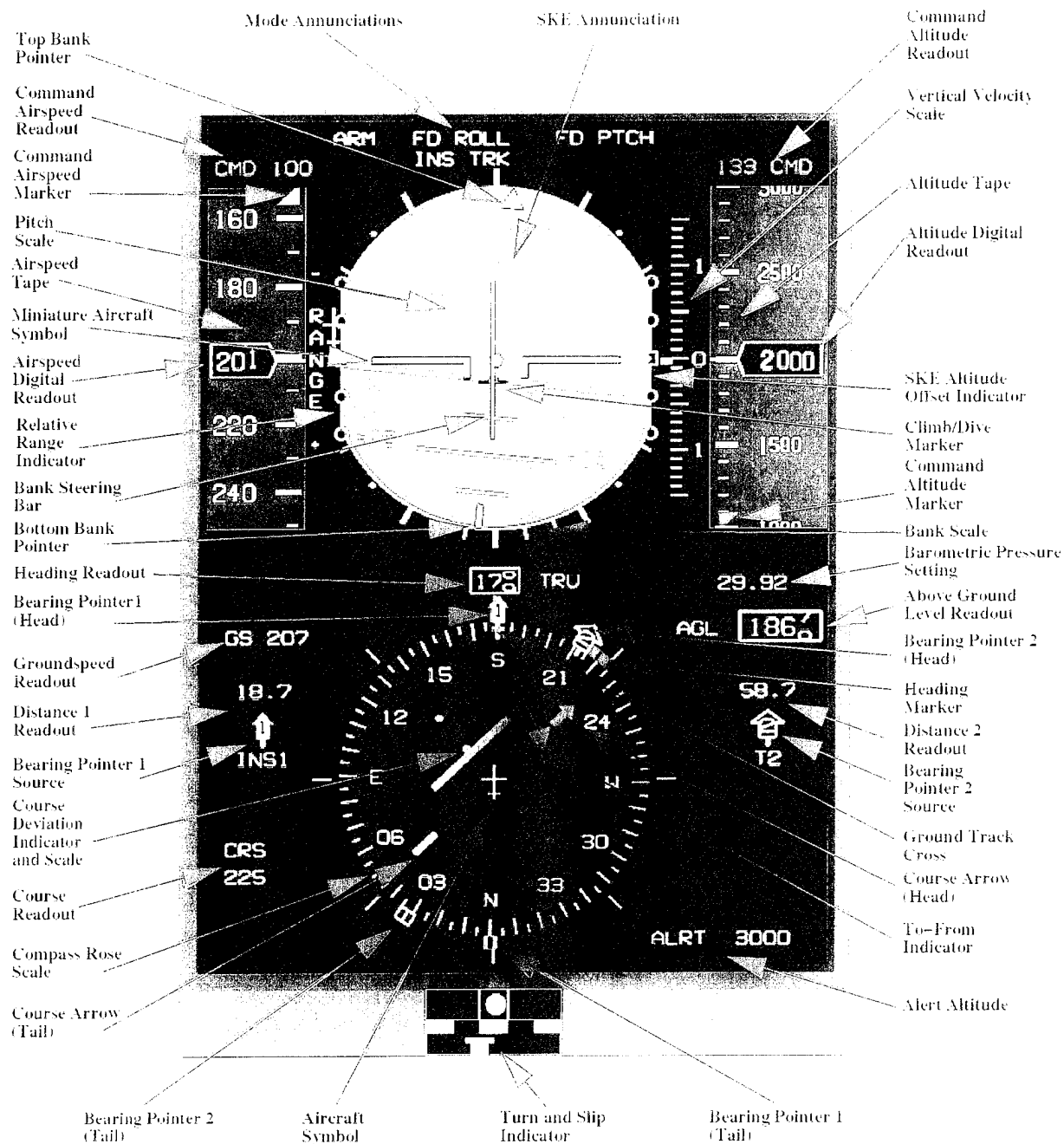
In summary, the part-task and full-mission pilot-in-the-loop evaluations provided valuable insights into the C-141 upgrade program. The extensive simulation effort allowed the program office to identify numerous design deficiencies and solutions prior to hardware and software integration into the aircraft, thereby significantly reducing overall technical risk.

## REFERENCES

- Air Force Manual 51-37, (1986). Flying Training--Instrument Flying. Headquarters US Air Force, Washington D.C.
- Cone, S., Toms, M., Gier, G. and Brown, T., and Patzek, M. (1995). Evaluation of Proposed C-141 Electronic Display Formats and Menus: Volume 1: C-141 Part-Task Simulation, Wright Laboratory Technical Report.
- Flight Information Publication. (1993). Defense Mapping Agency Aerospace Center, DOD.
- MIL-STD-1472D (1989), *Military Standard, Human Engineering Design Criteria For Military Systems, Equipment and Facilities*.
- Reid, J.D. and Colle, H. (1988). Critical SWAT Values for Predicting Operator Overload. In Human Factors Society - 32nd Annual Meeting, Anaheim, CA.
- Reid, J. D., Potter, J.M., & Bressler, J.R. (1989). Subjective Workload Assessment Technique (SWAT): A User's Guide (AAMRL-TR-89-023). Wright-Patterson AFB, Ohio: Human System Division.
- Roscoe, S. N. (1968). Airborne displays for flight and navigation. Human Factors, 10, 321-332.
- TO 1C-141B-1, Flight Manual USAF Series Aircraft.
- Vidulich, M. A. (1989). The use of judgment matrices in subjective workload assessment. The Subjective Workload Dominance (SWORD) Technique. In Proceedings of Human Factors Society 33rd Annual Meeting, Vol 2 (pp. 1406-1410). Santa Monica, CA: Human Factors Society.
- Warner-Robins Air Logistics Center (1993), The C-141 Control Display System Concept of Operation, Revision B (CONOP, Rev B).
- Wickens, C. D. (1984). Engineering Psychology and Human Performance, Columbus, Ohio: Charles E. Merrill Publishing Co.

**APPENDIX A**

**PFD, SFD, AND C-141 ELECTROMECHANICAL DISPLAY ELEMENTS**



## PRIMARY FLIGHT DISPLAY ELEMENTS

## ATTITUDE DIRECTION INDICATOR

| ELEMENT   | FUNCTIONALITY  |
|---|--|
| BANK POINTERS AND SCALES                        | A moving pointer, fixed scale display that indicates aircraft bank angle. One is provided at the top and bottom of the ADI.  |
| CLIMB/DIVE MARKER                               | Displays the current climb-dive angle when read against the pitch scale.   |
| MINIATURE AIRCRAFT SYMBOL                       | The primary pitch reference for the ADI. It is fixed in the center of the ADI ball and indicates aircraft pitch when read with respect to the pitch scale.   |
| MODE ANNUNCIATIONS                              | Indicates what mode is being displayed on the ADI (i.e. SKE, ILS, etc.)  |
| PITCH SCALE                                     | The pitch scale serves as the reference scale for the miniature aircraft symbol. It moves relative to the fixed miniature aircraft symbol. Pitch lines are presented every 5 degrees and labeled every 10 degrees. Total instantaneous field of view is 45 degrees. When the true horizon representation exceeds the ADI instantaneous field of view, the line becomes "ghosted" and stays fixed on a position in the axis of aircraft pitch. When pitch exceeds -30 and +30 degrees, the ends of the pitch scale lines are angled 30 degrees away from the horizon. |
| PITCH AND BANK STEERING BARS                    | Indicates the amount and direction of the flight director roll and pitch steering error, when read against the miniature aircraft symbol.  |
| RISING RUNWAY                                   | Displays localizer deviation and radar altitude during landing.  |
| SINGLE CUE FLIGHT DIRECTOR                      | Provides commanded pitch and bank steering information.  |
| SKE VERTICAL DEVIATION INDICATOR                | Displays relative vertical position of the lead aircraft to the follower aircraft on a five dot scale. This display uses a "fly-to" design.  |
| SKE RELATIVE RANGE INDICATOR                    | Displays relative longitudinal spacing of the lead aircraft to the follower aircraft on a five dot scale. This display uses a "fly-from" design.   |
| VERTICAL DEVIATION SCALE (GLIDESLOPE DEVIATION) | Presents aircraft displacement above or below an ILS glideslope on a five dot scale.   |

## HORIZONTAL SITUATION INDICATOR

| ELEMENT                              | FUNCTIONALITY  |
|--------------------------------------|--|
| AIRCRAFT SYMBOL                      | A fixed symbol that represents ownship position with respect to the navigation situation.  |
| BEARING POINTER 1                    | Indicates the bearing to the station selected for BP1. The symbol rotates around the circumference of the compass card.  |
| BEARING POINTER 1 IDENTIFIER         | Identifies Nav source for Bearing Pointer 1 (VOR1, VOR2, TAC1, TAC2, INS1, INS2, ADF1, ADF2, ILS1, ILS2).  |
| BEARING POINTER 1 RANGE              | Displays DME Distance #1 below Bearing Pointer 1 Identifier.   |
| BEARING POINTER 2                    | Indicates the bearing to the station selected for BP2. The symbol rotates around the circumference of the compass card.  |
| BEARING POINTER 2 IDENTIFIER         | Identifies Nav source for Bearing Pointer 2 (VOR1, VOR2, TAC1, TAC2, INS1, INS2, ADF1, ADF2, ILS1, ILS2).  |
| BEARING POINTER 2 RANGE              | Displays DME Distance #2 below Bearing Pointer 1 Identifier.   |
| COMPASS ROSE SCALE                   | A compass designed using a 360-degree scale (N=0, E=90, S=180, & W=270) broken-down into five-degree increments. The scale rotates around the fixed aircraft symbol in response to aircraft heading changes. Heading can be read against the upper lubber line and in a digital readout box. The scale readout can show MAG, TRU, or GRID heading or groundtrack. Heading mode indicates magnetic heading. Groundtrack indicates heading while accounting for drift. |
| COURSE ARROW                         | Shows pilots selected course and rotates with the compass card once selected.  |
| COURSE DEVIATION INDICATOR AND SCALE | Displays direction and magnitude of deviation from the course.   |
| COURSE READOUT                       | Provides a digital readout of the selected course.   |
| DISTANCE READOUT                     | Indicates distance to the selected navigation aid to the nearest tenth of a mile and provides and indication that distance information is invalid. Two distance readouts are provided, one associated with each bearing pointer.   |
| GROUND TRACK CROSS                   | Indicates ground track when the EHSI is in heading mode and is overlaid on the compass rose scale.   |
| HEADING DIAMOND                      | Indicates heading when the EHSI is in track mode and is overlaid on the compass rose scale.  |
| HEADING MARKER                       | Provides a reference to the desired heading on the compass rose scale.   |
| TO-FROM INDICATOR                    | Indicates location of radio based NAVAIDS relative to the aircraft when read against HSI aircraft symbol.  |



## AIRSPEED INDICATOR

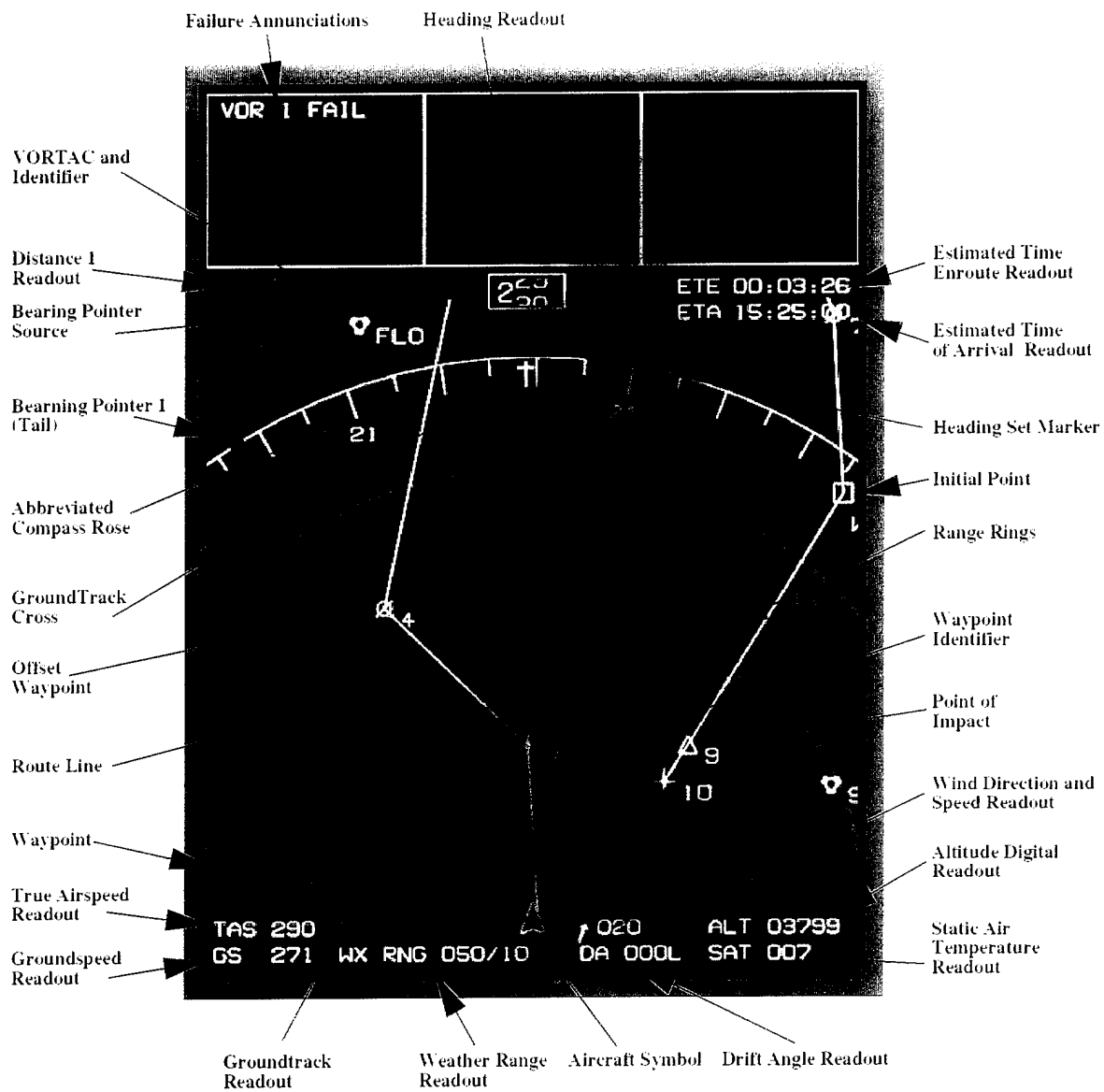
| ELEMENT                  | FUNCTIONALITY  |
|--------------------------|--|
| AIRSPEED DIGITAL READOUT | Provides a digital readout with a rolling counter type format of indicated airspeed.   |
| AIRSPEED TAPE            | Provides a moving tape that moves vertically with response to aircraft airspeed changes. Airspeed is read against a fixed reference line.  |
| COMMAND AIRSPEED PRESET  | Indicates commanded airspeed graphically on the airspeed tape. If the commanded airspeed value is not in view, otherwise the command marker will be positioned at the top or bottom of the airspeed tape.  |
| COMMAND AIRSPEED READOUT | Provides a digital readout of the commanded airspeed.  |
| GROUNDSPEED READOUT      | Provides a digital readout of the groundspeed.   |
| MACH INDICATOR           | Provides a digital readout of true mach from 0.01 to 0.99 Mach in hundredths of each mach increments. A warning is provided when the mach limit is being approached. As mach increases: 1) when mach exceeds .78, the boxed readout is displayed in yellow; 2) when mach exceeds .80, the window is displayed in red and the readout is displayed in yellow; and 3) when mach exceeds .825, both the window and the readout is displayed in red. |

## ALTITUDE SCALE

| ELEMENT                              | FUNCTIONALITY   |
|--------------------------------------|---|
| ALERT ALTITUDE                       | Provides a digital readout of selected alert altitude.  |
| ALTITUDE DIGITAL READOUT             | Provides a digital readout with a rolling counter type format of indicated airspeed.  |
| ALTITUDE TAPE                        | Provides a moving tape that moves vertically with response to aircraft altitude changes. Altitude is read against a fixed reference line.   |
| BAROMETRIC PRESSURE READOUT          | Provides a digital readout of the barometric altimeter setting.   |
| COMMAND AIRSPEED READOUT             | Provides a digital readout of the commanded altitude.   |
| COMMAND ALTITUDE PRESET              | Indicates commanded altitude graphically on the altitude tape. If the commanded altitude value is not in view, otherwise the command marker will be positioned at the top or bottom of the altitude tape. |
| RADAR ALTITUDE DIGITAL READOUT       | Provides a digital readout of the Above Ground Level (AGL) altitude.  |
| RADAR ALTITUDE THERMOMETER INDICATOR | Provides a thermometer ribbon that appears at the bottom of the altitude scale at 1000 ft. The difference between the top of the thermometer and the center reference line is the ground elevation.       |

## VERTICAL VELOCITY INDICATOR

| ELEMENT                    | FUNCTIONALITY   |
|----------------------------|---|
| VERTICAL<br>VELOCITY SCALE | Indicates rate of climb or descent in feet per minute using a vertical scale format. The vertical velocity is determined by reading the position of the thermometer type indicator against the left side of the scale. The scale normally provides a total range of 3000 fpm, with numeric labels at 0, -1000, and 1000 fpm. Vertical velocity exceeds 1500 fpm, a boxed digital readout is presented above the scale and the digital readout changes to show up 9.9 X 1000 fpm to the nearest 100 fpm. |



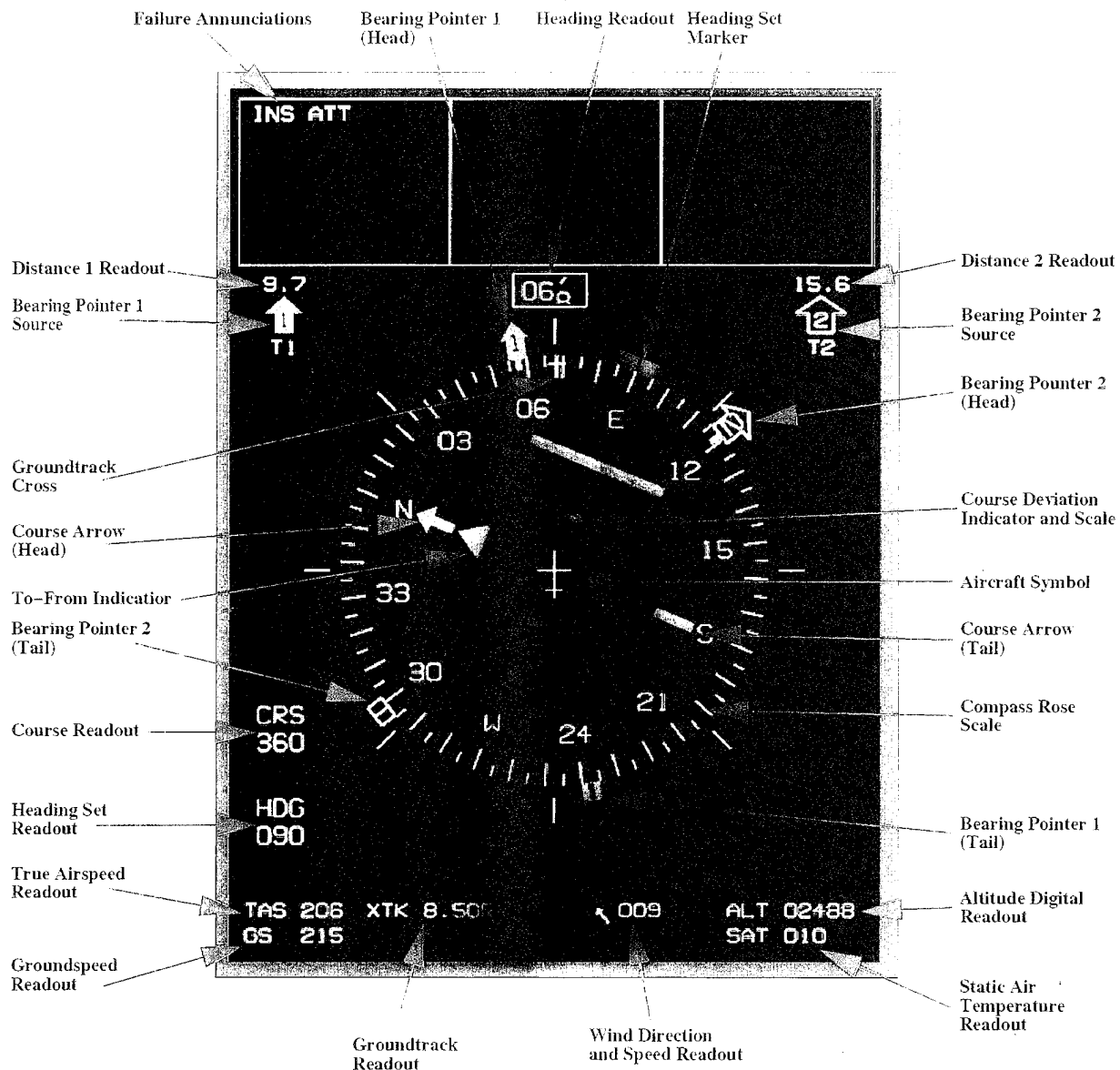
## SECONDARY FLIGHT DISPLAY MAP FORMAT

## SECONDARY FLIGHT DISPLAY COMMON ELEMENTS (HSI, MAP, SKE)

| ELEMENT                              | FUNCTIONALITY   |
|--------------------------------------|---|
| ALTITUDE READOUT                     | Display baro altitude digitally in Feet or Meters (dependent on ALT selection).   |
| BEARING POINTER 1                    | Indicates the bearing to the station selected for BP1. The symbol rotates around the circumference of the compass card.                           |
| BEARING POINTER 1 IDENTIFIER         | Identifies Nav source for Bearing Pointer 1 (VOR1, VOR2, TAC1, TAC2, INS1, INS2, ADF1, ADF2, ILS1, ILS2).   |
| BEARING POINTER 1 RANGE              | Displays DME Distance #1 below Bearing Pointer 1 Identifier.  |
| COURSE CROSS TRACK READOUT           | Alpha numeric display of horizontal deviation of desired track. L= indicates aircraft left of desired track / R=indicates right of desired track. |
| DRIFT ANGLE READOUT                  | Displays drift angle, incorporating an "L" or "R" character to indicate left and right drift.   |
| GROUND SPEED READOUT                 | Displays ground speed in Knots (0-500 knots).   |
| HEADING READOUT                      | Displays aircraft Heading digitally (if HSI= HDG) to the nearest degree.  |
| HEADING TYPE ANNUNCIATOR             | Displays Heading Mode when in TRUE, no display when in MAG.   |
| STATIC AIR TEMPERATURE (SAT) READOUT | Displays Static Air Temperature digitally in degrees (-100 to +50 deg C).   |
| TRUE AIRSPEED READOUT                | Displays True Airspeed digitally in Knots (70-999).   |
| WARNING/OFF MESSAGES                 | Displays 18 warning off messages at the top of the SFD.   |
| WIND ARROW                           | Icon representing wind direction relative to aircraft heading.  |
| WIND SPEED READOUT                   | Display digitally wind speed in knots (0 to 105).   |

## SECONDARY FLIGHT DISPLAY MAP FORMAT

| ELEMENT                         | FUNCTIONALITY  |                      |                        |   |   |    |   |    |    |     |    |     |    |
|---------------------------------|--|----------------------|------------------------|---|---|----|---|----|----|-----|----|-----|----|
| BEARING POINTER 1               | Indicates the bearing to the station selected for BP1. The symbol rotates around the circumference of the compass card.  |                      |                        |   |   |    |   |    |    |     |    |     |    |
| BEARING POINTER 1 IDENTIFIER    | Identifies Nav source for Bearing Pointer 1 (VOR1, VOR2, TAC1, TAC2, INS1, INS2, ADF1, ADF2, ILS1, ILS2).  |                      |                        |   |   |    |   |    |    |     |    |     |    |
| BEARING POINTER 1 RANGE         | Displays DME Distance #1 below Bearing Pointer 1 Identifier.   |                      |                        |   |   |    |   |    |    |     |    |     |    |
| BEARING POINTER 2               | Indicates the bearing to the station selected for BP2. The symbol rotates around the circumference of the compass card.  |                      |                        |   |   |    |   |    |    |     |    |     |    |
| BEARING POINTER 2 IDENTIFIER    | Identifies Nav source for Bearing Pointer 2 (VOR1, VOR2, TAC1, TAC2, INS1, INS2, ADF1, ADF2, ILS1, ILS2).  |                      |                        |   |   |    |   |    |    |     |    |     |    |
| BEARING POINTER 2 RANGE         | Displays DME Distance #2 below Bearing Pointer 1 Identifier.   |                      |                        |   |   |    |   |    |    |     |    |     |    |
| COURSE READOUT (CRS)            | Indicates selected course to the nearest degree (000 to 359 degrees).  |                      |                        |   |   |    |   |    |    |     |    |     |    |
| COURSE CROSS-TRACK READOUT      | Alpha numeric display of horizontal deviation of desired track. L= indicates aircraft left of desired track / R=indicates right of desired track.  |                      |                        |   |   |    |   |    |    |     |    |     |    |
| HEADING SET MARKER              | Displays heading set by Reference Set Panel by icon symbol which moves on compass card.  |                      |                        |   |   |    |   |    |    |     |    |     |    |
| HEADING DIAMOND                 | Icon which indicates aircraft heading when HSI is in Track Mode.   |                      |                        |   |   |    |   |    |    |     |    |     |    |
| GROUND TRACK CROSS              | Indicates aircraft ground track when HSI is in Heading Mode.   |                      |                        |   |   |    |   |    |    |     |    |     |    |
| PARTIAL COMPASS                 | A partial compass card which rotates to indicate aircraft Heading or Ground Track (dependent on selected HSI mode) at the top of the display.  |                      |                        |   |   |    |   |    |    |     |    |     |    |
| RADAR RANGE RINGS               | Four circles representing equidistant ranges from the aircraft.  |                      |                        |   |   |    |   |    |    |     |    |     |    |
| RADAR RANGE RING LABELS         | <p>Consists of 4 rings equally spaced indicates a distance each ring is from the aircraft.</p> <table> <tr> <th>Total Distance Shown</th><th>Distance Between Rings</th></tr> <tr> <td>5</td><td>1</td></tr> <tr> <td>25</td><td>5</td></tr> <tr> <td>50</td><td>10</td></tr> <tr> <td>150</td><td>30</td></tr> <tr> <td>300</td><td>60</td></tr> </table> | Total Distance Shown | Distance Between Rings | 5 | 1 | 25 | 5 | 50 | 10 | 150 | 30 | 300 | 60 |
| Total Distance Shown            | Distance Between Rings   |                      |                        |   |   |    |   |    |    |     |    |     |    |
| 5                               | 1  |                      |                        |   |   |    |   |    |    |     |    |     |    |
| 25                              | 5  |                      |                        |   |   |    |   |    |    |     |    |     |    |
| 50                              | 10   |                      |                        |   |   |    |   |    |    |     |    |     |    |
| 150                             | 30   |                      |                        |   |   |    |   |    |    |     |    |     |    |
| 300                             | 60   |                      |                        |   |   |    |   |    |    |     |    |     |    |
| TACAN WAYPOINTS                 | Icon representing the position of a TACAN station. Capable of displaying up to three TACAN station icons. Waypoint # ID is displayed with each icon on course.   |                      |                        |   |   |    |   |    |    |     |    |     |    |
| NORMAL WAYPOINTS                | Icon representing position of a flight path waypoint. Capable of displaying up to 9 flight path waypoints. Waypoint # ID is displayed with each icon on course.  |                      |                        |   |   |    |   |    |    |     |    |     |    |
| COURSE LINES                    | Straight lines between consecutive waypoints indicating course.  |                      |                        |   |   |    |   |    |    |     |    |     |    |
| ESTIMATED TIME ENROUTE (ETE)    | Indicates the time remaining to drop zone or the next waypoint. The time counts down to next waypoint.   |                      |                        |   |   |    |   |    |    |     |    |     |    |
| ESTIMATED TIME OF ARRIVAL (ETA) | Displays estimated time of arrival in a 24 hour, minutes, seconds format.  |                      |                        |   |   |    |   |    |    |     |    |     |    |
| FIXED AIRCRAFT SYMBOL           | Fixed symbol serving as center of partial compass.   |                      |                        |   |   |    |   |    |    |     |    |     |    |

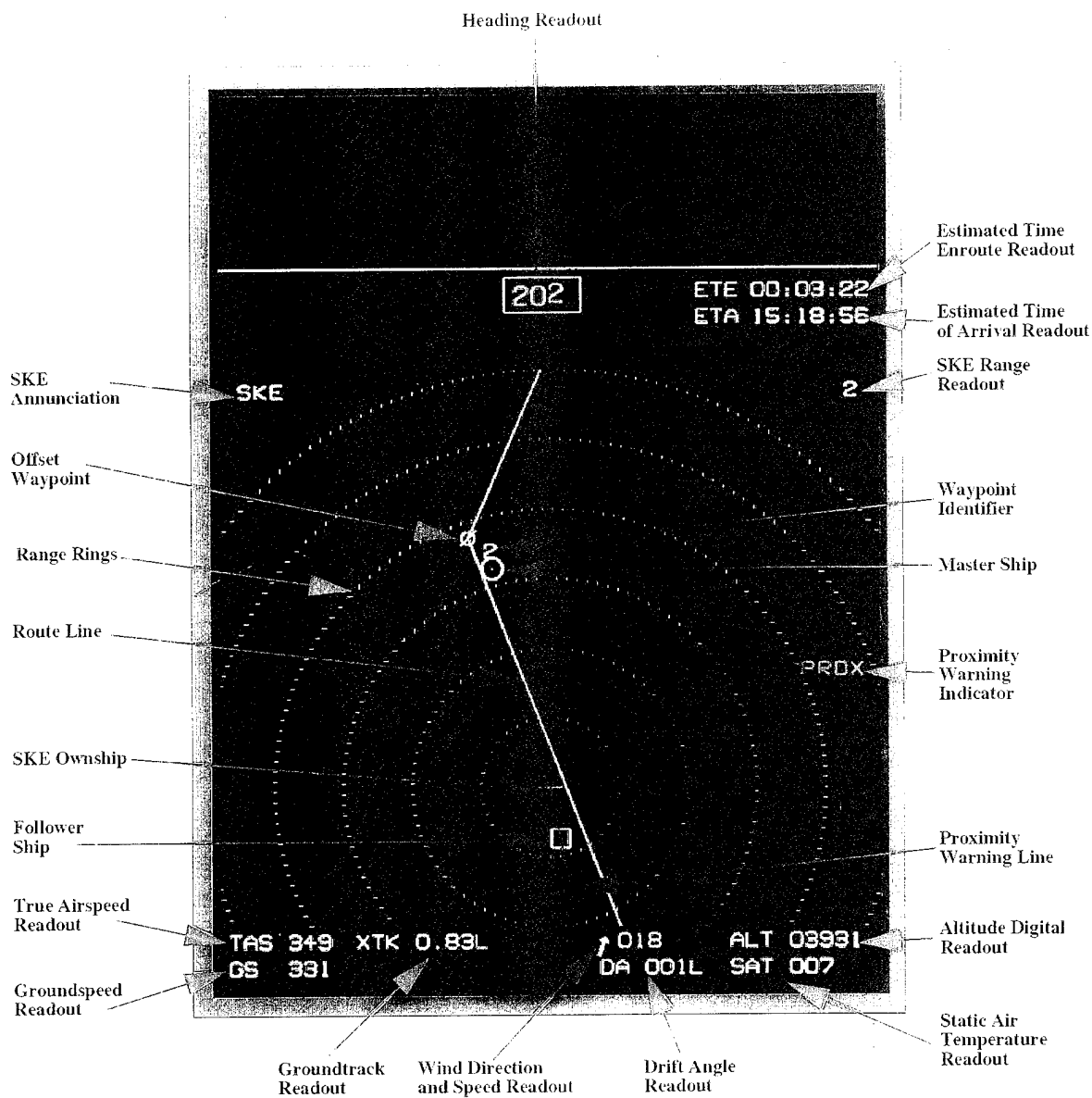


## SECONDARY FLIGHT DISPLAY HORIZONTAL SITUATION INDICATOR FORMAT

## SECONDARY FLIGHT DISPLAY HORIZONTAL SITUATION INDICATOR FORMAT

| ELEMENT                           | FUNCTIONALITY   |
|-----------------------------------|---|
| BEARING POINTER 1 (BP1)           | Indicates the bearing to the station selected for BP1. The symbol rotates around the circumference of the compass card.   |
| BEARING POINTER 1 IDENTIFIER      | Identifies Nav source for Bearing Pointer 1 (VOR1, VOR2, TAC1, TAC2, INS1, INS2, ADF1, ADF2, ILS1, ILS2).   |
| BEARING POINTER 1 RANGE           | Displays DME Distance #1 below Bearing Pointer 1 Identifier   |
| BEARING POINTER 2 (BP2)           | Indicates the bearing to the station selected for BP2. The symbol rotates around the circumference of the compass card.   |
| BEARING POINTER 2 IDENTIFIER      | Identifies Nav source for Bearing Pointer 2 (VOR1, VOR2, TAC1, TAC2, INS1, INS2, ADF1, ADF2, ILS1, ILS2).   |
| BEARING POINTER 2 RANGE           | Displays DME Distance #2 below Bearing Pointer 2 Identifier   |
| COURSE (CRS) READOUT              | Indicates selected course to the nearest degree (000 to 359 degrees)  |
| COURSE DEVIATION INDICATOR        | Indicates horizontal deviation from course.<br><br>For VOR/TAC nav mode: it is a function of course and BP1 angle so as to indicate 5 degree error per dot on the deviation scale. Motion is limited to $\pm 11$ degrees.<br><br>For LOCALIZER nav mode: It is a function of Localizer deviation from ILS ratio. Motion is limited to 2.2 dots.<br><br>For INS nav mode: It is a function of crosstrack deviation from the INS. |
| COURSE ARROW WITH DEVIATION SCALE | Displays direction and magnitude of deviation from course when read against the Course arrow and Deviation Scale.   |
| COURSE TO / FROM ARROW            | Rotates with the course arrow inside compass card. It points in the same direction as the course arrow when Selected Course 1 and Bearing Pointer 1 are within 90 deg of each other.  |
| EXPANDED HSI FIXED SYMBOLOGY      | Fixed aircraft symbol and major hash marks at 45 degree intervals.  |
| COMPASS CARD                      | Indicates aircraft Heading or Ground Track (per HSI Mode) at the top of the display by rotation.  |
| HEADING SET READOUT               | Displays digitally heading set by Reference Set Panel.  |
| HEADING SET MARKER                | Displays heading set by Reference Set Panel by icon symbol which moves on compass card.   |
| GROUND TRACK CROSS                | Icon which indicates aircraft ground track when HSI is in Heading Mode.   |
| HEADING DIAMOND                   | Icon which indicates aircraft heading when HSI is in Track Mode.  |
| RADAR OVERLAY                     | Displays external Radar video is displayed with SFD/MAP Format overlaid.  |

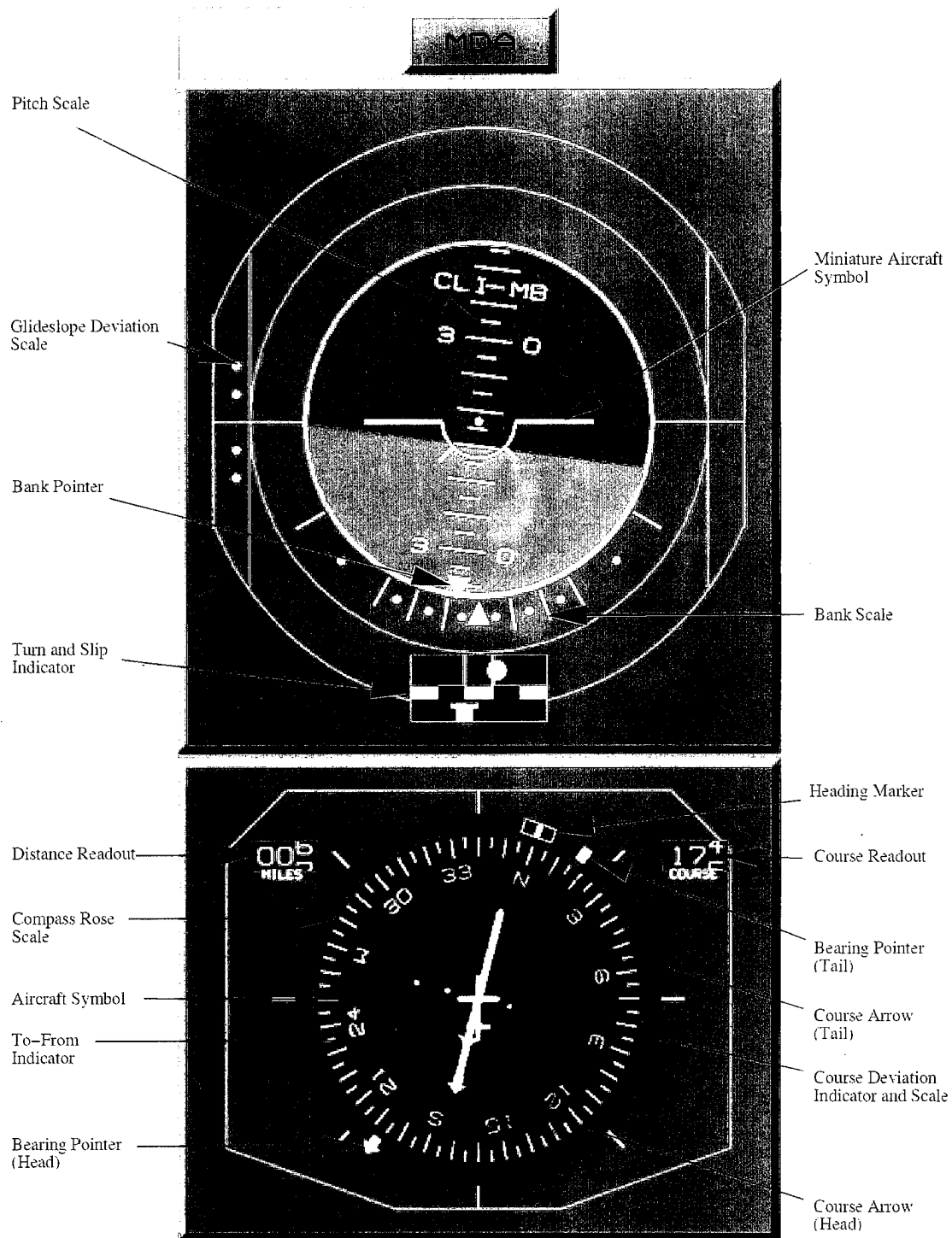




SECONDARY FLIGHT DISPLAY SKE FORMAT

## SECONDARY FLIGHT DISPLAY SKE FORMAT

| ELEMENTS                      | FUNCTIONALITY   |
|-------------------------------|---|
| SKE ZONE MARKER               | Vertical line segment representing zone marker position relative to aircraft.   |
| MASTER SHIP                   | Icon representing the position of the master ship.  |
| SKE RANGE READOUT             | Displays digitally the SKE Range (x1000) and corresponds to the number of feet between the rings. (1, 2, 4, 8, 16).   |
| SKE CAUTION ANNUNCIATOR       | Displays SKE "CAUTION" text for caution conditions.   |
| SKE TEST ANNUNCIATOR          | Displays SKE "TEST" text for test conditions.   |
| FOLLOWER SHIPS                | Icon representing the position of a follower ship (capable of displaying 38 follower ships).  |
| SKE RANGE RINGS               | Displays SKE range rings for SKE Mode.<br><br>CENTER, four proportionally larger circles (or partial circles) centered at the display center.<br><br>UP, six proportionally spaced circles centered 25% down from the top of the SKE presentation.<br><br>DOWN, six proportionally spaced circles centered 75% down from the top of the SKE presentation. |
| MASTER ANNUNCIATOR            | Displays Text "M" to indicate Master Ship.  |
| MASTER LOST ANNUNCIATOR       | Displays text "Master Lost".  |
| PROXIMITY WARNING ANNUNCIATOR | Displays text "PROX" to indicate SKE Proximity Warning.   |
| PROXIMITY WARNING LINE        | Line from center of SKE ring (ownship symbol) through ship indicating PROXIMITY to outer SKE rings.   |
| SKE OWNSHIP                   | Symbol displayed in the center of SKE rings indicating Ownship.   |
| ESTIMATED TIME ENROUTE        | Indicates the time remaining to drop zone or the next waypoint. The time counts down to next waypoint.  |
| ESTIMATED TIME OF ARRIVAL     | Displays estimated time of arrival to next waypoint in a 24 hour, minutes, seconds format.  |
| SKE ANNUNCIATOR               | Displays "SKE" Text to annunciate SKE Mode.   |



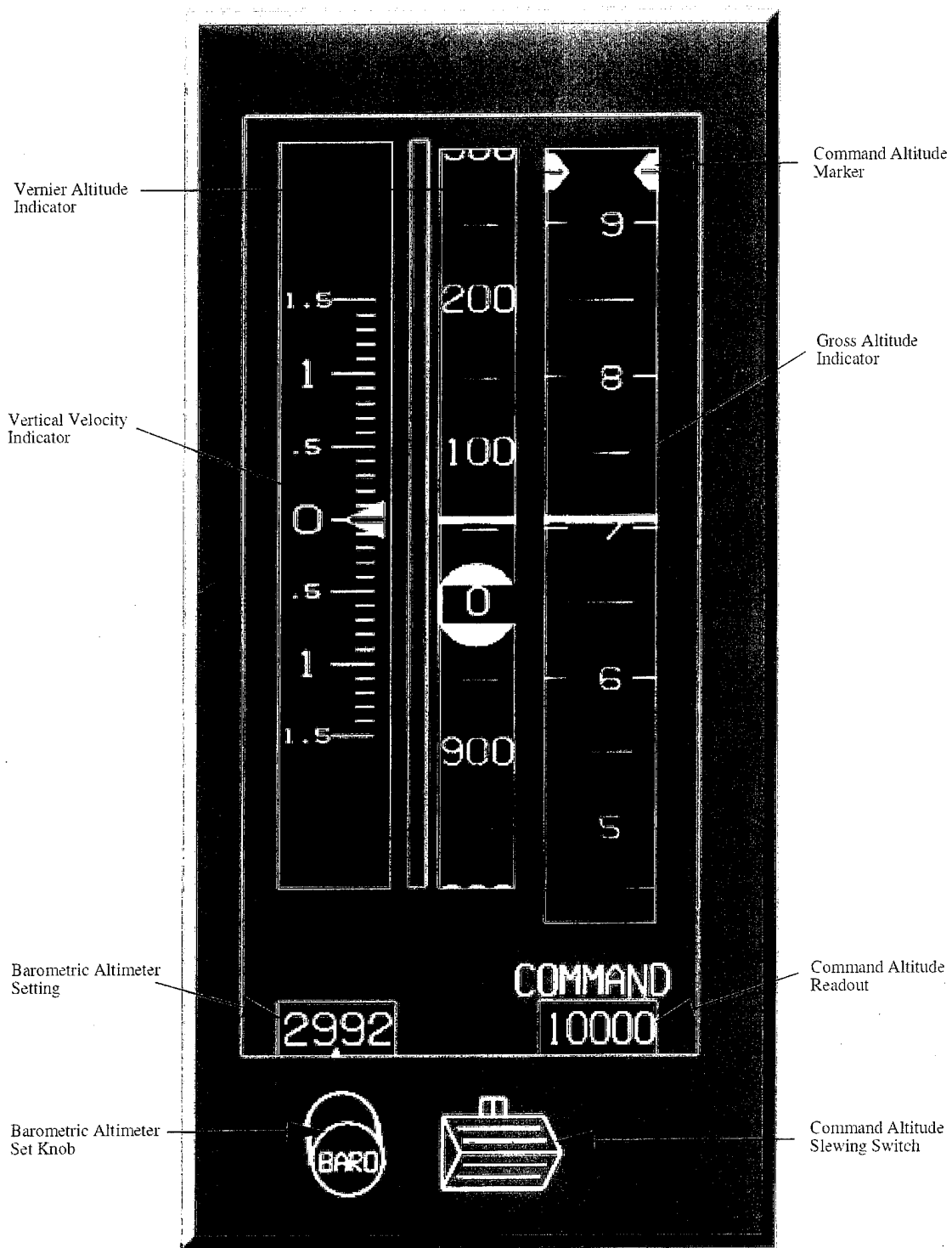
**C-141 ELECTROMECHANICAL ADI AND HSI**

## C-141 ADI ELEMENTS

| ELEMENT   | FUNCTIONALITY  |
|---|--|
| MINIATURE AIRCRAFT SYMBOL                       | The primary flight control reference for the ADI. It is fixed in the center of the ADI ball and indicates aircraft pitch when read with respect to the pitch scale.  |
| PITCH AND BANK STEERING BARS                    | Indicate the magnitude and direction of pitch and bank steering error when read against the miniature aircraft symbol. (Not Shown)   |
| BANK POINTERS AND SCALES                        | A moving pointer, fixed scale display that indicates aircraft bank angle. One is provided at the top and bottom of the ADI. Utilizes five-degree increments to measure up to 60 degrees of bank angle.   |
| PITCH SCALE                                     | The pitch scale serves as the reference scale for the miniature aircraft symbol. It is positioned on the ADI sphere and moves with respect to the miniature aircraft symbol. Scale lines are provided every 5 degrees but are labeled every 10 degrees. Total instantaneous field of view is approximately 90 degrees. |
| TURN AND SLIP INDICATOR                         | The needle and ball indicate rate of turn and slip/skid, respectively.   |
| VERTICAL DEVIATION SCALE (GLIDESLOPE DEVIATION) | Presents aircraft displacement above or below an ILS glideslope.   |

## C-141 HSI ELEMENTS

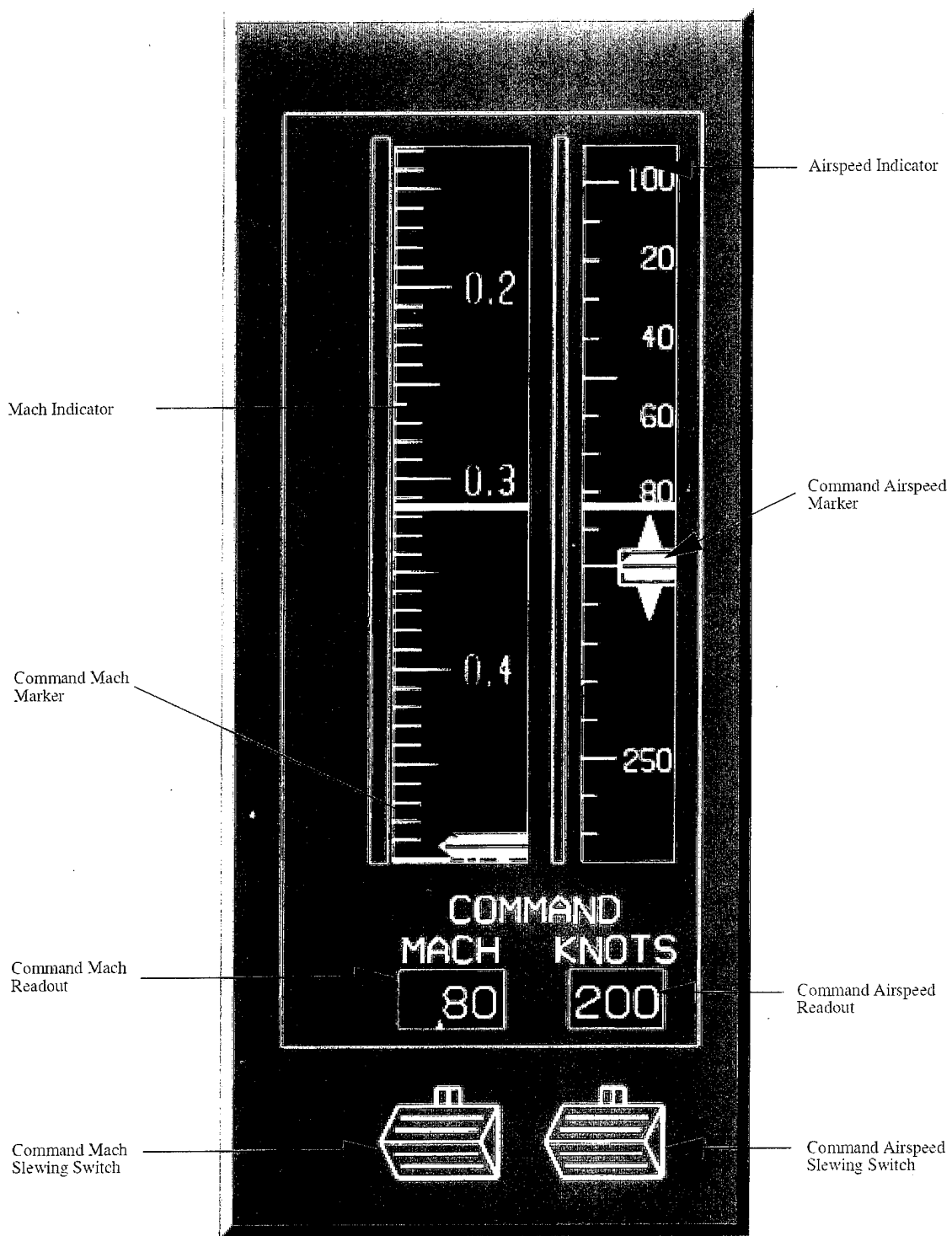
| ELEMENT                              | FUNCTIONALITY  |
|--------------------------------------|--|
| HEADING MARKER                       | Provides a reference to the desired heading on the compass rose scale.   |
| COMPASS ROSE SCALE                   | A compass showing a 360-degree scale (N=360, E=90, S=180, & W=270) broken-down into five-degree increments. The scale rotates around the fixed aircraft symbol in response to aircraft heading changes. Heading can be read against the upper lubber line. |
| COURSE READOUT                       | Provides a rolling drum presentation of the pilot-selected course.   |
| AIRCRAFT SYMBOL                      | A fixed symbol that represents the ownship position with respect to the navigation situation.  |
| COURSE ARROW                         | Shows the pilot-selected course against the compass rose scale. Once set, it rotates with the compass card in response to aircraft heading changes.  |
| COURSE DEVIATION INDICATOR AND SCALE | Displays direction and magnitude of deviation from the course on a 5 dot scale.  |
| BEARING POINTER                      | Indicates relative and magnetic bearing to the selected navigation aid.  |
| DISTANCE READOUT                     | Rolling drum digital presentation displaying distance to the TACAN station when either INS or TACAN is selected.   |
| TO-FROM INDICATOR                    | Indicates location of radio based NAVAIDS relative to the aircraft when read against HSI aircraft symbol.  |



**C-141 ELECTROMECHANICAL ALTITUDE INDICATOR**

## C-141 ALTITUDE INDICATOR

| ELEMENT                           | FUNCTIONALITY  |
|-----------------------------------|--|
| VERTICAL VELOCITY INDICATOR       | Uses a moving pointer fixed scale format to display rate of climb or descent in feet per minute. The scale shows a total range of 3000 feet per minute. When the vertical velocity exceeds +/- 1500 fpm, digital readouts at the top or bottom of the VVI display fpm 100 fpm increments.  |
| VERNIER ALTITUDE INDICATOR        | Provides a vertical tape display that moves in response to aircraft changes in altitude. The scale is labeled in 100 feet increments with graduation marks every 50 feet. The vernier and gross altitude scales must both be read to determine specific aircraft altitude. Both are read against a fixed reference line. The vernier scale is primarily used to obtain trend and precise altitude information. |
| GROSS COMMAND ALTITUDE INDICATOR  | Indicates current altitude on a vertical moving scale. The scale is labeled in thousands of feet, ranges from -1000 feet to +60,000 feet, and provides graduation marks every 500 feet. The scale is intended to provide a gross indication of altitude rather than trend and precise altitude information. It is intended to be used in conjunction with the vernier altitude scale.                          |
| BAROMETRIC ALTIMETER SETTING      | Rolling drum digital presentation that indicates the barometric pressure setting.  |
| COMMAND ALTITUDE MARKER           | A short horizontal bar that is positioned on the vernier and gross altitude scales over the value set in the command altitude readout window. If the commanded value is not in view, the command marker will be positioned at the top or bottom of the instrument.   |
| COMMAND ALTITUDE READOUT          | Rolling drum format presentation of the commanded altitude.  |
| BAROMETRIC ALTIMETER SETTING KNOB | Control used to set the barometric pressure setting.   |
| COMMAND ALTITUDE SLEWING SWITCH   | Control used to set the command altitude.  |



**C-141 ELECTROMECHANICAL MACH AIRSPEED INDICATOR**

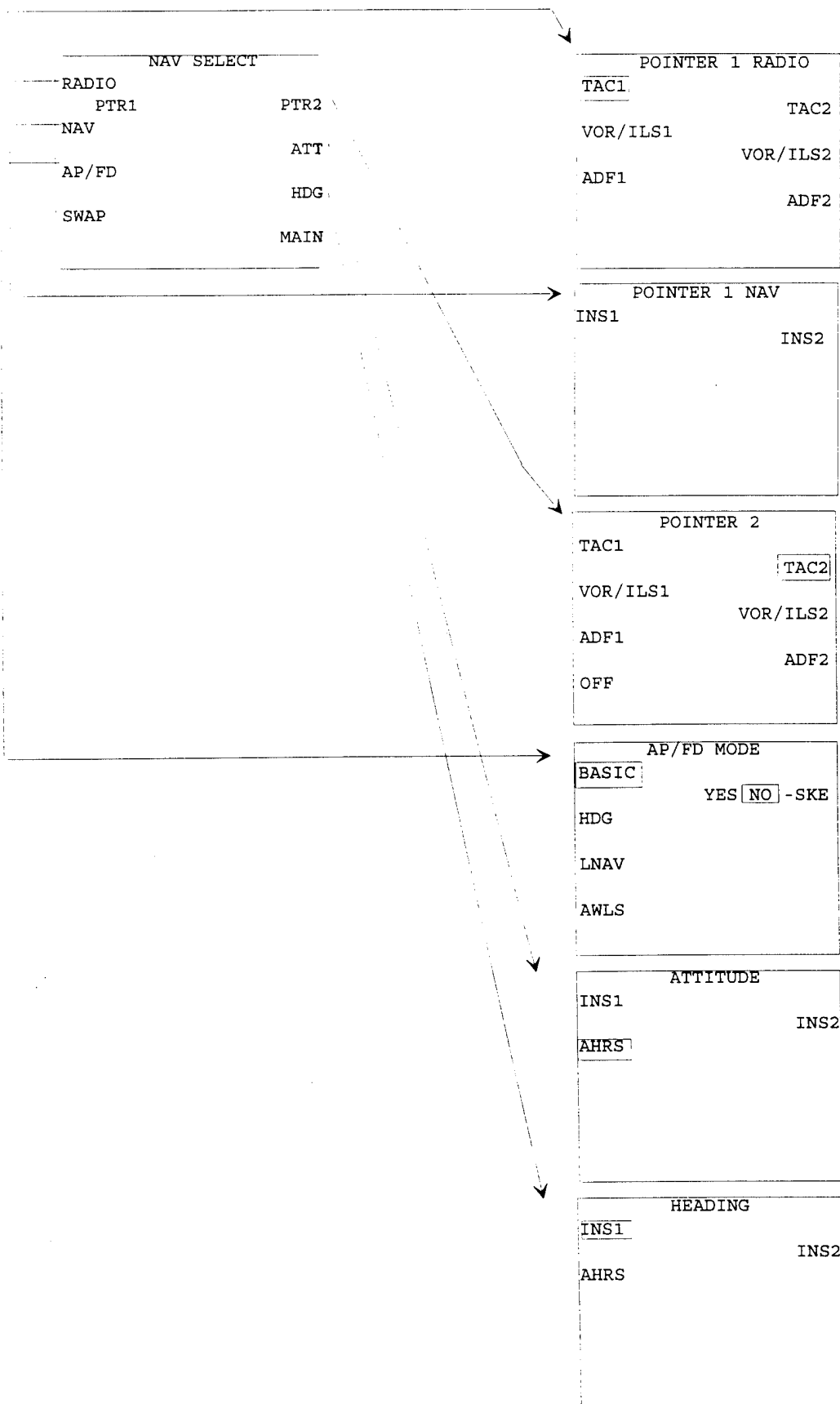


## C-141 MACH AIRSPEED INDICATOR

| ELEMENT                         | FUNCTIONALITY  |
|---------------------------------|--|
| MACH INDICATOR                  | Vertical tape format that moves in response to aircraft changes in mach. The scale displays mach from 0.2 to 1.0 Mach in hundredths of each mach increments. Each one-tenth mach is numbered.  |
| COMMAND MACH MARKER             | A short horizontal bar that is positioned on the Mach scale over the value set in the command Mach readout window. If the commanded value is not in view, the command marker will be positioned at the top or bottom of the scale, as appropriate.           |
| COMMAND MACH SLEWING SWITCH     | Control used to set the command Mach marker.   |
| COMMAND MACH READOUT            | Rolling drum presentation of commanded Mach setting.   |
| AIRSPEED INDICATOR              | Provides a vertical tape display that moves in response to aircraft airspeed changes. Airspeed is read against a fixed index line.   |
| COMMAND AIRSPEED MARKER         | A short horizontal bar that is positioned on the airspeed scale over the value set in the commanded airspeed readout window. If the commanded value is not in view, the command marker will be positioned at the top or bottom of the scale, as appropriate. |
| COMMAND AIRSPEED SLEWING SWITCH | Control used to set the command airspeed.  |
| COMMAND AIRSPEED READOUT        | Rolling drum presentation of the commanded airspeed.   |

**APPENDIX B**  
**DAMU HIERARCHICAL STRUCTURE**

EITHER / OR



|                 |      |
|-----------------|------|
| FSAS/CDU REPEAT |      |
| TAC             | MIX  |
| TACAN           | JAX  |
| LT N 30         | 27.0 |
| LG W 81         | 33.5 |
| CH 92           | 0    |
| DIST NM         | 161  |
| MAIN            |      |
| MAIN MENU       |      |
| NAV SELECT      | SKE  |
| PFD             | BIT  |
| SFD             |      |
| DISPLAY CONTROL |      |
| FSAS/CDU REPEAT |      |

|                 |            |
|-----------------|------------|
| STATUS          |            |
| RADIO           |            |
| PTR1-TAC1       | TAC2-PTR2  |
| NAV             | INS1-ATT   |
| AP/FD-BASIC     | INS1-HDG   |
| SWAP            |            |
| POINTER 1 RADIO |            |
| TAC1            | TAC2       |
| VOR/ILS1        | VOR/ILS2   |
| ADF1            | ADF2       |
| POINTER 1 NAV   |            |
| INS1            | INS2       |
| POINTER 2       |            |
| TAC1            | TAC2       |
| VOR/ILS1        | VOR/ILS2   |
| ADF1            | ADF2       |
| OFF             |            |
| AP/FD MODE      |            |
| BASIC           | YES NO-SKE |
| HDG             |            |
| LNAV            |            |
| AWLS            |            |
| ATTITUDE        |            |
| INS1            | INS2       |
| AHRS            |            |
| HEADING         |            |
| INS1            | INS2       |
| AHRS            |            |

PRIM FLT DISPLAY  
CDM- ON OFF  
          FT MTRS -SCALE  
HSI- HDG TRK  
                  MB IN -BARO  
FD- BARS BALL  
HDG- TRUE SYN  
                                  MAIN

SECND FLT DISPLAY

HSI

- ZM

MAP

WIND

SKE

OFF ON - CWA

MAIN

MAP

RADAR-ON OFF

ON OFF -TACS

^ 300  
150  
RNG- 50  
V 25  
5

WIND

WIND

DRIFT

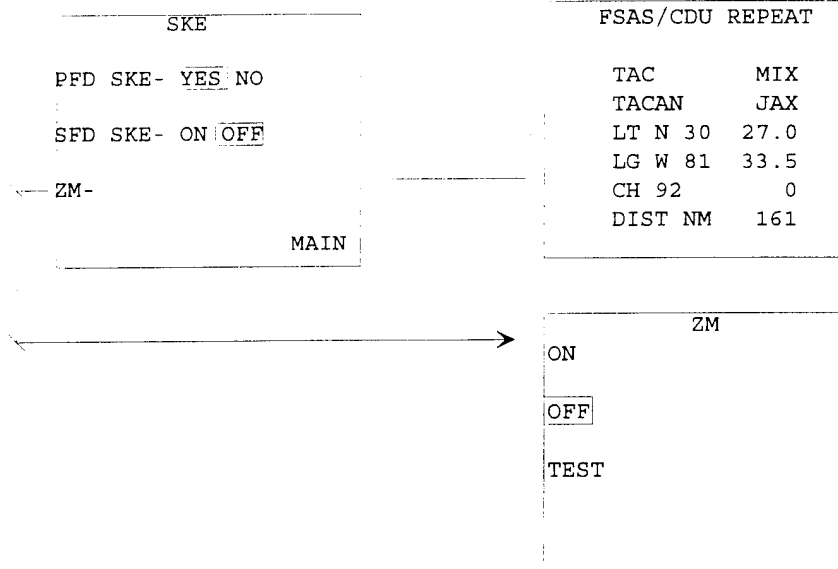
BOTH

ON

OFF

TEST

ZM



**APPENDIX C**  
**QUESTIONNAIRE AND SWORD FORMS**

## MISSION QUESTIONNAIRE

(to be given upon the completion of each AIRLAND mission)

Subject Number: \_\_\_\_\_

Date: \_\_\_\_\_

Cockpit Configuration (circle one): CONOP CDS / C-141

Mission Configuration (circle one): McGuire to Pope / McGuire to Fayetteville

**Instructions:** Please answer the following questions as much detail as possible.

1. Use the workload scale below to rate the following tasks.

Comments:

**A. Did not affect workload**

**B. Slightly increased workload**

**C. Moderately increased workload**

**D. Substantially increased workload**

- a) \_\_\_\_\_ Hand flying the mission
- b) \_\_\_\_\_ Thunderstorm avoidance
- c) \_\_\_\_\_ INS failure
- d) \_\_\_\_\_ DAMU failure (for CONOP CDS missions)
- e) \_\_\_\_\_ Other (specify)

2. How would you rate the level of difficulty in completing this mission?

\_\_\_\_\_ easy      \_\_\_\_\_ medium      \_\_\_\_\_ difficult

3. Do you feel that you were able to successfully complete all tasks in this mission?

\_\_\_\_\_ Yes      \_\_\_\_\_ No

IF NO, please comment:

4. What specific problems did you encounter while flying the mission?

5. What operational factors that were not simulated here would increase your workload in a real-world mission?

6. Other comments (use back of form, if necessary):



## MISSION QUESTIONNAIRE

(to be given upon the completion of each AIRDROP mission)

Subject Number: \_\_\_\_\_

Date: \_\_\_\_\_

Cockpit Configuration (circle one): CONOP CDS / C-141

Mission Configuration (circle one): Sicily Drop / Luzon Drop

**Instructions:** Please answer the following questions as much detail as possible.

1. Use the workload scale below to rate the following tasks.

- A. Did not affect workload
- B. Slightly increased workload
- C. Moderately increased workload
- D. Substantially increased workload

Comments:

- a) \_\_\_\_\_ Hand flying the mission
- b) \_\_\_\_\_ Maintaining formation flight
- c) \_\_\_\_\_ Airdrop functions
- d) \_\_\_\_\_ Other (specify)
- e) \_\_\_\_\_ Other (specify)

2. How would you rate the level of difficulty in completing this mission?

\_\_\_\_\_ easy      \_\_\_\_\_ medium      \_\_\_\_\_ difficult

3. Do you feel that you were able to successfully complete all tasks in this mission?

\_\_\_\_\_ Yes      \_\_\_\_\_ No

IF NO, please comment:

4. What specific problems did you encounter while flying the mission?

5. What operational factors that were not simulated here would increase your workload in a real-world mission?

6. Other comments (use back of form, if necessary):

# FUNCTION QUESTIONNAIRE

(to be given upon completion of each cockpit configuration)

Subject Number: \_\_\_\_\_

Date: \_\_\_\_\_

Cockpit Configuration (circle one): CONOP CDS / C-141

**Instructions.** Use the scale below to rate how well the cockpit design supports the following tasks. Please provide comments and suggested design alternatives for any item rated "borderline or worse" (i.e., c, d, or e.) Base your responses on your participation in the airland and airdrop simulation missions as well as your operational experience.

**Response Scale:**

- a. **Completely Acceptable:** Good design as is
- b. **Moderately Acceptable:** Minor design deficiencies that do not impact pilot performance.
- c. **Borderline:** Design deficiencies that could impact pilot performance; changes desirable.
- d. **Moderately Unacceptable:** Design deficiencies that will degrade pilot performance; corrections required.
- e. **Completely Unacceptable:** Design does not provide intended function, or design deficiencies result in mission failure, redesign required.

**Comments:**

---

## 1. BASIC INSTRUMENT FLIGHT TASKS

- a) \_\_\_\_ Determine ground track
- b) \_\_\_\_ Determine pitch
- c) \_\_\_\_ Determine aircraft bank
- d) \_\_\_\_ Determine vertical velocity
- e) \_\_\_\_ Determine heading
- f) \_\_\_\_ Acquire airspeed trend information
- g) \_\_\_\_ Acquire altitude trend information
- h) \_\_\_\_ Capture/Maintain altitude
- i) \_\_\_\_ Capture/Maintain airspeed
- j) \_\_\_\_ Capture/Maintain heading
- k) \_\_\_\_ Overall basic flight instrument tasks

## 2. NAVIGATION TASKS

- a) \_\_\_\_ Fly a Standard Instrument Departure (SID)
- b) \_\_\_\_ Assign Navaids to Bearing Pointers
- c) \_\_\_\_ Select flight director modes
- d) \_\_\_\_ Verify flight director modes
- e) \_\_\_\_ Set heading and command markers
- f) \_\_\_\_ Navigate using INS
- g) \_\_\_\_ Navigate using radio-based Navaids
- h) \_\_\_\_ Acquire and maintain course
- i) \_\_\_\_ Verify navigation set-up
- j) \_\_\_\_ Weather avoidance
- k) \_\_\_\_ Selection and control of map ranges
- l) \_\_\_\_ Overall navigation tasks

**Response Scale:**

- a. Completely Acceptable:** Good design as is
- b. Moderately Acceptable:** Minor design deficiencies that do not impact pilot performance.
- c. Borderline:** Design deficiencies that could impact pilot performance; changes desirable.
- d. Moderately Unacceptable:** Design deficiencies that will degrade pilot performance; corrections required.
- e. Completely Unacceptable:** Design does not provide intended function, or design deficiencies result in mission failure, redesign required.

**Comments:**

---

**3. SKE TASKS**

- a) \_\_\_\_ Selection and Control of SKE information
- b) \_\_\_\_ Activation of SKE system
- c) \_\_\_\_ Fly formation using SKE
- d) \_\_\_\_ Overall SKE tasks

**4. APPROACH TASKS**

- a) \_\_\_\_ Fly an ILS approach
- b) \_\_\_\_ Fly a NDB approach
- c) \_\_\_\_ Fly a CAT II approach
- d) \_\_\_\_ Fly a TACAN approach
- e) \_\_\_\_ Overall Approach tasks

**5. OTHER TASKS**

- a) \_\_\_\_ Maintain situational awareness throughout mission
- b) \_\_\_\_ Configuring displays
- c) \_\_\_\_ Performing efficient instrument cross-check
- d) \_\_\_\_ Managing cockpit displays/controls in low workload conditions
- e) \_\_\_\_ Managing cockpit displays/controls in high workload conditions
- f) \_\_\_\_ This cockpit configuration can be used with an acceptable level of safety in a standard operational environment.

Additional Space for Comments:

6. Do you feel that this display configuration can effectively support requirements of the following missions?

|                    | YES   | NO    | IF NO, WHY? |
|--------------------|-------|-------|-------------|
| SOLL 2             | _____ | _____ | _____       |
| CAT II Approach    | _____ | _____ | _____       |
| Air Refueling      | _____ | _____ | _____       |
| Airdrop            | _____ | _____ | _____       |
| Airland            | _____ | _____ | _____       |
| Low Level Tactical | _____ | _____ | _____       |
| Extended Missions  | _____ | _____ | _____       |
| Other _____        | _____ | _____ | _____       |

7. Are there any emergency conditions that you have encountered in your operational experience that will not be effectively supported with this configuration?

\_\_\_\_\_ YES      \_\_\_\_\_ NO

If YES, what are they?

8. Did you experience any problems or think you would have difficulty using this cockpit configuration in normal conditions?

\_\_\_\_\_ YES      \_\_\_\_\_ NO

If YES, please explain.

9. Did you experience any problems or think you would have any difficulty using this cockpit configuration in high workload conditions?

\_\_\_\_\_ YES      \_\_\_\_\_ NO

If YES, please explain.

10. What specific design characteristics were particularly helpful in accomplishing the missions?

11. What specific design characteristics were hard to use and increased workload?

12. What design changes would you make to this cockpit configuration?

Required:

Desired:

## CONOP CDS CONFIGURATION QUESTIONNAIRE

(to be given after both missions are completed with the CONOP CDS configuration)

The following questions focus on the CONOP Control/Display System (CDS). There are 4 sections to this questionnaire: Section 1 contains questions relating to the Primary Flight Display (PFD), Section 2 contains questions relating to the Secondary Flight Display (SFD), Section 3 contains questions relating to the Display Avionics Management Unit (DAMU) and Section 4 contains several questions relating to other control panels. Please enter subject number and date at the beginning of each section.

### SECTION 1 - Primary Flight Display (PFD)

Subject Number: \_\_\_\_\_

Date: \_\_\_\_\_

**Instructions.** This section focuses on symbology design and mechanization for the CONOP PFD format. Rate each item using the scale below by entering the appropriate letter in the blank beside each question. Please provide comments and any suggestions for design changes for any item rated as "borderline" or worse (i.e., c, d, or e).

#### Response Scale:

- a. **Completely Acceptable:** Good design as is.
- b. **Moderately Acceptable:** Minor design deficiencies that do not impact pilot performance.
- c. **Borderline:** Design deficiencies that could impact pilot performance; changes desirable.
- d. **Moderately Unacceptable:** Design deficiencies that will degrade pilot performance; corrections required.
- e. **Completely Unacceptable:** Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

#### 1. Attitude Direction Indicator (ADI)

Comments:

- 
- a) \_\_\_\_\_ Size of ADI
  - b) \_\_\_\_\_ Pitch Scale Design (scaling, precision, labels, bendy bars)
  - c) \_\_\_\_\_ Miniature Aircraft Symbol Design
  - d) \_\_\_\_\_ ADI field-of-view
  - e) \_\_\_\_\_ Climb Dive Marker design / mechanization (size, color, shape, movement, etc)
  - f) \_\_\_\_\_ Design of bank scales and pointers (precision, range, symbols, etc.)
  - g) \_\_\_\_\_ Design of pitch and bank steering bars (length, color, width, etc)
  - h) \_\_\_\_\_ Font sizes on the ADI
  - i) \_\_\_\_\_ Degree of clutter on the ADI
  - j) \_\_\_\_\_ Color coding usage
  - k) \_\_\_\_\_ Overall ADI design / mechanization
  - l) \_\_\_\_\_ Presentation of SKE information
  - m) \_\_\_\_\_ Other (specify)

## 2. Horizontal Situation Indicator (HSI)

Comments:

- 
- a) \_\_\_\_\_ Size of HSI
  - b) \_\_\_\_\_ HSI Scale design (tics, labels, etc)
  - c) \_\_\_\_\_ Aircraft symbol design
  - d) \_\_\_\_\_ Heading marker design / mechanization
  - e) \_\_\_\_\_ Heading diamond and track cross design / mechanization
  - f) \_\_\_\_\_ Course readout presentation and placement
  - g) \_\_\_\_\_ Bearing Pointer Identifier information presentation and placement
  - h) \_\_\_\_\_ Distance presentation and placement
  - i) \_\_\_\_\_ Degree of clutter on the HSI
  - j) \_\_\_\_\_ Color coding usage
  - k) \_\_\_\_\_ Overall HSI design / mechanization
  - l) \_\_\_\_\_ Other (specify)

## 3. Altitude Indicator / Vertical Velocity Indicator (VVI)

Comments:

- 
- a) \_\_\_\_\_ Commanded altitude presentation (bow tie)
  - b) \_\_\_\_\_ Radar altitude presentations
  - c) \_\_\_\_\_ Altitude Indicator scale design / mechanization
  - d) \_\_\_\_\_ Alert altitude readout presentation and placement
  - e) \_\_\_\_\_ Background shading and contrast of the altitude tape and scale markings
  - f) \_\_\_\_\_ Digital Altitude Readout presentation
  - g) \_\_\_\_\_ Meters mode design / mechanization
  - h) \_\_\_\_\_ Overall altitude indicator and tape design / mechanization
  - i) \_\_\_\_\_ Overall VVI design / mechanization
  - j) \_\_\_\_\_ Other (specify)

## 4. Airspeed Indicator

Comments:

- 
- a) \_\_\_\_\_ Digital readout design / mechanization
  - b) \_\_\_\_\_ Airspeed scale design / mechanization
  - c) \_\_\_\_\_ Mach information presentation and placement
  - d) \_\_\_\_\_ Commanded airspeed (bow tie) presentation
  - e) \_\_\_\_\_ Background shading and contrast of airspeed tape and scale markings
  - f) \_\_\_\_\_ Overall airspeed indicator design / mechanization
  - g) \_\_\_\_\_ Other (specify)

## 5. Overall PFD Format

**Comments:**

- 
- a) \_\_\_\_\_ Arrangement of primary flight display components (HSI, Altimeter, Airspeed Scale, VVI, ADI ball)
  - b) \_\_\_\_\_ Discriminability of individual symbols / information
  - c) \_\_\_\_\_ Overall level of clutter on the PFD
  - d) \_\_\_\_\_ Status Annunciations design / mechanization
  - e) \_\_\_\_\_ Symbol and character sizes
  - f) \_\_\_\_\_ Color usage on the PFD
  - g) \_\_\_\_\_ Overall PFD design and mechanization
  - h) \_\_\_\_\_ Other (specify)

Comments or suggestions for design improvement (please use back of form for additional space)

## SECTION 2 - Secondary Flight Display (SFD)

Subject Number: \_\_\_\_\_

Date: \_\_\_\_\_

**Instructions.** This section focuses on symbology design and mechanization for the CONOP SFD format. Rate each item using the scale below by entering the appropriate letter in the blank beside each question. Please provide comments and any suggestions for design changes for any item rated as "borderline" or worse (i.e., c, d, or e). If the question requires a written response, please be as detailed as possible.

### Response Scale:

- a. **Completely Acceptable:** Good design as is.
- b. **Moderately Acceptable:** Minor design deficiencies that do not impact pilot performance.
- c. **Borderline:** Design deficiencies that could impact pilot performance; changes desirable.
- d. **Moderately Unacceptable:** Design deficiencies that will degrade pilot performance; corrections required.
- e. **Completely Unacceptable:** Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

### 1. General (common to all formats)

Comments: \_\_\_\_\_

- 
- a) \_\_\_\_\_ True Airspeed (TAS) presentation
  - b) \_\_\_\_\_ Ground Speed presentation
  - c) \_\_\_\_\_ Cross Track Readout presentation
  - d) \_\_\_\_\_ Drift angle / wind direction & speed presentation
  - e) \_\_\_\_\_ Altitude readout presentation
  - f) \_\_\_\_\_ Static Air Temperature (SAT) presentation
  - g) \_\_\_\_\_ FAIL / SFD and PFD Repeat annunciators presentation
  - h) \_\_\_\_\_ Other (specify) \_\_\_\_\_

### 2. HSI Format

Comments: \_\_\_\_\_

- 
- a) \_\_\_\_\_ Size of the Expanded HSI
  - b) \_\_\_\_\_ Bearing Pointers Identifier / Range Information presentation
  - c) \_\_\_\_\_ Digital Course / Heading Set Readout presentation
  - d) \_\_\_\_\_ Degree of clutter on expanded HSI
  - e) \_\_\_\_\_ Color coding usage
  - f) \_\_\_\_\_ Overall Expanded HSI design
  - g) \_\_\_\_\_ Other (specify) \_\_\_\_\_



h) Is there any unnecessary or inappropriate data presented that you would take off the HSI format?

\_\_\_\_\_ YES \_\_\_\_\_ NO

If YES, what data?

i) Would you add anything to the HSI format?

\_\_\_\_\_ YES \_\_\_\_\_ NO

If YES, what would you add and where would you put it? (please use back of form if necessary)

j) Other comments (please use back of form for additional space)

### 3. MAP Format

**Comments:**

- 
- a) \_\_\_\_\_ Size of MAP-partial compass display
  - b) \_\_\_\_\_ Estimated Time Enroute/Arrival (ETE / ETA) Information presentation
  - c) \_\_\_\_\_ Radar Range Rings/ Labels design / mechanization
  - d) \_\_\_\_\_ Fixed Aircraft Symbol presentation
  - e) \_\_\_\_\_ Radar Overlay (color video) design / mechanization
  - f) \_\_\_\_\_ TACAN / Normal Waypoints presentation
  - g) \_\_\_\_\_ Presentation of Course Lines and Readout
  - h) \_\_\_\_\_ Heading Set Marker design / mechanization
  - i) \_\_\_\_\_ Bearing Pointers design / mechanization
  - j) \_\_\_\_\_ Bearing Pointer 1 Identifier / Range Information presentation and placement
  - k) \_\_\_\_\_ Heading diamond / Track cross design
  - l) \_\_\_\_\_ Degree of clutter on the MAP display
  - m) \_\_\_\_\_ Color coding usage
  - n) \_\_\_\_\_ Overall SFD MAP design
  - o) \_\_\_\_\_ Other (specify)

p) Is there any unnecessary or inappropriate data presented that you would take off the MAP format?

\_\_\_\_\_ YES \_\_\_\_\_ NO

If YES, what data?

q) Would you add anything to the MAP format?

\_\_\_\_\_ YES \_\_\_\_\_ NO

If YES, what would you add and where would you put it? (Use back of form if necessary)

r) Other Comments: (Use back of form if necessary)

#### 4. SKE Format

Comments:

- 
- a) ☐ Size of the SKE display
  - b) ☐ Reference modes (SKE-Center, SKE-up, SKE-down) presentation
  - c) ☐ Estimated Time Enroute / Arrival (ETE/ETA) presentation
  - d) ☐ SKE Zone Marker (ZM) design / mechanization
  - e) ☐ SKE Range Readout and Range Rings design
  - f) ☐ Presentation of standard SKE symbology (e.g., master ship / ownship / follower symbols. etc.)
  - g) ☐ Presentation of Master / Master Lost Annunciators
  - h) ☐ Presentation of Proximity Warning Annunciator and Line
  - i) ☐ Presentation of SKE Caution Annunciator
  - j) ☐ Presentation of SKE Test Annunciator
  - k) ☐ Presentation of SKE / NO SKE data annunciators
  - l) ☐ Degree of clutter on the SKE display
  - m) ☐ Color coding usage
  - n) ☐ Overall SFD SKE format design
  - o) ☐ Other (specify) \_\_\_\_\_

- p) Is there any unnecessary or inappropriate data presented that you would take off the SKE format?

☐ YES ☐ NO

If YES, what data?

- q) Would you add anything to the SKE format?

☐ YES ☐ NO

If YES, what would you add and where would you put it? (Use back of form if necessary)

- r) Other Comments: (Use back of form if necessary)

### SECTION 3 - Display Avionics Management Unit (DAMU)

Subject Number: \_\_\_\_\_

Date: \_\_\_\_\_

**Instructions:** The following questions focus on the DAMU menu system. There are several rating scales used in this section. For each question, please enter your rating in the space provided and provide comments for those ratings where comments are requested. If the question requires a written response, please be as detailed as possible.

For the following rating scale, please comment on any rating that is borderline or below (i.e., c, d or e).

**Rating Scale:**

- a. **Completely Acceptable:** Good design as is.
- b. **Moderately Acceptable:** Minor design deficiencies that do not impact pilot performance.
- c. **Borderline:** Design deficiencies that could impact pilot performance; changes desirable.
- d. **Moderately Unacceptable:** Design deficiencies that will degrade pilot performance; corrections required.
- e. **Completely Unacceptable:** Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

**Comments:**

- 
- a) \_\_\_\_\_ Understandability and clarity of the menu page titles
  - b) \_\_\_\_\_ Overall operational utility of the DAMU Menu System
  - c) \_\_\_\_\_ Understandability and ease of use of NAV SELECT Menu options
  - d) \_\_\_\_\_ Understandability and ease of use of SFD Menu options
  - e) \_\_\_\_\_ Understandability and ease of use of PFD Menu options
  - f) \_\_\_\_\_ Understandability and ease of use of DISPLAY CONTROL Menu options
  - g) \_\_\_\_\_ Ease of accessing the other crew member's DAMU displays/controls/
  - h) \_\_\_\_\_ Ease of interpreting and implementing SKE related-options

Use this rating scale for Questions i-l. Please comment in the space provided below each question if the rating is Sometimes or Never (i.e., c or d).

- a. **Always**
- b. **Usually**
- c. **Sometimes**
- d. **Never**

- i) \_\_\_\_\_ Did you "get lost" navigating through the menu system?
- j) \_\_\_\_\_ Are options where you expected them to be in the menu structure?

k) \_\_\_\_\_ Does the design degrade your ability to perform your tasks?

l) \_\_\_\_\_ Did you understand the functions being accomplished by the different menu options?

Use the following scale for Questions m-p. If answered "d" or "e", please comment in the space provided below each question.

**a. Strongly Agree**

**b. Moderately Agree**

**d. Moderately Disagree**

**e. Strongly Disagree**

m) \_\_\_\_\_ No design changes are needed to the DAMU before it is suitable for installation into the C-141.

n) \_\_\_\_\_ The DAMU can be used in an operational environment with an acceptable level of safety

o) \_\_\_\_\_ The DAMU will effectively support all operational mission requirements.

Please recommend any improvements to the current menu design that you feel would improve efficiency and reduce workload.

## SECTION 4 - CONTROL PANELS

Subject Number: \_\_\_\_\_

Date: \_\_\_\_\_

Consider the responses to the following as integrating with other components of the CDS.

**Response Scale:**

- a. **Completely Acceptable:** Good design as is.
- b. **Moderately Acceptable:** Minor design deficiencies that do not impact pilot performance.
- c. **Borderline:** Design deficiencies that could impact pilot performance; changes desirable.
- d. **Moderately Unacceptable:** Design deficiencies that will degrade pilot performance; corrections required.
- e. **Completely Unacceptable:** Design does not provide intended function, or design deficiencies result in mission failure; redesign required.

**Comments:**

- 
- a) \_\_\_\_\_ Mode Select Panel Design / Mechanization
  - b) \_\_\_\_\_ Radar Altimeter Design / Mechanization
  - c) \_\_\_\_\_ Overall Reference Set Panel Design / Mechanization
  - d) \_\_\_\_\_ Ease of setting commanded altitude and altitude alert
  - e) \_\_\_\_\_ Ease of setting heading marker
  - f) \_\_\_\_\_ Ease of setting course marker

# FINAL QUESTIONNAIRE

(to be given upon completion of all 4 missions)

Subject Number: \_\_\_\_\_

Date: \_\_\_\_\_

1. Indicate your preference for either the CONOP CDS design or the C-141 Design for the following items.

|  | Strongly<br>Prefer<br>CDS | Moderately<br>Prefer<br>CDS | No<br>Preference | Moderately<br>Prefer<br>C-141 | Strongly<br>Prefer<br>C-141 |
|--|---------------------------|-----------------------------|------------------|-------------------------------|-----------------------------|
| a) ADI                                     |                           |                             |                  |                               |                             |
| b) HSI                                     |                           |                             |                  |                               |                             |
| c) Altimeter                               |                           |                             |                  |                               |                             |
| d) Airspeed Indicator                      |                           |                             |                  |                               |                             |
| e) Altitude Indicator                      |                           |                             |                  |                               |                             |
| f) VVI                                     |                           |                             |                  |                               |                             |
| g) MACH Indicator                          |                           |                             |                  |                               |                             |
| h) SKE Format                              |                           |                             |                  |                               |                             |
| i) Map Format                              |                           |                             |                  |                               |                             |
| j) Radar Overlay                           |                           |                             |                  |                               |                             |
| k) SKE range, altitude, crosscheck display |                           |                             |                  |                               |                             |
| l) General Control Interface               |                           |                             |                  |                               |                             |
| m) Placement/Arrangement of Controls       |                           |                             |                  |                               |                             |
| n) Overall Design                          |                           |                             |                  |                               |                             |

Comments (for above items):

2. Is the CONOP CDS "as good as" the C-141 in meeting operational requirements?

\_\_\_\_\_ YES      \_\_\_\_\_ NO

If NO, please explain.

3. For the novice pilot, what training requirements do you feel would be needed?

4. For the average pilot, what training requirements do you feel would be needed?

5. For the experienced pilot, what training requirements do you feel would be needed?

6. Indicate the acceptability/unacceptability of the following cockpit features using the following rating scale:

- a. **Completely Acceptable:** Good design as is.
- b. **Moderately Acceptable:** Minor design deficiencies that do not impact pilot performance.
- c. **Borderline:** Design deficiencies that could impact pilot performance; changes desirable.
- d. **Moderately Unacceptable:** Design deficiencies that will degrade pilot performance; corrections required.
- e. **Completely Unacceptable:** Design does not provide intended function, or design deficiencies result in mission failure; redesign required

- a) \_\_\_\_\_ Placement of displays
- b) \_\_\_\_\_ Throttle characteristics
- c) \_\_\_\_\_ Flight Characteristics
- d) \_\_\_\_\_ Engine Displays
- e) \_\_\_\_\_ Reference Set Panel
- f) \_\_\_\_\_ Mode Select Panel
- g) \_\_\_\_\_ (C-141 only) NAV SEL Panel
- h) \_\_\_\_\_ (C-141 only) ADI Select and Air Delivery Switch
- i) \_\_\_\_\_ Legibility of Displays
- j) \_\_\_\_\_ Overall cockpit geometry

7. What factors, besides display formats, contributed to your workload during simulation flight?

8. Do you feel you were able to adapt to the simulator aeromodel?

\_\_\_\_\_ YES      \_\_\_\_\_ NO

If NO, please comment.

9. Any other comments on the study or the CDS?

## SWORD QUESTIONNAIRE INSTRUCTIONS

The SWORD technique assesses workload by utilizing a series of pairwise comparisons between various system configurations. For this study, system configurations consist of combinations of three cockpit configurations and three task types. The cockpit configurations are: 1) CONOP CDS, 2) Simulated C-141, and 3) Real World C-141. The tasks are: 1) NAV - selection of a primary Bearing Pointers / Nav aids and use of the HSI (use of the NAV SELECT page or panel), 2) FLY - use of primary flight instruments and 3) SKE - use of SKE instruments and flight navigation.

Making comparison judgments for some design/task configurations may seem unnatural. However, it is imperative for analysis purposes, that you rate to the best of your ability the design/task configuration that you think will cause higher workload. Base your responses on hands-on experience, tasks you have performed during testing, and operational experience.

The following examples compare workload between one or two task types: 1) assigning a navigational source to a primary bearing pointer (NAV) and 2) use of primary flight instruments (FLY) combined with one of three cockpit configurations (CONOP, SIM C-141, C141).

**Example 1-** shows that the NAV task causes *substantially more workload* than the FLY task utilizing CONOP cockpit configuration.

>>>>      >>>      >>      >      <      <<      <<<      <<<<

**EQUAL**

CONOP- NAV √    \_    \_    \_    \_    \_    \_    \_    |    \_    \_    \_    \_    \_    \_    \_    CONOP - FLY

**Example 2 -** shows that the NAV task causes *moderately more workload* for the CONOP cockpit configuration than for the C-141 cockpit configuration.

>>>>      >>>      >>      >      <      <<      <<<      <<<<

**EQUAL**

CONOP - NAV    \_    \_    \_    \_    √    \_    \_    \_    |    \_    \_    \_    \_    \_    \_    C-141- NAV

**Example 3-** shows that the FLY task utilizing the C-141 configuration causes *slightly more workload* than the NAV task utilizing the CONOP configuration.

>>>>      >>>      >>      >      <      <<      <<<      <<<<

**EQUAL**

CONOP- NAV    \_    \_    \_    \_    √    \_    \_    \_    |    \_    \_    \_    \_    \_    \_    C-141 - FLY

**Example 4-** shows that the NAV task utilizing the CONOP configuration and the FLY task utilizing the C-141 configuration caused an *equal* amount of workload.

>>>>      >>>      >>      >      <      <<      <<<      <<<<

**EQUAL**

CONOP- NAV    \_    \_    \_    \_    \_    \_    |    √    \_    \_    \_    \_    \_    \_    C-141 - FLY



## EXAMPLES OF SWORD FORMS

SUBJECT # \_\_\_\_\_

1

**Which Cockpit Configuration / Function is more difficult to use?**

|             | >>>> | >>> | >>  | >   | EQUAL | <   | <<  | <<< | <<<< |                    |
|-------------|------|-----|-----|-----|-------|-----|-----|-----|------|--------------------|
| CONOP - NAV | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | CONOP - FLY        |
| CONOP - NAV | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | CONOP - SKE        |
| CONOP - NAV | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | SIM C-141 - NAV    |
| CONOP - NAV | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | SIM C-141 - FLYING |
| CONOP - NAV | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | SIM C-141 - SKE    |
| CONOP - NAV | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | C-141 - NAV        |
| CONOP - NAV | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | C-141 - FLYING     |
| CONOP - NAV | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | C-141 - SKE        |
| CONOP - FLY | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | CONOP - SKE        |
| CONOP - FLY | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | SIM C-141 - NAV    |
| CONOP - FLY | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | SIM C-141 - FLYING |
| CONOP - FLY | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | SIM C-141 - SKE    |
| CONOP - FLY | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | C-141 - NAV        |
| CONOP - FLY | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | C-141 - FLYING     |
| CONOP - FLY | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | C-141 - SKE        |

**COCKPIT CONFIGURATION:**  
CONOP  
SIM C-141  
C-141

**FUNCTION:**  
NAV = Selection of Bearing Pointers / Navsids and use of HSI  
Fly = Use of Primary Flight Instruments  
SKE = Use of SKE Instruments and Flight Information

SUBJECT # \_\_\_\_\_

2

**Which Cockpit configuration / Function is more difficult to use?**

|                 | >>>> | >>> | >>  | >   | EQUAL | <   | <<  | <<< | <<<< |                 |
|-----------------|------|-----|-----|-----|-------|-----|-----|-----|------|-----------------|
| CONOP - SKE     | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | SIM C-141 - NAV |
| CONOP - SKE     | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | SIM C-141 - FLY |
| CONOP - SKE     | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | SIM C-141 - SKE |
| CONOP - SKE     | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | C-141 - NAV     |
| CONOP - SKE     | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | C-141 - FLY     |
| CONOP - SKE     | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | C-141 - SKE     |
| SIM C-141 - NAV | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | SIM C-141 - FLY |
| SIM C-141 - NAV | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | SIM C-141 - SKE |
| SIM C-141 - NAV | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | C-141 - NAV     |
| SIM C-141 - NAV | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | C-141 - FLY     |
| SIM C-141 - NAV | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | C-141 - SKE     |
| SIM C-141 - FLY | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | SIM C-141 - SKE |
| SIM C-141 - FLY | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | C-141 - NAV     |
| SIM C-141 - FLY | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | C-141 - FLY     |
| SIM C-141 - FLY | ___  | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  | C-141 - SKE     |

**COCKPIT CONFIGURATION:**  
CONOP  
SIM C-141  
C-141

**FUNCTION:**  
NAV = Selection of Bearing Pointers / Navsids and use of HSI  
Fly = Use of Primary Flight Instruments  
SKE = Use of SKE Instruments and Flight Information

SUBJECT # \_\_\_\_\_

3

**Which Cockpit Configuration / Function is more difficult to use?**

|                 |     |     |     | >   | EQUAL | <   | <<  | <<< | <<<< |
|-----------------|-----|-----|-----|-----|-------|-----|-----|-----|------|
| SIM C-141 - SKE | ___ | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  |
| C-141 - NAV     | ___ | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  |
| SIM C-141 - SKE | ___ | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  |
| C-141 - FLY     | ___ | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  |
| SIM C-141 - SKE | ___ | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  |
| C-141 - SKE     | ___ | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  |
| C-141 - NAV     | ___ | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  |
| C-141 - FLY     | ___ | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  |
| C-141 - NAV     | ___ | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  |
| C-141 - SKE     | ___ | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  |
| C-141 - FLY     | ___ | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  |
| C-141 - SKE     | ___ | ___ | ___ | ___ | ___   | ___ | ___ | ___ | ___  |

**COCKPIT CONFIGURATION:**  
 CONOP  
 SIM C-141  
 C-141

**FUNCTION:**  
 NAV = Selection of Bearing Pointers / Nav aids and use of HSI  
 Fly = Use of Primary Flight Instruments  
 SKE = Use of SKE Instruments and Flight Information

**APPENDIX D**  
**QUESTIONNAIRE RESPONSE RATINGS AND COMMENTS**

## CONFIGURATION QUESTIONNAIRE RESPONSES

|  | C-141 MEAN | FREQUENCY |   |   |   |   | CDS MEAN | FREQUENCY |   |   |   |   |
|--|------------|-----------|---|---|---|---|----------|-----------|---|---|---|---|
|  |            | 5         | 4 | 3 | 2 | 1 |          | 5         | 4 | 3 | 2 | 1 |
| <b>1. Basic Instrument Flight Tasks</b>        |            |           |   |   |   |   |          |           |   |   |   |   |
| A. Ground track                                | 4.08       | 6         | 2 | 3 | 1 | 0 | 4.67     | 9         | 2 | 1 | 0 | 0 |
| B. Pitch                                       | 4.83       | 10        | 2 | 0 | 0 | 0 | 4.58     | 9         | 1 | 2 | 0 | 0 |
| C. Aircraft bank                               | 5.00       | 12        | 0 | 0 | 0 | 0 | 4.58     | 8         | 3 | 1 | 0 | 0 |
| D. Vertical velocity                           | 4.75       | 9         | 3 | 0 | 0 | 0 | 4.58     | 7         | 5 | 0 | 0 | 0 |
| E. Heading                                     | 4.75       | 10        | 1 | 1 | 0 | 0 | 4.83     | 10        | 2 | 0 | 0 | 0 |
| F. Airspeed trend info                         | 4.17       | 8         | 1 | 1 | 1 | 1 | 4.42     | 8         | 2 | 1 | 1 | 0 |
| G. Altitude trend info                         | 4.58       | 8         | 3 | 1 | 0 | 0 | 4.58     | 9         | 2 | 0 | 1 | 0 |
| H. Capture / maintain altitude                 | 4.58       | 9         | 1 | 2 | 0 | 0 | 4.33     | 7         | 2 | 3 | 0 | 0 |
| I. Capture / maintain airspeed                 | 4.75       | 9         | 3 | 0 | 0 | 0 | 4.50     | 8         | 2 | 2 | 0 | 0 |
| J. Capture / maintain heading                  | 4.83       | 10        | 2 | 0 | 0 | 0 | 5.00     | 12        | 0 | 0 | 0 | 0 |
| K. Overall instrument flight tasks             | 4.58       | 8         | 3 | 1 | 0 | 0 | 4.58     | 8         | 3 | 1 | 0 | 0 |
| <b>2. Navigation Tasks</b>                     |            |           |   |   |   |   |          |           |   |   |   |   |
|  | C-141 MEAN | FREQUENCY |   |   |   |   | CDS MEAN | FREQUENCY |   |   |   |   |
|  |            | 5         | 4 | 3 | 2 | 1 |          | 5         | 4 | 3 | 2 | 1 |
| A. SID   | 4.50       | 7         | 4 | 1 | 0 | 0 | 4.83     | 10        | 2 | 0 | 0 | 0 |
| B. Nav aids to bearing pointer                 | 3.92       | 5         | 3 | 2 | 2 | 0 | 5.00     | 12        | 0 | 0 | 0 | 0 |
| C. Select flight director modes                | 4.83       | 10        | 2 | 0 | 0 | 0 | 4.83     | 10        | 2 | 0 | 0 | 0 |
| D. Verify flight director modes                | 4.83       | 10        | 2 | 0 | 0 | 0 | 5.00     | 12        | 0 | 0 | 0 | 0 |
| E. Set heading & command markers               | 4.83       | 10        | 2 | 0 | 0 | 0 | 3.92     | 6         | 3 | 1 | 0 | 2 |
| F. Navigate using INS                          | 4.75       | 9         | 3 | 0 | 0 | 0 | 4.83     | 11        | 0 | 1 | 0 | 0 |
| G. Navigate using radio-based nav aids         | 4.42       | 8         | 2 | 1 | 1 | 0 | 4.92     | 11        | 1 | 0 | 0 | 0 |
| H. Acquire and maintain course                 | 4.83       | 10        | 2 | 0 | 0 | 0 | 4.75     | 10        | 1 | 1 | 0 | 0 |
| I. Verify navigation set-up                    | 4.67       | 9         | 2 | 1 | 0 | 0 | 4.92     | 11        | 1 | 0 | 0 | 0 |
| J. Weather avoidance                           | 4.50       | 8         | 2 | 2 | 0 | 0 | 5.00     | 12        | 0 | 0 | 0 | 0 |
| K. Selection and control of map ranges         | 4.75       | 9         | 3 | 0 | 0 | 0 | 4.92     | 11        | 1 | 0 | 0 | 0 |
| L. Overall navigation tasks                    | 4.58       | 8         | 3 | 1 | 0 | 0 | 4.75     | 9         | 3 | 0 | 0 | 0 |
| <b>3. SKE Tasks</b>                            |            |           |   |   |   |   |          |           |   |   |   |   |
|  | C-141 MEAN | FREQUENCY |   |   |   |   | CDS MEAN | FREQUENCY |   |   |   |   |
|  |            | 5         | 4 | 3 | 2 | 1 |          | 5         | 4 | 3 | 2 | 1 |
| A. Selection and control of SKE info           | 4.42       | 7         | 3 | 2 | 0 | 0 | 4.58     | 8         | 3 | 1 | 0 | 0 |
| B. Activation of SKE system                    | 4.42       | 7         | 3 | 2 | 0 | 0 | 4.67     | 11        | 0 | 0 | 0 | 1 |
| C. Fly formation using SKE                     | 3.42       | 3         | 2 | 4 | 3 | 0 | 4.33     | 7         | 2 | 3 | 0 | 0 |
| D. Overall SKE                                 | 4.00       | 2         | 8 | 2 | 0 | 0 | 4.73     | 8         | 3 | 0 | 0 | 0 |
| <b>4. Approach Tasks</b>                       |            |           |   |   |   |   |          |           |   |   |   |   |
|  | C-141 MEAN | FREQUENCY |   |   |   |   | CDS MEAN | FREQUENCY |   |   |   |   |
|  |            | 5         | 4 | 3 | 2 | 1 |          | 5         | 4 | 3 | 2 | 1 |
| A. ILS approach                                | 4.92       | 11        | 1 | 0 | 0 | 0 | 4.75     | 10        | 1 | 1 | 0 | 0 |
| B. NDB approach                                | 3.58       | 3         | 2 | 6 | 1 | 0 | 4.92     | 11        | 1 | 0 | 0 | 0 |
| C. CATII approach                              | 4.80       | 8         | 2 | 0 | 0 | 0 | 5.00     | 7         | 0 | 0 | 0 | 0 |
| D. TACAN approach                              | 4.92       | 11        | 1 | 0 | 0 | 0 | 5.00     | 11        | 0 | 0 | 0 | 0 |
| E. Overall approach tasks                      | 4.50       | 7         | 4 | 1 | 0 | 0 | 5.00     | 12        | 0 | 0 | 0 | 0 |
| <b>5. Other Tasks</b>                          |            |           |   |   |   |   |          |           |   |   |   |   |
|  | C-141 MEAN | FREQUENCY |   |   |   |   | CDS MEAN | FREQUENCY |   |   |   |   |
|  |            | 5         | 4 | 3 | 2 | 1 |          | 5         | 4 | 3 | 2 | 1 |
| A. Situational awareness                       | 4.50       | 8         | 2 | 2 | 0 | 0 | 5.00     | 12        | 0 | 0 | 0 | 0 |
| B. Configuring displays                        | 4.58       | 9         | 1 | 2 | 0 | 0 | 4.83     | 10        | 2 | 0 | 0 | 0 |
| C. Efficient cross-check                       | 3.67       | 3         | 2 | 7 | 0 | 0 | 4.75     | 9         | 3 | 0 | 0 | 0 |
| D. Managing displays/controls in low workload  | 4.75       | 9         | 3 | 0 | 0 | 0 | 5.00     | 12        | 0 | 0 | 0 | 0 |
| E. Managing displays/controls in high workload | 4.42       | 6         | 5 | 1 | 0 | 0 | 4.42     | 6         | 5 | 1 | 0 | 0 |
| F. Acceptable level of safety                  | 4.42       | 7         | 4 | 0 | 1 | 0 | 4.67     | 10        | 1 | 0 | 1 | 0 |

| 5. Display Configuration Effectively<br>Support the Following: | C-141 MEAN | FREQUENCY |  |   |  | CDS MEAN | FREQUENCY |  |   |  |
|--|------------|-----------|--|---|--|----------|-----------|--|---|--|
|  |            | Y         |  | N |  |          | Y         |  | N |  |
| SOLL 2   |            | 5         |  | 2 |  |          | 6         |  | 1 |  |
| CATII  |            | 12        |  | 0 |  |          | 11        |  | 0 |  |
| Air refueling  |            | 12        |  | 0 |  |          | 12        |  | 0 |  |
| Airdrop  |            | 11        |  | 1 |  |          | 10        |  | 1 |  |
| Airland  |            | 12        |  | 0 |  |          | 12        |  | 0 |  |
| Low level tactical   |            | 12        |  | 0 |  |          | 12        |  | 0 |  |
| Extended mission   |            | 12        |  | 0 |  |          | 12        |  | 0 |  |

## **C-141 CONFIGURATION: Open-Ended Question Responses & Comments**

6. Do you feel that this display configuration can effectively support requirements of the following missions? If no, Why?

Other:

**Subject 9:** the system has proven itself capable of performing the above missions however, there is always room for improvement.

**Subject 12:** pathfinder.

7. Are there any emergency conditions that you have encountered in your operational experience that will not be effectively supported with this configuration?

**Subject 7:** dual ADI failure

8. Did you experience any problems or think you would have difficulty using this cockpit configuration in normal conditions?

**Subject 3:** mainly the cross-check deficiencies noted earlier.

**Subject 5:** problems with NDB-only approaches, instrument approaches and departures with cross-tuning of NAVAIDS, switching radios between pilot and co-pilot. Taking your hand off, the steering wheel during taxi to check the ADI selection air delivery switches is borderline unsafe-as it is during the before landing check.

9. Did you experience any problems or think you would have difficulty using this cockpit configuration in high workload conditions?

**Subject 3:** changing command markers requires definite head down use.

**Subject 4:** typical high workload usually involves reprogramming the FSAS. As I stated above it is very much a head-down instrument.

**Subject 5:** during the NDB approach in the WX. The primary NAVAID (ADI for the BDHI) is out of your normal cross-check and pulls essential info like ADI, airspeed, and altitude out of cross-check. BDHI requires too much interpretation for a primary navigation instrument-should be backup only.

**Subject 8:** position of FSAS (heads down display) information.

**Subject 12:** positioning of BDHI with ADI needles must look down to check drift. (especially bad in WX).

10. What specific design characteristics were particularly helpful in accomplishing the missions?

**Subject 1:** the fact that I have flown with this configuration for almost 7 years.

**Subject 2:** INS failure in C-141 was easier to select AHRS than is CONOP

**Subject 3:** NAV select panel was very easy to use.

**Subject 5:** ability to switch NAVAIDS on the NAV select panel almost instantly. Plain, simple format for displays.

**Subject 8:** this config is what I am use to.

**Subject 11:** for airdrop - having a groundtrack mode would make it much easier to fly the proper track across the DZ. Also having all airdrop data represented on a single instrument would make the cross-check easier.

11. What specific design characteristics were hard to use and increased workload?

**Subject 1:** none, I have been using them a long time.

**Subject 2:** NO

**Subject 3:** change the altimeter tapes to an easier read presentation. Bring RRI closer to cross-check.

**Subject 4:** autopilot is also difficult to use/reach the co-pilot.

**Subject 5:** see NDB above, changing radios, navigating off of one radio NAVAID at a time (except BDHI).

**Subject 7:** flying SKE can be hard to fly during critical phases without an autopilot.

**Subject 9:** biggest factor was using the HSI for an NDB approach. I preferred using the CONOP/CDS config, for shooting approaches.

**Subject 10:** switches being spread out.

**Subject 11:** more effort is required to fly formation because of the positions on the different SKE instruments.

**Subject 12:** positioning of BDHI during NDB approach makes a tougher cross-check. Positioning of SKE RRI during airdrop phases makes for tougher cross-check.

12. What design changes would you make to this cockpit configuration?

a) Required:

**Subject 2:** put in the CONOP CDS.

**Subject 4:** none.

**Subject 5:** SKE scope changed to include WX radar, NDB received on HSI, move ADI select a air delivery switch control to a right-handed function which is more head-up.

**Subject 8:** lighting needs to be uniform and each instrument lighted / controlled individually.

**Subject 11:** allow for a size depiction while you retain ability to display WX radar. You really need to see both at the same time. Put all airdrop info on a single display. Make it easier to display groundtrack.

b) Desired:

**Subject 1:** more up to date system, the CDS should make that happen.

**Subject 2:** put in the CONOP CDS

**Subject 5:** SKE scope in front of pilot(s).

**Subject 7:** consolidate SKE cross-check enable coupling of SKE to autopilot.

**Subject 8:** FSAS - didn't like heads down display. HSI - ADF capable.

**Subject 9:** ADF pointers implemented on the HSI. SKE scope in a more favorable viewing position.

**Subject 11:** make it easier to access FSAS info.

**Subject 12:** put RRI above ADI. Be able to use bearing pointer on HSI with NDB's (ADI's).6. Do you feel that this display configuration can effectively support requirements of the following missions:? If no, WHY?

Other:

**Subject 9:** I feel this system would benefit aircrews flying any type of mission.

**Subject 12:** pathfinder.

## **CDS CONFIGURATION: Open-Ended Question Responses & Comments**

7. Are there any emergency conditions that you have encountered in your operational experience that will not be effectively supported with this configuration?

**Subject 5:** loss of electrical power - will the pilots instruments still be fed through the emergency busses? How will this charger affect the electrical fire checklist, loss of all generators, and loss of normal DC power.

**Subject 10:** standby equipment a must (analog).

**Subject 12:** I still would like a normal ADI somewhere as well as needle and ball.(in case of failure where LCD functions are totally lost.)

8. Did you experience any problems or think you would have difficulty using this cockpit configuration in normal conditions?

9. Did you experience any problems or think you would have difficulty using this cockpit configuration in high workload conditions?

**Subject 2:** lack of training. With little practice and training you can master this setup which I believe will cut down workload and make the job easier.

**Subject 5:** design limits on primary display for airspeed, altitude, RRI. Minor problems with VVI and jumbled data with SKE presentation. You could make the airspeed tape smaller by putting the dashes between the numbers, shrinking the window.

**Subject 6:** during high workloads - I took the option of simplifying the info as much as I could - I would turn off PTR#2 and the CDM and ignore/remove from the normal cross-check - info that overloaded the situation.

**Subject 7:** if tasked to do all flying, DAMU control, and radio changes, it would be a lot of work.

**Subject 9:** at this point I don't feel I know the menu flow 100%. Again, given time to use this system anyone should master it.

10. What specific design characteristics were particularly helpful in accomplishing the missions?

**Subject 1:** All information is in the same place, right under my nose. So I did not have to look around to find info. Also having the ability to have 3 power sources for the attitude and heading system (AHRS, INS 1/2). Ability to put more than one display on the HSI, TAC / VOR, at the same time.

**Subject 2:** ADI, airspeed, altitude, and HSI in close proximity of each other. A much easier and quicker cross-check

**Subject 4:** dual pointers, CDM, SKE intrack data very close to the rest of your cross-check.

**Subject 5:** ADF capability on the HSI is tremendous. The SWAP feature is great. Being able to put weather info on the SKE display is awesome. "RED"-out NAVAIDS which aren't working - prevents false course intercept for localizer / glideslope.

**Subject 6:** having the MAP display next to the PFD, having the DAMU up front, having the RSP on the center console, fore/aft reference for SKE on ADI

**Subject 7:** consolidate SKE cross-check, track function is a good function so you know ground track vs. only heading on PFD.

**Subject 8:** enlarged HSI on SFD. CDM.



**Subject 9:** using the SKE SFD made flying an airdrop mission quite comfortable as far as the cross-check. Also, it is nice to still be able to use WX radar at the same time you are using SKE on the SFD.

**Subject 10:** SKE cross-check reduced to a straight line!!

**Subject 11:** having two pointers to assign NAVAIDS. Having ADF available on the HSI. Having a lot more info available on the instrument panels.

**Subject 12:** the SKE setup/presentation is great having the RRI on the ADI makes for a much easier cross-check. I also like being able to pull up a digital true track readout.

11. What specific design characteristics were hard to use and increased workload?

**Subject 1:** SKE range indicator and airspeed indicator

**Subject 2:** DAMU control changing from pilot to co-pilot control and setting his Nav aids for him. With a little hands-on it will probably be pretty easy.

**Subject 3:** the altitude and airspeed markers increased workload.

**Subject 4:** some pages on the DAMU were hard to find.

**Subject 5:** selector knobs too close on HDG, altimeter, and altitude. Wound up adjusting things I didn't want. Activating / deactivating SKE functions during taxi and before landing checks. Overall, too many buttons to push to obtain desired NAVAID changes.

**Subject 6:** the DAMU wasn't necessarily hard to see but at this stage it did increase my workload.

**Subject 7:** DAMU control - mostly had problems due to lack of experience with unit.

**Subject 8:** none.

**Subject 9:** DAMU - just a matter of using it more so response time would increase.

**Subject 10:** command marker toggles.

**Subject 11:** the switch for setting the Heading command marker.

**Subject 12:** lack of experience with DAMU increased some workload some. Bank pointer at top was a bit annoying.

12. What design changes would you make to this cockpit configuration?

a) Required:

**Subject 1:** SKE range indicator

**Subject 2:** DME and XTK or DA marker (HSI)

**Subject 3:** keep Mach display permanent.

**Subject 5:** see previous page.

**Subject 7:** not having HSI on SFD. SAT display not needed. Delete course track from SKE scope on SFD unless specifically selected. Remove the word "RANGE" on ADI.

**Subject 8:** none airland, airdrop - better contrast to VDI and RRI.

**Subject 9:** the CRS which appears at the bottom left of the HSI is sometimes hard to notice. I feel a better position might be up higher between the ADI and HSI.

**Subject 10:** command marker toggles with some feel to them.

**Subject 11:** allow HSI to display track info while in MAG mode - that is a must. Also the recommendations outlined in the comments sections on the preceding pages.

b) Desired:

**Subject 1:** airspeed indicator and flight director bars wider/brighter

**Subject 2:** white box around DME and super impose XTK or DA marker (HSI) over bearing pointers so it doesn't get hidden.

**Subject 5:** see previous page.

**Subject 7:** not having HSI on SFD. SAT display not needed. Delete course track from SKE scope on SFD unless specifically selected. Remove the word "RANGE" on ADI.

**Subject 8:** none airland, airdrop - better contrast to VDI and RRI.

**Subject 9:** the CRS which appears at the bottom left of the HSI is sometimes hard to notice. I feel a better position might be up higher between the ADI and HSI.

**Subject 10:** how interfacing reference ground speed instead of actual groundspeed with the airspeed deviation cue on the ADI? Using the FSAS/windshear inputs, the cue could turn yellow at 10 KIAS slow/fast, then red at 15 and above. Otherwise all you're doing is replicating what's displayed elsewhere. (on the MFD).

**Subject 12:** move the bank pointer. Add the ability to have INS selected on the #2 bearing pointer.

## CDS ELEMENT QUESTIONNAIRE RESPONSES

| PFD  |      |           |   |   |   |   |  |
|--|------|-----------|---|---|---|---|--|
| 1. Attitude Direction Indicator (ADI)                                      | MEAN | FREQUENCY |   |   |   |   |  |
|  |      | 5         | 4 | 3 | 2 | 1 |  |
| A. Size  | 4.83 | 10        | 2 | 0 | 0 | 0 |  |
| B. Pitch scale design  | 4.33 | 7         | 2 | 3 | 0 | 0 |  |
| C. Miniature aircraft symbol   | 4.83 | 10        | 2 | 0 | 0 | 0 |  |
| D. ADI FOV   | 4.75 | 10        | 1 | 1 | 0 | 0 |  |
| E. CDM design/mechanization  | 4.58 | 7         | 5 | 0 | 0 | 0 |  |
| F. Design of bank scales and pointers                                      | 4.33 | 6         | 4 | 2 | 0 | 0 |  |
| G. Design of pitch and bank steering bars                                  | 4.83 | 10        | 2 | 0 | 0 | 0 |  |
| H. Font sizes  | 4.92 | 11        | 1 | 0 | 0 | 0 |  |
| I. Degree of clutter   | 4.75 | 9         | 3 | 0 | 0 | 0 |  |
| J. Color coding  | 4.83 | 10        | 2 | 0 | 0 | 0 |  |
| K. Overall design/mechanization  | 4.75 | 9         | 3 | 0 | 0 | 0 |  |
| L. Presentation of SKE info  | 3.58 | 4         | 3 | 3 | 0 | 2 |  |
| 2. Horizontal Situation Indicator (HSI)                                    | MEAN | FREQUENCY |   |   |   |   |  |
|  |      | 5         | 4 | 3 | 2 | 1 |  |
| A. Size  | 5.00 | 12        | 0 | 0 | 0 | 0 |  |
| B. HSI scale design  | 4.83 | 10        | 2 | 0 | 0 | 0 |  |
| C. Aircraft symbol design  | 5.00 | 12        | 0 | 0 | 0 | 0 |  |
| D. Heading marker design/mechanization                                     | 4.00 | 5         | 3 | 3 | 1 | 0 |  |
| E. Heading diamond and track cross design/mechanization                    | 4.42 | 6         | 5 | 1 | 0 | 0 |  |
| F. Course readout placement/presentation                                   | 4.08 | 5         | 3 | 4 | 0 | 0 |  |
| G. Bearing pointer identifier info presentation/placement                  | 4.75 | 10        | 1 | 1 | 0 | 0 |  |
| H. Distance presentation/placement   | 4.92 | 11        | 1 | 0 | 0 | 0 |  |
| I. Degree of clutter   | 4.75 | 9         | 3 | 0 | 0 | 0 |  |
| J. Color coding  | 4.75 | 9         | 3 | 0 | 0 | 0 |  |
| K. Overall design/mechanization  | 4.58 | 7         | 5 | 0 | 0 | 0 |  |
| 3. Altitude Indicator / Vertical Velocity Indicator (VVI)                  | MEAN | FREQUENCY |   |   |   |   |  |
|  |      | 5         | 4 | 3 | 2 | 1 |  |
| A. Commanded altitude presentation (bow tie)                               | 4.25 | 8         | 0 | 3 | 1 | 0 |  |
| B. Radar altitude presentation   | 4.25 | 8         | 1 | 2 | 0 | 1 |  |
| C. Altitude indicator scale design/mechanization                           | 4.08 | 5         | 3 | 4 | 0 | 0 |  |
| D. Alert altitude readout presentation/placement                           | 4.92 | 11        | 1 | 0 | 0 | 0 |  |
| E. Background shading and contrast on the altitude tape and scale markings | 4.83 | 11        | 0 | 1 | 0 | 0 |  |
| F. Digital altitude readout presentations                                  | 4.08 | 6         | 3 | 1 | 2 | 0 |  |
| G. Meters mode design/mechanization  | 5.00 | 12        | 0 | 0 | 0 | 0 |  |
| H. Overall altitude indicator and tape design/mechanization                | 4.33 | 6         | 4 | 2 | 0 | 0 |  |
| I. Overall VVI design/mechanization  | 4.50 | 8         | 2 | 2 | 0 | 0 |  |
| 4. Airspeed Indicator  | MEAN | FREQUENCY |   |   |   |   |  |
|  |      | 5         | 4 | 3 | 2 | 1 |  |
| A. Digital readout design/mechanization                                    | 4.33 | 7         | 3 | 1 | 1 | 0 |  |
| B. Airspeed scale design/mechanization                                     | 4.58 | 9         | 1 | 2 | 0 | 0 |  |
| C. Mach info presentation/placement  | 4.17 | 4         | 6 | 2 | 0 | 0 |  |
| D. Commanded airspeed presentation (bow tie)                               | 4.50 | 9         | 1 | 1 | 1 | 0 |  |
| E. Background shading and contrast on the airspeed tape and scale markings | 4.92 | 11        | 1 | 0 | 0 | 0 |  |
| F. Overall airspeed indicator design/mechanization                         | 4.50 | 7         | 4 | 1 | 0 | 0 |  |

| 5. Overall PFD Format                           | MEAN | FREQUENCY |   |   |   |   |
|---|------|-----------|---|---|---|---|
|   |      | 5         | 4 | 3 | 2 | 1 |
| A. Arrangement of PFD components                | 4.92 | 11        | 1 | 0 | 0 | 0 |
| B. Discriminability of individuals symbols/info | 4.83 | 10        | 2 | 0 | 0 | 0 |
| C. Overall level of clutter                     | 4.50 | 6         | 6 | 0 | 0 | 0 |
| D. Status annunciations design/mechanization    | 4.75 | 9         | 3 | 0 | 0 | 0 |
| E. Symbol and character sizes                   | 4.58 | 8         | 3 | 1 | 0 | 0 |
| F. Color usage                                  | 4.67 | 8         | 4 | 0 | 0 | 0 |
| G. Overall design/mechanization                 | 4.67 | 8         | 4 | 0 | 0 | 0 |

| SFD  |      |           |   |   |   |    |
|--|------|-----------|---|---|---|----|
| 1. General   | MEAN | FREQUENCY |   |   |   |    |
|  |      | 5         | 4 | 3 | 2 | 1  |
| A. True airspeed (TAS) presentation                                      | 4.92 | 11        | 1 | 0 | 0 | 0  |
| B. Ground speed presentation   | 4.83 | 10        | 2 | 0 | 0 | 0  |
| C. Cross track readout presentation                                      | 4.91 | 10        | 1 | 0 | 0 | 0  |
| D. Drift angle / wind direction and speed presentation                   | 4.75 | 9         | 3 | 0 | 0 | 0  |
| E. Altitude readout presentation   | 4.82 | 9         | 2 | 0 | 0 | 0  |
| F. Static air temperature (SAT) presentation                             | 4.58 | 8         | 3 | 1 | 0 | 0  |
| G. FAIL/SFD and PFD repeat annunciators presentation                     | 4.45 | 7         | 3 | 0 | 1 | 0  |
| 2. HSI Format  | MEAN | FREQUENCY |   |   |   |    |
|  |      | 5         | 4 | 3 | 2 | 1  |
| A. Size of expanded HSI  | 5.00 | 12        | 0 | 0 | 0 | 0  |
| B. Bearing pointer identifier / range info presentation                  | 4.75 | 10        | 1 | 1 | 0 | 0  |
| C. Digital course / heading set readout presentation                     | 5.00 | 12        | 0 | 0 | 0 | 0  |
| D. Degree of clutter on expanded HSI                                     | 4.92 | 11        | 1 | 0 | 0 | 0  |
| E. Color coding  | 4.91 | 10        | 1 | 0 | 0 | 0  |
| F. Overall expanded HSI design   | 4.73 | 9         | 1 | 1 | 0 | 0  |
| G. Other (Comments)t   |      |           |   |   | Y | N  |
| H. Unnecessary/inappropriate data that you would take off the HSI format |      |           |   |   | 3 | 9  |
| I. Add anything to the HSI format  |      |           |   |   | 4 | 8  |
| 3. Map Format  | MEAN | FREQUENCY |   |   |   |    |
|  |      | 5         | 4 | 3 | 2 | 1  |
| A. Size of MAP-partial compass display                                   | 4.92 | 11        | 1 | 0 | 0 | 0  |
| B. ETA/ETE information presentation                                      | 4.92 | 11        | 1 | 0 | 0 | 0  |
| C. Radar range rings/labes design/mechanization                          | 5.00 | 12        | 0 | 0 | 0 | 0  |
| D. Fixed aircraft symbol presentation                                    | 4.83 | 10        | 2 | 0 | 0 | 0  |
| E. Radar overlay (color video) design/mechanization                      | 4.75 | 10        | 1 | 1 | 0 | 0  |
| F. TACAN / normal waypoint presentation                                  | 5.00 | 12        | 0 | 0 | 0 | 0  |
| G. Presentation of course lines and readout                              | 5.00 | 12        | 0 | 0 | 0 | 0  |
| H. Heading set marker design/mechanization                               | 4.75 | 9         | 3 | 0 | 0 | 0  |
| I. Bearing pointers design/mechanization                                 | 5.00 | 12        | 0 | 0 | 0 | 0  |
| J. Bearing pointer 1 identifier / range info presentation/placement      | 4.75 | 10        | 1 | 1 | 0 | 0  |
| K. Heading diamond / track cross design                                  | 4.73 | 8         | 3 | 0 | 0 | 0  |
| L. Degree of clutter on MAP display                                      | 4.75 | 9         | 3 | 0 | 0 | 0  |
| M. Color coding usage  | 4.92 | 11        | 1 | 0 | 0 | 0  |
| N. Overall SFD MAP design  | 4.91 | 10        | 1 | 0 | 0 | 0  |
| O. Other (Comments)  |      |           |   |   | Y | N  |
| P. Unnecessary/inappropriate data you would take off the MAP format      |      |           |   |   | 2 | 10 |
| Q. Add anything to the MAP format (Possible Comments)                    |      |           |   |   | 5 | 7  |

| 4. SKE Format |  | MEAN | FREQUENCY |   |   |   |    |
|---------------|--|------|-----------|---|---|---|----|
|               |  |      | 5         | 4 | 3 | 2 | 1  |
| A.            | Size of SKE Display  | 5.00 | 11        | 0 | 0 | 0 | 0  |
| B.            | Reference modes presentation                                     | 4.90 | 9         | 1 | 0 | 0 | 0  |
| C.            | ETE/ETA presentation   | 5.00 | 12        | 0 | 0 | 0 | 0  |
| D.            | SKE ZM design/mechanization                                      | 4.82 | 9         | 2 | 0 | 0 | 0  |
| E.            | SKE range readout and range rings design                         | 4.83 | 10        | 2 | 0 | 0 | 0  |
| F.            | Presentation of standard SKE symbology                           | 5.00 | 12        | 0 | 0 | 0 | 0  |
| G.            | Presentation of master/master lost annunciators                  | 5.00 | 9         | 0 | 0 | 0 | 0  |
| H.            | Presentation of proximity warning annunciator and line           | 5.00 | 12        | 0 | 0 | 0 | 0  |
| I.            | Presentation of SKE caution annunciator                          | 5.00 | 9         | 0 | 0 | 0 | 0  |
| J.            | Presentation of SKE test annunciators                            | 5.00 | 9         | 0 | 0 | 0 | 0  |
| K.            | Presentation of SKE/NO SKE data annunciators                     | 5.00 | 10        | 0 | 0 | 0 | 0  |
| L.            | Degree of clutter on the SKE display                             | 4.75 | 10        | 1 | 1 | 0 | 0  |
| M.            | Color coding usage   | 5.00 | 12        | 0 | 0 | 0 | 0  |
| N.            | Overall SFD SKE format design                                    | 5.00 | 12        | 0 | 0 | 0 | 0  |
| O.            | Other (Comments)   |      |           |   |   | Y | N  |
| P.            | Unnecessary/inappropriate data you would take off the SKE format |      |           |   |   | 2 | 10 |
| Q.            | Add anything to the SKE format (Possible Comments)               |      |           |   |   | 1 | 11 |

| DAMU |   |      |           |   |    |    |   |
|------|---|------|-----------|---|----|----|---|
|      |   | MEAN | FREQUENCY |   |    |    |   |
|      |   |      | 5         | 4 | 3  | 2  | 1 |
| A.   | Understandability/clarity of menu pages                               | 4.58 | 7         | 5 | 0  | 0  | 0 |
| B.   | Overall operational utility of DAMU menu system                       | 4.42 | 7         | 3 | 2  | 0  | 0 |
| C.   | Understandability/ease of use of NAV select menu option               | 4.58 | 8         | 3 | 1  | 0  | 0 |
| D.   | Understandability/ease of use of SFD menu options                     | 4.75 | 9         | 3 | 0  | 0  | 0 |
| E.   | Understandability/ease of use of PFD menu options                     | 4.67 | 8         | 4 | 0  | 0  | 0 |
| F.   | Understandability/ease of use of DISPLAY CONTROL menu option          | 4.58 | 8         | 3 | 1  | 0  | 0 |
| G.   | Ease of accessing the other crew member's DAMU displays/controls      | 4.42 | 6         | 5 | 1  | 0  | 0 |
| H.   | Ease of interpreting/implementing SKE related-options                 | 4.50 | 8         | 3 | 0  | 1  | 0 |
| I.   | "Get lost" navigating through the menu system                         | 2.00 | 0         | 0 | 0  | 12 | 0 |
| J.   | Options where you expected them to be in the menu structure           | 3.17 | 0         | 2 | 10 | 0  | 0 |
| K.   | Design degrade your ability to perform your tasks                     | 1.92 | 0         | 1 | 0  | 8  | 3 |
| L.   | Understand functions being accomplished by the different menu options | 3.67 | 0         | 8 | 4  | 0  | 0 |
| M.   | No DAMU design changes needed before it is suitable for installation  | 2.58 | 0         | 1 | 8  | 0  | 3 |
| N.   | Used in an operational environment with an acceptable level of safety | 3.50 | 0         | 7 | 4  | 1  | 0 |
| O.   | Will effectively support all operational mission requirements         | 3.33 | 0         | 7 | 3  | 1  | 1 |

Questions A-H

- 5 = Completely Acceptable
- 4 = Moderately Acceptable
- 3 = Borderline
- 2 = Moderately Unacceptable
- 1 = Completely Unacceptable

Questions I-L

- 4 = Always
- 3 = Usually
- 2 = Sometimes
- 1 = Never

Questions M-O

- 4 = Strongly Agree
- 3 = Moderately Agree
- 2 = Moderately Disagree
- 1 = Strongly Disagree

## **PFD: Open-Ended Questions**

i) Comments or suggestions for design improvement (please use back of form for additional space).

**Subject 5:** overall, the color coding should help enhance the cross-check or bring attention to things that are important, the primary performance instruments - airspeed, altitude, and VVI should all be in the same color while secondary stuff should be in white or another unobtrusive color.

**Subject 6:** I'm not sure for the best location, but the opportunity to be able to call up a small round dial clock would be helpful - rarely do the clocks work in the C-141 - and having one accessible would help - especially for approach (MAP) timing.

**Subject 10:** swap CRS with GS (place box around course). Get rid of AGL ( place ALRT in it's place).

**Subject 12:** I would keep Mach info in view always and have a command marker. I would move course window to upper right of HSI. Put AGL readout elsewhere.

## **SFD: Open-Ended Questions**

### **2. HSI Format**

h) Is there any unnecessary or inappropriate data presented that you would take off the HSI format?

If YES, what data?

**Subject 5:** RA (Radar Altimeter) - move to LL corner and reduce size - also change from scroll to readout like current RA.

**Subject 11:** SAT on SFD

**Subject 12:** altitude readout unnecessary. It is nice but not needed there.

i) Would you add anything to the HSI format?

If YES, what would you add and where would you put it? (please use back of form if necessary)

**Subject 5:** 2 optional windows at bottom for 3 engine altitude and a window for 2 digits of GA EPR or VMFR for those who like to set that.

**Subject 9:** move the CRS to an area where it is more readily seen.

**Subject 11:** track option in mag mode.

**Subject 12:** I would move X-track to where altitude readout currently is.

j) Other comments (please use back of form for additional space)

### **3. MAP Format**

p) Is there any unnecessary or inappropriate data presented that you would take off the MAP format?

If YES, what data?

**Subject 5:** but I would move and reduce the heading window and move the wind arrow, DA, GS, and cross-track to the top while putting TOA / ETE on the bottom.

**Subject 9:** not quite sure how valuable SAT is? This info could be retrieved from the FSAS and decrease clutter on the MAP. Also, with regard to the map format, I might consider getting rid of the ALT feature. A good cross-check, based on task saturation should always include the altimeter.

**Subject 12:** same comments as on expanded HSI.

q) Would you add anything to the MAP format?

If YES, what would you add and where would you put it? (Use back of form if necessary)

**Subject 2:** terrain features on the ground.

**Subject 3:** the 'spokes' used on the MFD are helpful for post AR positions (60 degree angle off tanker include these on map)

**Subject 5:** delay function for ground track. Other NAVAIDS / fixes / jetways, etc.

**Subject 6:** ref GS.

**Subject 12:** I would like to see the 30 degree and 60 degree lines on MFD. These are important for WX avoidance and during formation AR (Air Refueling).

r) Other Comments: (Use back of form if necessary)

### **DAMU: Open-Ended Questions**

p) Please recommend any improvements to the current menu design that you feel would improve efficiency and reduce workload.

**Subject 4:** back of page 7.

**Subject 5:** putting INS as an option for radio aids instead of a separate NAV option for PTR 1 and 2. Having the option to turn the SKE on and off from the main menu without selecting both PFD and SFD when you turn it off - everything including the ZM should go off. Overall have menus be functionally driven as opposed to display - driven for example, if I want a MAP display up, I want to press a button under the main menu for MAP and have the software call up the SFD display. Don't make me think "OKAY" the map is on the SFD so I'll press that button first, then the MAP button, etc. Make it simple so that during an emergency, I don't have to think through a menu selection process - it should be as user-friendly as possible.

**Subject 12:** pilot and copilot DAMU's must operate off of different power sources / electronic buses.

## FINAL QUESTIONNAIRE RESPONSES

|   |      | FREQUENCY           |                       |               |                         |                       |
|---|------|---------------------|-----------------------|---------------|-------------------------|-----------------------|
|   | MEAN | Strongly Prefer CDS | Moderately Prefer CDS | No Preference | Moderately Prefer C-141 | Strongly Prefer C-141 |
| Q1. Preference for CONOP CDS (5) or C-141 design (1):           |      |                     |                       |               |                         |                       |
| A. ADI  | 3.67 | 2                   | 7                     | 0             | 3                       | 0                     |
| B. HSI  | 4.42 | 7                   | 3                     | 2             | 0                       | 0                     |
| C. Altimeter  | 3.58 | 1                   | 6                     | 4             | 1                       | 0                     |
| D. Airspeed indicator   | 3.25 | 3                   | 4                     | 1             | 1                       | 3                     |
| E. Altitude indicator   | 2.75 | 1                   | 2                     | 3             | 5                       | 1                     |
| F. VVI  | 2.50 | 0                   | 1                     | 5             | 5                       | 1                     |
| G. Mach indicator   | 2.33 | 0                   | 2                     | 4             | 2                       | 4                     |
| H. SKE format   | 4.75 | 9                   | 3                     | 0             | 0                       | 0                     |
| I. Map format   | 4.67 | 8                   | 4                     | 0             | 0                       | 0                     |
| J. Radar overlay  | 4.33 | 7                   | 3                     | 1             | 1                       | 0                     |
| K. SKE range, altitude, crosscheck display                      | 4.17 | 8                   | 2                     | 0             | 0                       | 2                     |
| L. General control interface                                    | 3.64 | 2                   | 5                     | 3             | 0                       | 1                     |
| M. Placement / arrangement of controls                          | 3.73 | 2                   | 6                     | 1             | 2                       | 0                     |
| N. Overall design   | 4.64 | 7                   | 4                     | 0             | 0                       | 0                     |
|   |      |                     |                       |               |                         |                       |
|   |      |                     |                       |               |                         |                       |
|   |      |                     |                       |               |                         |                       |
| Q2. CONOP CDS as good as the C-141 in meeting operational needs |      |                     |                       |               | YES                     | NO                    |
|   |      |                     |                       |               | 10                      | 2                     |
|   |      |                     |                       |               |                         |                       |



|  |      | FREQUENCY           |                       |               |                         |                       |
|--|------|---------------------|-----------------------|---------------|-------------------------|-----------------------|
|  | MEAN | Strongly Prefer CDS | Moderately Prefer CDS | No Preference | Moderately Prefer C-141 | Strongly Prefer C-141 |
| Q6. Acceptability / unacceptability of following cockpit features: |      |                     |                       |               |                         |                       |
| A. Placement of displays   | 4.83 | 10                  | 2                     | 0             | 0                       | 0                     |
| B. Throttle characteristics  | 4.50 | 7                   | 4                     | 1             | 0                       | 0                     |
| C. Flight characteristics  | 4.25 | 6                   | 3                     | 3             | 0                       | 0                     |
| D. Engine displays   | 4.92 | 11                  | 1                     | 0             | 0                       | 0                     |
| E. Reference set panel   | 4.55 | 7                   | 3                     | 1             | 0                       | 0                     |
| F. Mode select panel   | 4.75 | 6                   | 2                     | 0             | 0                       | 0                     |
| G. (C-141 only) NAV SEL Panel                                      | 5.00 | 12                  | 0                     | 0             | 0                       | 0                     |
| H. (C-141 only) ADI select and Air Delivery Switch                 | 4.42 | 9                   | 0                     | 2             | 1                       | 0                     |
| I. Legibility of displays  | 4.92 | 11                  | 1                     | 0             | 0                       | 0                     |
| J. Overall cockpit geometry  | 4.83 | 10                  | 2                     | 0             | 0                       | 0                     |
|  |      |                     |                       |               |                         |                       |
|  |      |                     |                       |               | YES                     | NO                    |
| Q8. Able to adapt to the simulator aeromodel                       |      |                     |                       |               | 12                      | 0                     |

## Open Ended Questions:

2. Is the CONOP CDS "as good as" the C-141 in meeting operational requirements?

**Subject 1:** with only minor problem areas that should be fixed before the final model.

**Subject 2:** I believe once you get hands on experience. Easier cross-check.

**Subject 5:** There is too much info displayed in too small an area. My only real concern is that the altimeter and airspeed do not stand out nor is trend info easy to interpret. I spent much too much mental energy interpreting what was displayed and "looking" for info instead of it being readily apparent as it was on the C-141 design.

**Subject 6:** Not yet, I feel that the airspeed and altitude tapes (CONOP) cause stresses in the cockpit - especially during high workloads. They req'd too much attention from other cross-checks.

**Subject 12:** I do have questions about functionality with NVG's and reliability of LCD's and power sources for LCD's and DAMU's at respective crew positions being independent.

3. For the novice pilot, what training requirements do you feel would be needed?

**Subject 1:** The basic academics involved in upgrading to a new AFCS should do well. The T-1 training program would be a good one to look at, the pilots that start with that system are about as novice as you will find.

**Subject 2:** DAMU panel. Learning how to set up Nav aids the SWAP function and giving co-pilot control of your panel. Selecting co-pilots control in case of DAMU failure. DAMU control inboard outboard displays.

**Subject 3:** for the novice pilot (probably not airdrop yet) extensive continuation training maybe needed due to lack of understanding of even the current 141 design - switching between the 2 as the planes came on line will degrade performance.

**Subject 4:** DAMU training and explanations of where everything is located.

**Subject 5:** train to decipher airspeed and altitude readout. Also training needed on the bigger ADI - so you don't under rotate. Classes to understand each display thoroughly lots of training with display control. Simulator training and a few locals.

**Subject 6:** for a student in UPT - the T-1 will provide the basic training, and Altus will be able to provide the normal transition. Thus no additional training required.

**Subject 7:** 4 day sim course, 3 locals and check-ride.

**Subject 8:** 8 hrs sim training, 8 hrs VFR training.

**Subject 9:** thorough explanation and sufficient hands-on training with the DAMU.

**Subject 10:** more hands-on than conceptual. Probably an added sim on two to the training syllabus.

**Subject 11:** A 2-3 ground training program followed by 2 local flights including sims.

**Subject 12:** novices would need training on DAMU use and which displays to have selected at which time. Also, need to learn which info vital and which is just good to have.

4. For the average pilot, what training requirements do you feel would be needed?

**Subject 1:** The average pilot would need a class and 1 or 2 sim rides, the normal 4 hr sim we fly would probably work. Then they would improve more when they flew with the new system.

**Subject 2:** same. It's not that difficult selecting types of attitude and heading reference in emergency situations.

**Subject 3:** mostly DAMU training for familiarity would be needed. Also switching to a new autopilot would require equal training time as the DAMU.

**Subject 4:** same as above.

**Subject 5:** control of displays and just familiarization flights and sims.

**Subject 6:** simulator time.

**Subject 7:** 3 day sim course, 2 locals, and check-ride.

**Subject 8:** 4 hrs sim training, 4 hrs DaxVFR training.

**Subject 9:** minimal explanation of systems and operating modes.

**Subject 10:** same as above.

**Subject 11:** 2 days ground training and 1 local.

**Subject 12:** DAMU training and learn capabilities of system. Learn new habit patterns on where to find certain info.

5. For the experienced pilot, what training requirements do you feel would be needed?

**Subject 1:** I feel the short training session that I received by the experimenter was enough for me to feel comfortable with the system. But a standardized class and 1 or 2 sim rides would guarantee the experienced pilot would have no problems with the system. And could keep the young pilots out of trouble with it.

**Subject 2:** hands-on practice. Very little.

**Subject 3:** probably very little again, getting comfortable with the DAMU would be the main thrust.

**Subject 4:** same. Everything is simple, its just different.

**Subject 5:** controlling DAMU, simulator (one), one local flight.

**Subject 6:** the experienced C-141 pilot will need the same training as the "average pilot" because this is a new system for both of them. They will both have to develop new cross-checks.

**Subject 7:** 3 day sim course, 1 local, and check-ride.

**Subject 8:** 4 hrs sim training, 2 hrs VFR.

**Subject 9:** very little.

**Subject 10:** more training than the others, mainly due to there-learning curve. It's be more difficult to "unlearn" entrenched systems.

**Subject 11:** same as 4.

**Subject 12:** DAMU training. Capability and reliability of system.

7. What factors, besides display formats, contributed to your workload during simulation flight?

**Subject 1:** your lead pilot during the airdrop missions should be downgrades and possibly FEB'd for unsafe flying. It makes the workload so artificial that the pilot flying must abandon training to just follow lead in and out formation, or even lead yourself at times.

**Subject 2:** hand flying. Lack of prebrief or route and approach study. But, it really isn't necessary for the data collected

**Subject 3:** throttle seat, yoke relationship was off a bit. Also lack of motion made level flight more difficult.

**Subject 4:** lead aircraft was unpredictable.

**Subject 5:** simulator limits for flight characteristics; roll, overly - sensitive pitch. Jumpy VVI.

**Subject 6:** inability to trim to level flight, left bank of 3 degrees.

**Subject 7:** hand flt.

**Subject 9:** WX avoidance increased workload by a very small amount. Failures in INS and radio NAVAIDS also increased workload by a minimal amount.

**Subject 10:** no motion. Heavy yoke action. Yoke wanting to turn left all the time.

**Subject 11:** trying to interpret a lot more data.

**Subject 12:** the sim -- No sim flies just like the airplane. General unfamiliarity of system.

8. Do you feel you were able to adapt to the simulator aeromodel?

**Subject 1:** it took the better part of 3 missions to start to feel at all comfortable. I had not noticed the difference in the scales of the ADI, airspeed, and altimeter. This causes the rates of change to differ. Also, the scale of the ADI causes small corrections to look big.

**Subject 10:** I didn't like it, though.

9. Any other comments on the study or CONOP system:

**Subject 1:** the people have done an excellent job with this study from my point of view.

**Subject 3:** during AD missions, there was a lot of uncertainty of what lead was going to do or lead would climb, slow, etc. w/o relaying it to #2. Since it wasn't even consistent between the 2 AD missions, the data may not reflect a relationship between CONOP and C-141.

**Subject 5:** I want to make sure that when meters and millibars are selected for the PFD that the altimeter can be adjusted. Also, don't have settings for altitudes which convert to even thousands of feet, make sure its meters (e.g. 4100m, 4200m, etc.)

**Subject 9:** overall, I prefer the CONOP system. The various functions are excellent and can drastically improve the pilot's cross-check of instrumentation.

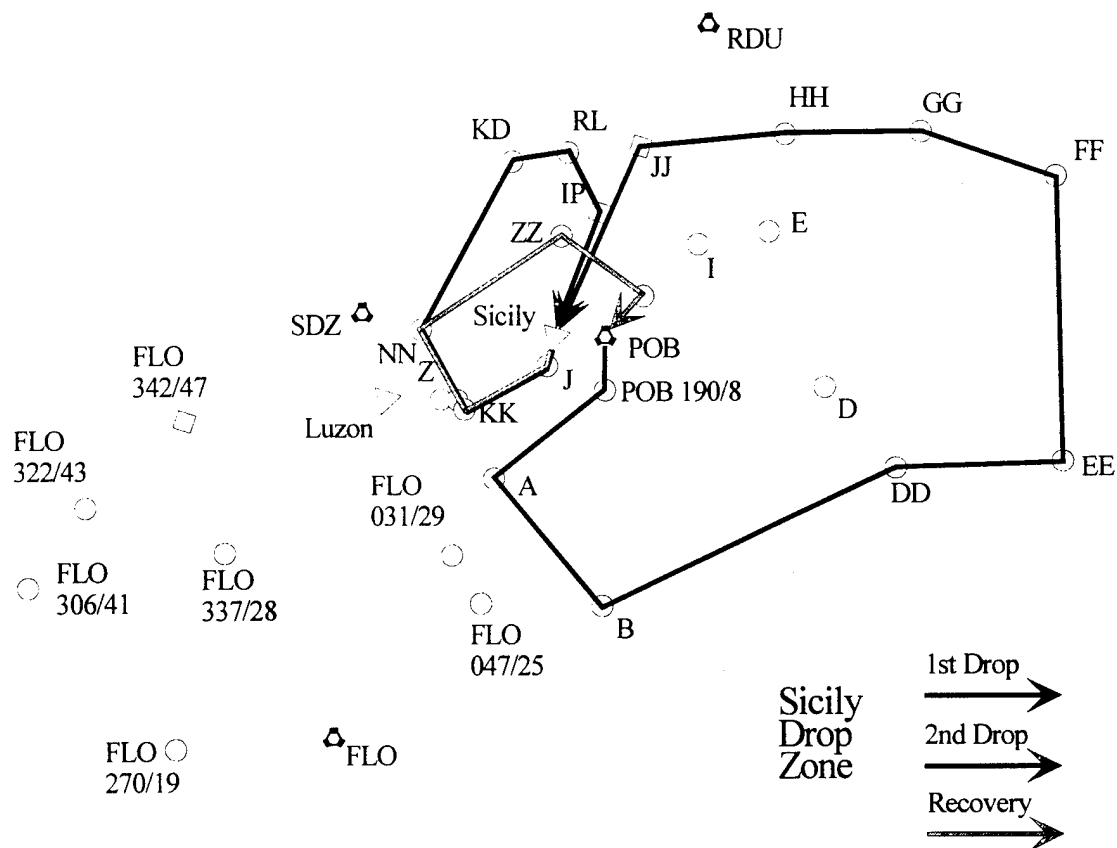
**Subject 11:** a very good system, but it needs a few things changed as outlined in these critiques.

**Subject 12:** I really like the system. Especially for SKE flights.

**APPENDIX E**  
**MISSION PROFILES AND SCRIPTS**

### Station Keeping Equipment (SKE) Scenario Sicily Drop Zone

General. The mission is a training airdrop of heavy equipment flown out of Pope AFB. The subject Pilot will hand-fly the number two aircraft in a three-ship formation using station keeping equipment to maintain lateral and vertical position. The Copilot, tunes the navigation and communications radios for the Pilot and makes radio calls after the format splits up for individual landings back at Pope. AFB.



### Pre-Brief

- Parachutes - drop altitude less than 800 AGL, harness required
- Smoke
- Weather
- DZ control
- Monitor command post
- Flight plan, SK SA S/E

### SKE FCI check

- Simulate Navigator checkout
- Set SKE master
  1. Cross-track 500R/L
  2. In-track 4000/8000 feet
  3. Master and Deputy Master enable slots 01- zone marker; 11, 12, 13 for lead and wingmen respectively
  4. Proximity warning set to 2000 feet

### Experiment Setup

- Turn on Data Collection
- Call up FSAS on experimenter's station
- Turn on Flight Director
- Turn on Track Up
- Turn on Control Loader
- Verify touch screen works
- Verify winds on
- Takeoff and Landing data

### FSAS

- Navigator loads high precision waypoints
- Controls FSAS/INS
- IP, DZ symbols not circular
- Load drop data

### Before Takeoff

- Typical radio setup; U1-interplane, V1-guard, U2-DZ, V2-ATC
- Set SKE on PFD, SFD
- DICU 4000' range rings

### **RELEASE SIMULATOR**

#### Tower

**135.025 (PopeTower.aiff)**

Lead: "Pope Tower, Veda 10 flight ready for takeoff, controlled takeoff time in two minutes"

Tower: "Veda 10 flight hold short pending IFR release"

Lead: "Veda 10 flight holding short"

Tower: "Veda 10 flight cleared for takeoff, on departure climb and maintain 4000 feet. Contact Fayetteville Approach 133.0."

Lead: "Cleared for takeoff, climbing to 4000 feet, Veda 10 flight go 133.0"

### **Lineup Checklist (Called for by Pilot)**

E: "Spoilers"  
CP, P: "Closed and Armed"  
E: "IFF"  
CP: "Set"  
E: "Continuous Ignition"  
CP: "On" (as required)  
E: "Engine Anti-Ice"  
CP: "Off" (as required)  
E: "Anti-Collision/Strobe Lights"  
CP: "Set"  
E: "Pitot Heat and Temp Probe De-Ice"  
CP: "On"  
E: "Angle of Attack De-Ice"  
CP: "On"  
E: "Takeoff Light"  
P: "Checked"  
E: "Lineup Check - Completed"

### **1300z .....Lead Takeoff**

#### **Takeoff RWY 23**

- Takeoff 20 seconds after Lead
- 70% N1 for takeoff

### **After Takeoff, Climb Checklist (Called for by Pilot)**

E: "Spoilers"  
CP: "Closed and Disarmed"  
E: "Landing Gear Warning Horn Cut-Out Switch"  
CP: "Off"  
E: "Exterior Lights" (strokes off)  
CP: "Extended and On" (as required)  
E: "No Smoking Switch"  
CP: "Off" (as required)  
E: slight delay then, "After Takeoff, Climb Check - Completed"

#### **Assembly**

- 1000 FPM while accelerating to 200 KCAS
- 200 KCAS/2000 FPM to 4000 MSL
- At or before 1 DME, turn left heading 160M (FCI's used after initial heading)
- Cross 3.5 DME south at or above 1200
- Intercept POB 190 radial to the POB 190/8
- Lead limited to 20 degrees of bank
- Climb and maintain 4000 MSL
- At POB 190/8 turn right, heading 225T
- While in SKE, all true headings will have to be corrected for drift
- Accelerate to join on lead when on departure heading and lead has been identified using SKE, radar or visual means



### Fayetteville App (FaytApp2988.aiff)

Lead: "Fayetteville Approach, Veda 10, flight of three, passing 1000, climbing 2000"

App: "Veda 10, radar contact, Pope altimeter now 29.88"

Lead: "Veda 10 flight, 29.88"

- FCI: "988" BAR"

#### Turn Prep

N: "2 miles to turn"

N: "Heading 225T" (needs drift correction)

N: "Altitude 2000"

### 1302z .....2 (POB 190/8)

- Navigator verifies INS accuracy

### \*\*\* SWAT RATING FOR DEPARTURE EVENTS

#### Turn Prep

N: "5 miles to turn"

N: "Heading 145T" (needs drift correction)

N: "Altitude 4000"

### 1306z .....3 (A)

- FCI: "225 PH" present heading, "145 NH" new heading, "240 TAS" true airspeed, "←," 5 sec delay, "E", "145 NH"

#### En Route

- FCI: "230 IAS", when all aircraft are in position, accelerate.
- FCI: "+," 5 sec delay, "+, E" and tone
- Lead maintains 230 KCAS, ±20 KCAS cruise

#### Turn Prep

- Navigator calls 5 miles to turn
- Heading 060T
- Altitude 4000

### 1312z .....4 (B)

- FCI: "145 PH" present heading, "060 NH" new heading, "240 TAS" true airspeed, "←," 5 sec delay, "E" and tone at lead's turn point; start timer countdown, "060 NH"

### **Cruise Checklist (Called for by Pilot)**

E: "Cabin Altitude and Oxygen Quantity"  
CP: "2000 Feet, 20 Liters"  
E: "Anti-Ice/De-Ice"  
P: "Off" (as required)  
E: "Continuous Ignition"  
P: "On" (as required)  
E: "Seat Belt Switch"  
P: "On"  
E: "Altimeter"  
CP, P, N: "29.88"  
E: "Radar"  
P, N: "On and tuned" (as required)  
E: "Cruise Check - Completed"

### **Combat Entry Checklist (Called for by Pilot)**

E: "Altimeters"  
CP, P, N, E: "29.88"  
E: "Crew Briefing"  
P: "As required"  
E: "Combat Entry Checklist Complete"  
• Rest of checklist simulated

### **Approach (SeyJohn.aiff)**

App: "Veda 10 flight, contact Seymour Johnson approach on 119.7."  
Lead: "Veda 10 flight, go 119.7."  
• FCI "197 FRQ"  
Lead: "Seymour Johnson, Veda 10 flight of three with you level 4000."  
SJ: "Veda 10, radar contact."

### **Turn Prep**

N: "5 miles to turn"  
N: "Heading 087T"  
N: "Altitude 4000"

### **1322z .....5 (DD)**

- FCI: "060 PH" present heading, "087 NH" new heading, "240 TAS" true airspeed, "→," 5 sec delay, "E" and tone at lead's turn point; start timer countdown, heading "087 NH".

### **Turn Prep**

N: "5 miles to turn"  
N: "Heading 358T"  
N: "Altitude 4000"

### **1327z .....6 (EE)**

- FCI: "087 PH" present heading, "358 NH" new heading, "240 TAS" true airspeed, "←," 5 sec delay, "E" and tone at lead's turn point; start timer countdown, heading 358T

## Turn Prep

N: "5 miles to turn"  
N: "Heading 292T"  
N: "Altitude 4000"

### 1337z .....7 (FF)

- FCI: "358" present heading, "292" new heading, "240" true airspeed, "←," 5 sec delay, "E" and tone at lead's turn point; start timer countdown, heading 292T

#### Approach (RalDurh.Contact.aiff)

App: "Veda 10 flight, contact Raleigh-Durham approach control on 125.3."

Lead: "Veda 10 flight, go 125.3."

- FCI "253 FRQ"  
Lead: "Raleigh-Durham , Veda 10 flight of three with you 4000."  
RDU: "Veda 10, radar contact."

#### Equipment Pre-Slowdown Checklist (Called for by Navigator)

N: "Pre-Slowdown checklist"  
L, E: "Acknowledged"  
E: "Air Delivery Switch"  
P: "ZM"  
E: "Door Arming Switch"  
P: "Armed"  
E: "Pressure Door"  
P: "Cleared to Open"  
L: "Open" (delay until all doors open)  
E: "Altimeter"  
CP, P, N: "29.88"  
CP cross checks barometric and radar altimeters  
E: "Red Light"  
CP: "ON"  
E: "Command Markers"  
CP, P: "Set"  
E, L: "Pre-Slowdown Checklist-Completed"

## Turn Prep

N: "5 miles to turn"  
N: "Heading 268T"  
N: "Altitude 4000"

### 1341z .....8 (GG)

- FCI: "292 PH" present heading, "268 NH" new heading, "240 TAS" true airspeed, "←," 5 sec delay, "E" and tone at lead's turn point; start timer countdown, heading 268T

#### INS

- Navigator comes out of TACAN aided mode a minimum of 10 minutes prior to drop (Extinguish TAC lights on PICU)

## Turn Prep

N: "5 miles to turn"  
N: "Heading 264T"  
N: "Altitude 3000"

1345z .....9 (HH)

- FCI: "268 PH" present heading, "264 NH" new heading, "240 TAS" true airspeed, "←," 5 sec delay, "E" and tone at lead's turn point; start timer countdown, heading 264T

## Approach (RalDurhApp.aiff)

\*\*\*Lead: "Raleigh-Durham Approach Veda 10 flight request descent to 3200"  
\*\*\*RDU: "Veda 10 flight descent and maintain 3200"  
\*\*\*Lead: "Veda 10 cleared down to 3200"  
• FCI: "032 ALT", "↓", 5 sec delay, "E" and tone

## Range Control, on drop zone control frequency 314.2 (U2 radio) (RngCntrl.R5311.aiff)

Lead: "Range control, Veda 10 flight of three making two passes on Sicily DZ. First TOT is 1355z, request clearance into R5311"  
Range: "Veda 10 flight cleared into R5311"  
Lead: "Raleigh-Durham, VEDA 10 flight, cancel IFR."  
RDU: "VEDA 10 flight, Roger, cancel IFR."

## Copilot

- Copilot ensures that the INS not being used by the navigator is in airdrop mode
- Maximum range for the beacon is 20 NM, line-of-sight

\*\*\* SWAT RATING FOR CRUISE EVENTS UP TO THIS POINT

## Turn Prep

N: "5 miles to turn"  
N: "Heading 199T"  
N: "Altitude 3000"

1349z .....10 (JJ)

(Sicily IP)

- FCI: "264 PH" present heading, "199 NH" new heading, "240 TAS" true airspeed, "←," 5 sec delay, "E" and tone at lead's turn point; start timer countdown, heading 199T NH

## IP Considerations

- Depart on course using drift corrected heading to the CARP

## Drop Clearance (DropClear.1355z.aiff)

- One minute prior to TOT (earlier if possible)
- Call sign
- Drop zone and TOT
- Drop zone winds in blind 10 minutes prior
- Lead: "Range control, Veda 10 flight TOT remains 1355z, request clearance to drop"
- Range: "Veda 10, Sicily winds 280 at 5 knots, cleared to drop"

### Range Information

- Drop zone winds, received in blind 5 minutes prior
- Drop clearance 5 minutes prior
- ZM reception, clearance to drop
- Lead Navigator sends estimated drift and altimeter setting for the drop prior to slowdown
- FCI: "008 LD drift, "29.84" BAR

### 1353z .....Slowdown (14 miles out)

#### Slowdown

- FCI: "SD" (30 seconds prior to slowdown)
- FCI: "-." (5 seconds prior to slowdown)
- FCI: "E" (at slowdown)
- Throttles-idle
- Decelerate to 160K
- P: "Flaps 75 percent"
- Flaps-set (Wingmen times flaps to stay in position passing 190K)

#### Slowdown Checklist (Called for by copilot once flaps are set)

- L: "Acknowledged"
- E: "Doors"
- L: "Clear"
- E: "All Doors Switch"
- P: "Open" (Copilot actuates All Doors Switch on Pilot's command; Visually checks door position on ADS panel)
- E: "SKE Secondary Control Panel"
- N: "Set" (Wing navigators determine appropriate crosstrack information from the drift offset chart and set it after initiation of the slowdown)
- E: "Doors"
- L: "Open"
- E: "Slowdown Checklist"
- L, E: "Complete"

#### Descend

- ZM reception needed for descent and stabilization in IMC
- FCI: "↓" (5 second descent prep)
- FCI: "E" (begin descent)
- N: "Descend to 1280 FT"
- 160 KCAS, 1000 FPM
- Slow to 150 KCAS upon reaching drop altitude, 1280 MSL
- Achieve drop altitude and airspeed by stabilization point
- FCI: "006 LD"

\*\*\* WHEN DESCENDED AND LEVEL, SWAT RATING FOR DROP DESCENT EVENTS

#### Run-In

- Navigator describes aircraft position for the CARP
- Pilot maintains desired track

### **One Minute Advisory**

- N: "One Minute Advisory"
- L: "Acknowledged"
- Must be stabilized by 30 seconds or "no drop"

**1355z .....11 (Drop on Sicily)**

### **Heavy Equipment CARP Checklist**

- Lead sends FCI: "↓" five seconds prior to his drop
- Lead sends FCI: "E" at his INS drop time (backup timing for wing aircraft)
  - N: "Ten Second Advisory" (off own INS)
  - N: "Five, four, three, two, one"
  - N: "Green light" (Copilot activates Green Light Switch and Chute Release Switch until "All Clear")
  - L: "All Clear"
  - N: "Red Light" (At end of usable DZ)
- CP: "Red Light" (Copilot turns Green Light Switch off)
- CP: "Post Drop Checklist" (Copilot makes this call after completion of the Heavy Equipment CARP checklist)

### **12 (Escape (concurrent with Post-Drop Checklist))**

- FCI: "+" (one minute after Lead's Red Light)
- FCI: "E" (momentarily after prep command, execute DZ departure procedures)
- Accelerate to 160 KCAS
- Maintain 160 KCAS until all doors have closed
- Climb to 3000' MSL, 1000 FPM
- Navigator resets cross track

### **Heavy Equipment Post Drop Checklist (Copilot calls for after airdrop)**

- CP: "Post Drop Checklist" (Copilot initiates after completion of the airdrop)
- L, E: "Acknowledged"
- E: "Petal Doors and Ramp"
- L: "Closed"
- E: "SKE Secondary Control Panel"
- N: "Set"
- E: "Air Delivery Switch"
- P: "Off" (Aircraft will be at minimum IFR altitude prior to placing Aerial Delivery Switch to off)
- E: "Flaps"

- FCI: "230 IAS"
  - FCI: "+" (acceleration prep when all aircraft are in position, typically takes 3 minutes before ready for acceleration)
  - FCI: "E" (accelerate to 230 KCAS)
- P: "Flaps Up"
- CP: "Flaps Up"
- E: "Loadmasters Post Drop Checklist"
- L: "Completed"
- E: "Door Arming Switch"
- P: "Off"
- E: "Red Light Switch"
- CP: "Off"
- E: "Pressurization"
- P: "Off"
- E: "Post Drop Checklist-Completed"

#### Turn Prep

- N: "5 miles to turn"
- N: "Heading 237T"
- N: "Altitude 3000"

#### 1356z .....13 (J)

- FCI: "199 PH", "237 NH", "240 TAS", "→," 5 sec delay, "→, E", "237 NH"

#### Turn Prep

- N: "5 miles to turn"
- N: "Heading 335T"
- N: "Altitude 3000"

#### 1359z .....14 (KK)

- FCI: "237 PH", "335 NH", "240 TAS", "→," 5 sec delay, "→, E" "335 NH"

\*\*\* SWAT RATING FOR RUN-IN AND DROP EVENTS

\*\*\* SWAT RATING FOR ESCAPE EVENTS

#### Turn Prep

- N: "5 miles to turn"
- N: "Heading 024T"
- N: "Altitude 3000"

#### 1402z .....15 (NN)

- FCI: "335 PH", "024 NH", "240 TAS", "→," 5 sec delay, "→, E" "024 NH"

## Equipment Pre-Slowdown Checklist (Called for by Navigator)

N: "Pre-Slowdown checklist"  
L, E: "Acknowledged"  
E: "Air Delivery Switch"  
P: "ZM"  
E: "Door Arming Switch"  
P: "Armed"  
E: "Pressure Door"  
P: "Cleared to Open"  
L: "Open" (delay until all doors open)  
E: "Altimeter"  
CP, P, N: "29.88"  
CP cross checks barometric and radar altimeters  
E: "Red Light"  
CP: "ON"  
E: "Command Markers"  
CP, P: "Set"  
E, L: "Pre-Slowdown Checklist-Completed"

### Turn Prep

N: " 5 miles to turn"  
N: "Heading 081T"  
N: "Altitude 3000"

## 1408z .....16 (KD)

- FCI: "024 PH", "081 NH", "240 TAS", "→," 5 sec delay, "→, E" "081 NH"

### Turn Prep

N: " 5 miles to turn"  
N: "Heading 155T"  
N: "Altitude 3200"

## 1410z .....17 (RL)

- FCI: "081" PH", "155 NH", "032 ALT", "→, 5 sec delay, "E", "155 NH"

### Turn Prep

N: "5 miles to turn"  
N: "Heading 195T"  
N: "Altitude 2000"

### Range clearance (RngClear.aiff)

Lead: "Sicily CCT, Veda 10 flight of 3 request range clearance."  
CCT: "Cleared into R-5311, exit south, DZ winds 280 at 5 knots, cleared to drop."  
Lead: "Copy all, cleared to drop."

- Lead Navigator sends estimated drift and altimeter setting for the drop prior to slowdown
- FCI: "007 LD", "984 BAR"

## 1413z .....18 (IP & Slowdown)

### Drop Clearance (DropClear.1420z.aiff)

Lead: "Range control, Veda 10 flight TOT of 1420z, request clearance to drop"  
Range: "Veda 10, Sicily winds 260 at 7 knots, cleared to drop"

### Slowdown

- FCI: "SD" (30 seconds prior to slowdown)



- FCI: "-" (5 seconds prior to slowdown)
- FCI: "E" (at slowdown)
- Throttles-idle
- Decelerate to 160K
- P: "Flaps 58 percent"
- CP: "Flaps 58 percent"
- Flaps-set (Wing times flaps to stay in position passing 190K)

### Slowdown Checklist

- CP: "Slowdown Checklist" (once flaps are at computed setting)
- P, L: "Acknowledged"
- E: "Doors"
- L: "Clear"
- E: "All Doors Switch"
- P: "Open" (Copilot actuates All Doors Switch on Pilot's command; Visually checks door position on ADS panel)
- E: "SKE Secondary Control Panel"
- N: "Set" (Wing navigators determine appropriate crosstrack information from the drift offset chart and set it after initiation of the slowdown)
- E: "Doors"
- L: "Open"
- E: "Slowdown Checklist"
- L, E: "Complete"

### Descend

- ZM reception needed for descent and stabilization in IMC
- FCI: "↓" (5 second descent prep)
- FCI: "E" (begin descent)
- 160 KCAS, 1000 FPM
- Slow to 150 KCAS upon reaching drop altitude, 1280 MSL
- Achieve drop altitude and airspeed by stabilization point
- FCI: "006 LD" (updated drift information)

### \*\*\* SWAT RATING FOR DROP DESCENT EVENTS

#### Run-In

- Navigator describes aircraft position for the CARP
- Pilot maintains desired track

#### One Minute Advisory

- N: "One Minute Advisory"
- L: "Acknowledged"
- Must be stabilized by 30 seconds or "no drop"

1420z .....19 (Drop on Sicily)

#### Heavy Equipment CARP Checklist

- Lead sends FCI: "↓" five seconds prior to his drop
- Lead sends FCI: "E" at his INS drop time (backup timing for wing aircraft)
- N: "Ten Second Advisory" (off own INS)
- N: "Five, four, three, two, one"
- N: "Green light" (Copilot activates Green Light Switch and Chute Release Switch until "All Clear")
- L: "All Clear"
- N: "Red Light" (At end of usable DZ)
- CP: "Red Light" (Copilot turns Green Light Switch off)
- CP: "Post Drop Checklist" (Copilot makes this call after completion of the Heavy Equipment CARP checklist)

## 20 (Escape)

- FCI: "+" (one minute after Lead's Red Light)
- FCI: "E" (momentarily after prep command, execute DZ departure procedures)
- Accelerate to 160 KCAS
- Maintain 160 KCAS until all doors have closed
- Climb to 3000' MSL, 1000 FPM
- Navigator resets cross track

## Heavy Equipment Post Drop Checklist

- CP: "Post Drop Checklist"
- L, E: "Acknowledged"
- E: "Petal Doors and Ramp"
- L: "Closed"
- E: "SKE Secondary Control Panel"
- N: "Set"
- E: "Air Delivery Switch"
- P: "Off" (Aircraft will be at minimum IFR altitude prior to placing Aerial Delivery Switch to off)
- E: "Flaps"
- FCI: "230 IAS"
- FCI: "+" (acceleration prep when all aircraft are in position)
- FCI: "E" (accelerate to 230 KCAS)
- P, CP: "Flaps Up"
- CP: "Flaps are Up"
- E: "Loadmasters Post Drop Checklist"
- L: "Completed"
- E: "Door Arming Switch"
- P: "Off"
- E: "Red Light Switch"
- CP: "Off"
- E: "Pressurization"
- P: "Off"
- E: "Post Drop Checklist-Completed"

## Turn Prep

N: "5 miles to turn"  
N: "Heading 237T"  
N: "Altitude 3000"

### 1421z .....21 (J)

- FCI: "195 PH", "237 NH", "240 TAS", "→," 5 sec delay, "E", 237 NH"

\*\*\* SWAT RATING FOR RUN-IN AND DROP EVENTS FOR 2ND DROP

\*\*\* SWAT RATING FOR RECOVERY EVENTS FOR 2ND DROP

## Turn Prep

N: "5 miles to turn"  
N: "Heading 335T"  
N: "Altitude 3000"

### 1424z .....22 (KK)

- FCI: "→," 5 sec delay, "→, E" and tone at lead's turn point; start timer countdown, heading 335T

## Range Control (RngCtrl.Scores.aiff)

- Number passes
- Clear of DZ
- Drop scores
- Lead: "Range control, Veda 10 flight clear of R-5311"
- Range: "Veda 10 flight, on your first pass, Veda 11 scored a PI; Veda 12, 160 yards at 3 o'clock; Veda 13, 170 yards at 9 o'clock. On the second pass, Veda 11 50 yards at 2 o'clock; Veda 12, 160 yards at 3 o'clock; Veda 13, 170 yards at 9 o'clock "

## Combat Exit Checklist (Called for by Pilot)

- P: "Crew, Combat Exit Checklist"
- CP, N, E, S, L: "Acknowledged"
- E: "Observers"
- P: "Cleared to Reposition"
- E: "Battle Damage Assessment"
- CP, P, N, E, S, L: "Complete"
- Simulate rest of checklist complete
- E: "Combat Exit Checklist Complete"

## Turn Prep

- N: "5 miles to turn"
- N: "Heading 051T"
- N: "Altitude 3000"
- FCI: "200 IAS", "→," 5 sec delay, "E"

### 1427z .....23 (NN)

- FCI: "335 PH", 051 NH", "200 IAS", "→," 5 sec delay, "→", "E", "051 PH"
- Wingmen move to SKE inline on downwind for SKE arrival

### **Descent Checklist (Called for by Pilot)**

E: "Altimeters"  
CP, P, N: "29.88"  
E: "Radar"  
N: "On"  
E: "Crew Briefing"  
P: "Completed" (Pilot Briefs)  
E: "Radar Altimeter"  
P, N: "On/Set"  
E: "Thrust Reverse Limiter"  
CP: "Set"  
E: "Continuous Ignition"  
P: "On"  
E: "Seat Belt Switch"  
P: "On"  
E: "Seat Belt and Shoulder Harness"  
CP, P: "Adjusted"  
E: "Descent Check - Completed"

### **Approach Checklist (Called for by Pilot)**

E: "FSAS Landing Data"  
CP: "Programmed "  
E: "No Smoking Switch"  
P: "On"  
E: "Altimeter "  
CP, P, N: "29.88"  
E: "Landing Lights "  
CP: "Extended and On"  
E: "Approach Check - Completed"

### **Fayetteville App (FaytApp.2986.aiff)**

Lead: "Fayetteville Approach, Veda 10, flight of three, 4000"  
App: "Veda 10, radar contact, Pope altimeter now 29.86"  
Lead: "Veda 10 flight, 29.86"

- FCI "986 BAR"

### **Turn Prep**

N: "5 miles to turn"  
N: "Heading 139T"  
N: "Altitude 2000"

### **1433z .....24 (ZZ) (FaytApp.Localizer.aiff)**

Lead: "Fayetteville Approach, Veda 10 flight out of 4000"

App: "Veda 10 Flight, roger. Contact tower when established on the localizer"

- FCI: "→," 5 sec delay, "→, E" and tone at lead's turn point; start timer countdown, heading 139M, correct for drift, #2 turns 30 seconds later, #3 at 1 minute
- Make a level turn, throttles to idle when wings-level on a drift killed heading. Passing 190 KCAS, configure for approach
- Descend to 2000' on base, maintain 3000' if outside 15 DME

### **Before Landing Checklist (Called for by Pilot)**

E: "Landing Gear Warning Horn Cut-Out Switch"  
CP: "Normal"  
E: "Landing Gear"

CP: "Down"  
P: "Down and Centered"  
E: "Command Markers"  
CP, P: "Set"  
E: "Brake Pressure and Release Light"  
CP: "Normal and On"  
E: "Spoilers"  
CP: "Closed and Armed"  
E: "ADI Select Switch"  
CP, P: "Normal"  
E: "Before Landing Check Completed"

**1437z .....25 (Turn Final (PopeTower.ILS23.aiff))**

- Intercept ILS final
- Maintain 160 KCAS until POB NDB

Lead: "Pope Tower, Veda 11 six miles out, gear down, ILS 23 Pope"  
Tower: "Veda 11, cleared to land"  

- 12,000' minimum spacing, 16,000' desired from lead

Tower: "Veda 12, winds calm, cleared to land"

**1441z .....26 (Pope)**

- ILS Approach

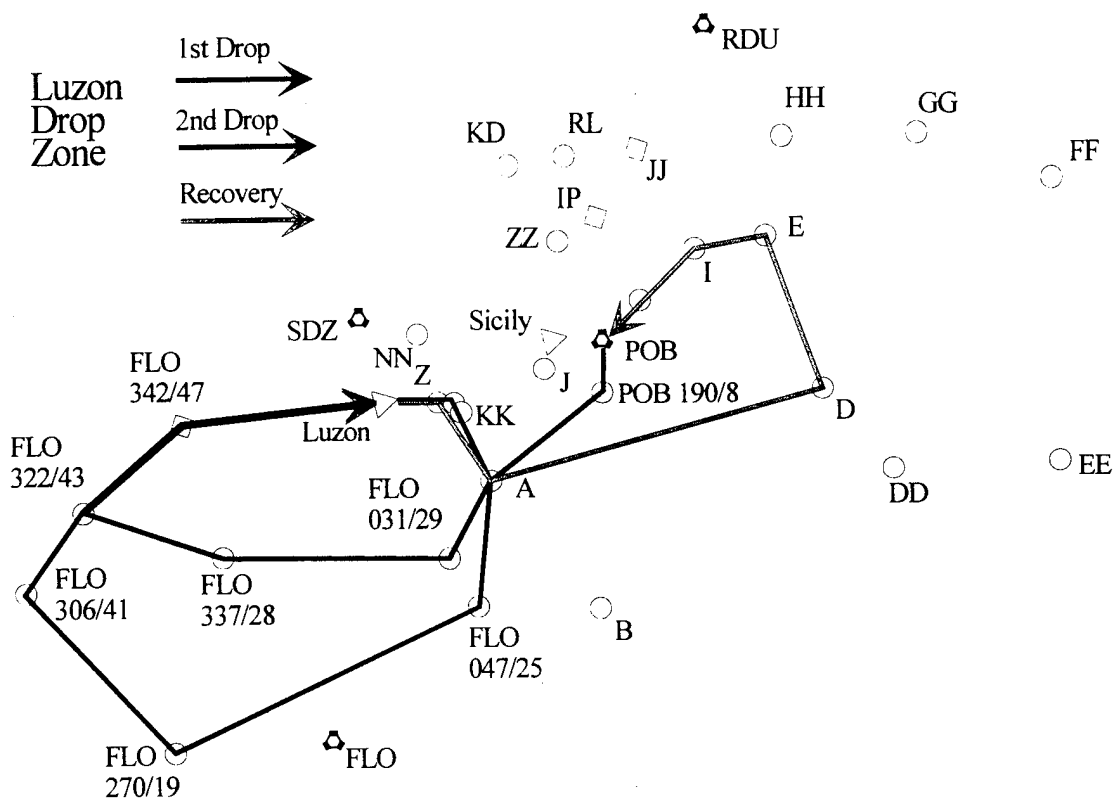
\*\*\* AFTER LANDING, SWAT RATINGS FOR APPROACH EVENTS

\*\*\* SWAT RATINGS FOR ENTIRE MISSION EVENTS

\*\*\* SWAT RATINGS FOR PROJECTED MISSION IF FLOWN REAL WORLD

## Station Keeping Equipment (SKE) Scenario Luzon Drop Zone

General. The mission is a training airdrop of heavy equipment flown out of Pope AFB. The subject Pilot will hand-fly the number two aircraft in a three-ship formation using station keeping equipment to maintain lateral and vertical position. The Copilot, tunes the navigation and communications radios for the Pilot and makes radio calls after the format splits up for individual landings back at Pope AFB.



#### Pre-Brief

- Parachutes - drop altitude less than 800 AGL, harness required
- Smoke
- Weather
- DZ control
- Monitor command post
- Flight plan, SK SA S/E

#### SKE FCI check

- Simulate Navigator checkout
- Set SKE master
  1. Cross-track 500R/L
  2. In-track 4000/8000 feet
  3. Master and Deputy Master enable slots 01- zone marker; 11, 12, 13 for lead and wingmen respectively
  4. Proximity warning set to 2000 feet

#### FSAS

- Navigator loads high precision waypoints
- Controls FSAS/INS
- IP, DZ symbols not circular
- Load drop data

#### Before Takeoff

- Typical radio setup; U1-interplane, V1-guard, U2-DZ, V2-ATC
- Set SKE on PFD, SFD
- DICU 4000' range rings

#### *RELEASE SIMULATOR*

#### Tower 135.025 (PopeTower.aiff)

- Lead: "Pope Tower, Veda 10 flight ready for takeoff, controlled takeoff time 13Z"
- Tower: "Veda 10 flight hold short pending IFR release"
- Lead: "Veda 10 flight holding short"
- Tower: "Veda 10 flight cleared for takeoff, on departure climb and maintain 4000 feet. Contact Fayetteville Approach 133.0."
- Lead: "Cleared for takeoff, climbing to 4000 feet, Veda 10 flight go 133.0"

### **Lineup Checklist (Called for by Pilot)**

E: "Spoilers"  
CP, P: "Closed and Armed"  
E: "IFF"  
CP: "Set"  
E: "Continuous Ignition"  
CP: "On" (as required)  
E: "Engine Anti-Ice"  
CP: "Off" (as required)  
E: "Anti-Collision/Strobe Lights"  
CP: "Set"  
E: "Pitot Heat and Temp Probe De-Ice"  
CP: "On"  
E: "Angle of Attack De-Ice"  
CP: "On"  
E: "Takeoff Light"  
P: "Checked"  
E: "Lineup Check - Completed"

### **1300z.....Lead Takeoff**

#### **Takeoff RWY 23**

- Takeoff 20 seconds after Lead
- 70% N1 for takeoff

#### **After Takeoff, Climb Checklist (Called for by Pilot)**

E: "Spoilers"  
CP: "Closed and Disarmed"  
E: "Landing Gear Warning Horn Cut-Out Switch"  
CP: "Off"  
E: "Exterior Lights" (strokes off)  
CP: "Extended and On" (as required)  
E: "No Smoking Switch"  
CP: "Off" (as required)  
E: Slight delay then, "After Takeoff, Climb Check - Completed"

#### **Assembly**

- 1000 FPM while accelerating to 200 KCAS
- 200 KCAS/2000 FPM to 4000 MSL
- At or before 1 DME, turn left heading 160M (FCI's used after initial heading)
- Cross 3.5 DME south at or above 1200
- Intercept POB 190 radial to the POB 190/8
- Lead limited to 20 degrees of bank
- Climb and maintain 4000 MSL
- At POB 190/8 turn right, heading 226T
- While in SKE, all true headings will have to be corrected for drift
- Accelerate to join on lead when on departure heading and lead has been identified using SKE, radar or visual means



**Fayetteville App (FaytApp.2988.aiff)**

Lead: "Fayetteville Approach, Veda 10, flight of three, passing 1000, climbing 2000"

App: "Veda 10, radar contact, Pope altimeter now 29.88"

Lead: "Veda 10 flight, 29.88"

- FCI: "988" BAR"

**Turn Prep**

N: "2 miles to turn"

N: "Heading 226T"

N: "Altitude 2000"

**1302z .....2 (POB 190/8)**

- FCI: "988 BAR"
- Navigator verifies INS accuracy

**\*\*\* SWAT RATING FOR DEPARTURE EVENTS**

**Turn Prep**

N: "5 miles to turn"

N: "Heading 183T" (needs drift correction)

N: "Altitude 4000"

**1313z .....3 (A)**

- FCI: "226 PH" present heading, "183 NH" new heading, "240" true airspeed, "→," 5 sec delay, "E" and tone at lead's turn point; start timer countdown (10-15 sec), "183 NH" heading.

**En Route**

- FCI: "230 IAS" When all aircraft are in position, accelerate
- FCI: "+," 5 sec delay, "+, E" and tone
- Lead Maintains 230 KCAS, ±20 KCAS cruise

**Turn Prep**

N: "5 miles to turn"

N: "Heading 242T"

N: "Altitude 4000"

**1318z .....4 (FLO 047/25)**

- FCI: "183 PH" present heading, "242 NH" new heading, "240 TAS" true airspeed, "→," 5 sec delay, "E" and tone at lead's turn point; start timer countdown, "242 NH"

### **Cruise Checklist (Called for by Pilot)**

E: "Cabin Altitude and Oxygen Quantity"  
CP: "2000 Feet, 20 Liters"  
E: "Anti-Ice/De-Ice"  
P: "Off" (as required)  
E: "Continuous Ignition"  
P: "On" (as required)  
E: "Seat Belt Switch"  
P: "On"  
E: "Altimeter"  
CP, P, N: "29.88"  
E: "Radar"  
P, N: "On and tuned" (as required)  
E: "Cruise Check - Completed"

### **Combat Entry Checklist (Called for by Pilot)**

P: "Crew, Combat Entry Checklist"  
E: "Altimeters"  
CP, P, N, E: "29.88"  
E: "Crew Briefing"  
P: "As required"  
• Rest of checklist simulated

### **Approach (FlorenceApp.Contact.aiff)**

App: "Veda 10 flight, contact Florence approach on 118.6"  
Lead: "Veda 10 flight, go 118.6."  
• FCI: "186 FRQ"  
Lead: "Florence App, Veda 10 flight of three with you level 4000."  
FLO: "Veda 10, radar contact."

### **Turn Prep**

N: "5 miles to turn"  
N: "Heading 328T"  
N: "Altitude 4000"

**1328z .....5 (FLO 270/19)**

- FCI: "242 NH" present heading, "328 NH" new heading, "240 TAS" true airspeed, "→," 5 sec delay, "E" and tone at lead's turn point; start timer countdown, "328 NH"

## Equipment Pre-Slowdown Checklist (Called for by Navigator)

N: "Pre-Slowdown checklist"  
L, E: "Acknowledged"  
E: "Air Delivery Switch"  
P: "Zone Marker"  
E: "Door Arming Switch"  
P: "Armed"  
E: "Pressure Door"  
P: "Cleared to Open"  
L: "Open" (Delay until all doors open)  
E: "Altimeter"  
CP, P, N: "29.88"  
CP Cross checks barometric and radar altimeters  
E: "Red Light"  
CP: "ON"  
E: "Command Markers"  
CP, P: "Set"  
E, L: "Pre-Slowdown Checklist-Completed"

## Approach (FlorenceApp.aiff)

Lead: "Florence Approach Veda 10 flight request descent to 3000"

FLO: "Veda 10 flight descent and maintain 3000"

Lead: "Veda 10 cleared down to 3000"

- FCI: "030 ALT", "↓", 5 sec delay, "E" and tone

## Turn Prep

N: "5 miles to turn"

N: "Heading 030T"

N: "Altitude 3000"

1335z .....6 (FLO 306/41)

- FCI: "328 PH" present heading, "030 NH" new heading, "240 TAS" true airspeed, "→", 5 sec delay, "E" and tone at lead's turn point; start timer countdown, heading "030 NH"

## Copilot

- Copilot ensures that the INS not being used by the navigator is in airdrop mode
- Maximum range is 20 NM, line-of-sight

## INS

- Navigator comes out of TACAN aided mode a minimum of 10 minutes prior to drop

## Turn Prep

N: "5 miles to turn"

N: "Heading 046T"

N: "Altitude 2100"

**1338z .....7 (FLO 322/43 (FlorenceApp.IFR.aiff))**

- FCI: "030 PH" present heading, "046 NH" new heading, "240 TAS" true airspeed, "→", 5 sec delay, "E" and tone at lead's turn point; start timer countdown, heading "046 NH"  
Lead: "Florence Approach, Veda 10 flight cancel IFR."  
FLO: "Veda 10 flight, roger, Monitor Fayetteville App 127.8"  
Lead: "Veda 10 flight"  
• FCI: "278 FRQ"

**Range Information**

- Drop zone winds, received in blind 5 minutes prior
- Drop clearance 5 minutes prior
- ZM reception, clearance to drop
- Lead Navigator sends estimated drift and altimeter setting for the drop prior to slowdown
- FCI: "004 RD" "884 BAR"
- FCI: "021 ALT", "↓", 5 sec delay, "E" and tone

**\*\*\* SWAT RATING FOR CRUISE EVENTS UP TO THIS POINT**

**Turn Prep**

- N: "5 miles to turn"
- N: "Heading 082T"
- N: "Altitude 2100"

**1343z .....8 (FLO 342/47 IP)**

- FCI: "046 PH", present heading, "082 NH" new heading, "240" true airspeed, "→", 5 sec delay, "E" and tone at lead's turn point; start timer countdown, heading "082 NH"

**MacKall Tower, 304.6 (MacKallTower.aiff)**

- Lead: "MacKall Tower, Veda 10 flight of three 20 miles west of Luzon DZ at two thousand one hundred feet."  
Range: "Veda 10 flight cleared into the ATA, call again at 5 Miles"

**IP Considerations**

- Depart on course using drift corrected heading to the CARP

**Drop Clearance Luzon CCT 142.2 (DropClear.LuzonCCT.aiff)**

- One minute prior to TOT (earlier if possible)
- Call sign
- Drop zone and TOT
- Drop zone winds in blind 10 minutes prior
- Lead: "Luzon CCT, Veda 10 flight TOT remains 1351, request clearance to drop"
- CCT: "Veda 10, Luzon winds 280 at 5 knots, cleared to drop"

**1346z .....Slowdown**

**Slowdown**

- FCI: "SD" (30 seconds prior to slowdown)
- FCI: "-" (5 seconds prior to slowdown)
- FCI: "E" (at slowdown)
- Throttles-idle
- Decelerate to 160K
- P: "Flaps 75 percent"
- Flaps-set (Wingmen times flaps to stay in position passing 190K)

**Slowdown Checklist (Called for by Copilot once flaps are set)**

- L: "Acknowledged"
- E: "Doors"
- L: "Clear"

E: "All Doors Switch"  
P: "Open" (Copilot actuates All Doors Switch on Pilot's command; Visually checks door position on ADS panel)  
E: "SKE Secondary Control Panel"  
N: "Set" (Wing navigators determine appropriate crosstrack information from the drift offset chart and set it after initiation of the slowdown)  
E: "Doors"  
L: "Open"  
E: "Slowdown Checklist"  
L, E: "Complete"

#### **Descend (Descend.MacKallT.aiff)**

- ZM reception needed for descent and stabilization in IMC
- FCI: "↓" (5 second descent prep)
- FCI: "E" (begin descent)
- N: "Descend to 1300"
- 160 KCAS, 1000 FPM
- Slow to 150 KCAS upon reaching drop altitude, 1300 MSL
- Achieve drop altitude and airspeed by stabilization point
- FCI: updated drift information
- FCI: "6 RD"
- Lead: "MacKall Tower, Veda 10 flight 5 miles"
- Tower: Veda 10 Flight, Roger"

#### **\*\*\* WHEN DESCENDED AND LEVEL, SWAT RATING FOR DROP DESCENT EVENTS**

##### **Run-In**

- Navigator describes aircraft position for the CARP
- Pilot maintains desired track

##### **One Minute Advisory**

- N: "One Minute Advisory"  
L: "Acknowledged"
- Must be stabilized by 30 seconds or "no drop"

#### **1351z .....9 (Drop on Luzon)**

- Lead sends FCI: "↓" five seconds prior to his drop
- Lead sends FCI: "E" at his INS drop time (backup timing for wing aircraft)

##### **Heavy Equipment CARP Checklist**

- N: "Ten Second Advisory" (off own INS)  
N: "Five, four, three, two, one"  
N: "Green light" (Copilot activates Green Light Switch and Chute Release Switch until "All Clear")  
L: "All Clear"  
N: "Red Light" (At end of usable drop zone)  
CP: "Red Light" (Copilot turns Green Light Switch off)  
CP: "Post Drop Checklist" (Copilot makes this call after completion of the Heavy Equipment CARP checklist)

##### **10 (Escape (concurrent with Post-Drop Checklist))**

- FCI: "+" (one minute after Lead's Red Light)
- FCI: "E" (momentarily after prep command, execute DZ departure procedures)
- Accelerate to 160 KCAS
- Maintain 160 KCAS until all doors have closed
- Climb to 3000' MSL, 1000 FPM
- Navigator resets cross track

##### **Heavy Equipment Post Drop Checklist (Copilot calls for after airdrop)**

- CP: "Post Drop Checklist"

L, E: "Acknowledged"  
 E: "Petal Doors and Ramp"  
 L: "Closed"  
 E: "SKE Secondary Control Panel"  
 N: "Set"  
 E: "Air Delivery Switch"  
 P: "Off" (Aircraft will be at minimum IFR altitude prior to placing Aerial Delivery Switch to off)  
 E: "Flaps"  
 • FCI: "230 IAS"  
 • FCI: "+" (acceleration prep when all aircraft are in position, typically takes 3 minutes before ready for acceleration)  
 • FCI: "E" (accelerate to 230 KCAS)  
 P: "Flaps Up"  
 CP: "Flaps Up"  
 E: "Loadmasters Post Drop Checklist"  
 L: "Completed"  
 E: "Door Arming Switch"  
 P: "Off"  
 E: "Red Light Switch"  
 CP: "Off"  
 E: "Pressurization"  
 P: "Pressurized"  
 E: "Post Drop Checklist-Completed"

#### Turn Prep

N: "5 miles to turn"  
 N: "Heading 156T"  
 N: "Altitude 3000"

#### 1353z ..... 11 (Escape Turn)

- FCI: "082 PH", "156 NH", "240 TAS", "→", "5 sec delay", "E", "156 NH"

#### Turn Prep

N: "5 miles to turn"  
 N: "Heading 205T"  
 N: "Altitude 3000"

#### 1356z ..... 12 (A)

- FCI: "156 PH", "205 NH", "240 TAS", "→", "5 sec delay", "E", "205 NH"

#### Equipment Pre-Slowdown Checklist

N: "Pre-Slowdown checklist"  
 L, E: "Acknowledged"  
 E: "Air Delivery Switch"  
 P: "ZM"  
 E: "Door Arming Switch"  
 P: "Armed"  
 E: "Pressure Door"  
 P: "Cleared to Open"  
 L: "Open"  
 E: "Altimeter"  
 CP, P, N: "29.84"  
 CP cross checks barometric and radar altimeters  
 E: "Red Light"

CP: "ON"  
E: "Command Markers"  
CP, P: "Set"  
E, L: "Pre-Slowdown Checklist-Completed"

Turn Prep

N: "5 miles to turn"  
N: "Heading 270T"  
N: "Altitude 3000"

**1359z .....13 (FLO 031/29)**

- FCI: "205 PH", "270 NH", "240 TAS", "→," 5 sec delay, "E", "270 NH"

Turn Prep

N: "5 miles to turn"  
N: "Heading 293T"  
N: "Altitude 3000"

\*\*\* SWAT RATING FOR RUN-IN AND DROP EVENTS

\*\*\* SWAT RATING FOR RECOVERY EVENTS

**1406z .....14 (FLO 337/28)**

- FCI: "270 PH", "293 NH", "240 TAS", "→," 5 sec delay, "E", "293 NH"

Turn Prep

N: "5 miles to turn"  
N: "Heading 046T"  
N: "Altitude 2100"

**1410z .....15 (FLO 322/43)**

- FCI: "293 PH", "046 NH", "240 TAS", "→," 5 sec delay, "E", "046 NH"

### Range clearance (**RngClear.LuzonCCT.aiff**)

Lead: "Luzon CCT, Veda 10 next TOT 1423z"

CCT: "Winds 280 at 5 knots, , cleared to drop."

Lead: "Clear to drop."

- Lead Navigator sends estimated drift and altimeter setting for the drop prior to slowdown

### Turn Prep

N: "5 miles to turn"

N: "Heading 082T"

N: "Altitude 2100"

### 1415z .....16 (**FLO 342/47**)

- FCI: "046 PH", "082 NH", "240 TAS", "→," 5 sec delay, "E", "082 NH"

### Drop Clearance (**DropClear.1423z.aiff**)

Lead: "Luzon CCT, Veda 10 flight TOT of 1423z, request clearance to drop"

Range: "Veda 10, Luzon winds 260 at 7 knots, cleared to drop"

### 1418z .....Slowdown

#### Slowdown (**MacKallTower.Luzon.aiff**)

- FCI: "SD" (30 seconds prior to slowdown)
- FCI: "-" (5 seconds prior to slowdown)
- FCI: "E" (at slowdown)
- Throttles-idle
- Decelerate to 160K
- P: "Flaps 58 percent"
- CP: "Flaps 58 percent"
- Flaps-set (Wing times flaps to stay in position passing 190K)

#### Slowdown Checklist

CP: "Slowdown Checklist" (once flaps are at computed setting)

P, L: "Acknowledged"

E: "Doors"

L: "Clear"

E: "All Doors Switch"

P: "Open" (Copilot actuates All Doors Switch on Pilot's command; Visually checks door position on ADS panel)

E: "SKE Secondary Control Panel"

N: "Set" (Wing navigators determine appropriate crosstrack information from the drift offset chart and set it after initiation of the slowdown)

E: "Doors"

L: "Open"

E: "Slowdown Checklist"

L, E: "Complete"

Lead: "MacKall Tower, Veda 10 Flight 5 miles west of Luzon"

Tower: "Veda 10 we have you in sight."



## Descend

- ZM reception needed for descent and stabilization in IMC
- FCI: "↓" (5 second descent prep)
- FCI: "E" (begin descent)
- 160 KCAS, 1000 FPM
- Slow to 150 KCAS upon reaching drop altitude, 1280 MSL
- Achieve drop altitude and airspeed by stabilization point
- FCI: "007 RD" (updated drift information)

## \*\*\* SWAT RATING FOR DROP DESCENT EVENTS

### Run-In

- Navigator describes aircraft position for the CARP
- Pilot maintains desired track

### One Minute Advisory

- N: "One Minute Advisory"
- L: "Acknowledged"
- Must be stabilized by 30 seconds or "no drop"

## 1423z ..... 17 (Drop on Luzon)

### Heavy Equipment CARP Checklist

- Lead sends FCI: "↓" five seconds prior to his drop
- Lead sends FCI: "E" at his INS drop time (backup timing for wing aircraft)
- N: "Ten Second Advisory" (off own INS)
- N: "Five, four, three, two, one"
- N: "Green light" (Copilot activates Green Light Switch and Chute Release Switch until "All Clear")
- L: "All Clear"
- N: "Red Light" (At end of usable drop zone)
- CP: "Red Light" (Copilot turns Green Light Switch off)
- CP: "Post Drop Checklist" (Copilot makes this call after completion of the Heavy Equipment CARP checklist)

### 18 (Escape)

- FCI: "+" (one minute after Lead's Red Light)
- FCI: "E" (momentarily after prep command, execute DZ departure procedures)
- Accelerate to 160 KCAS
- Maintain 160 KCAS until all doors have closed
- Climb to 4000' MSL, 1000 FPM
- Navigator resets cross track

## Heavy Equipment Post Drop Checklist

- CP: "Post Drop Checklist" (Copilot initiates after completion of the airdrop)
- L: E: "Acknowledged"
- E: "Petal Doors and Ramp"
- L: "Closed"
- E: "SKE Secondary Control Panel"
- N: "Set"
- E: "Air Delivery Switch"
- P: "Off" (Aircraft will be at minimum IFR altitude prior to placing Aerial Delivery Switch to off)
- E: "Flaps"
- FCI: "230 IAS"
- FCI: "+" (acceleration prep when all aircraft are in position)
- FCI: "E" (accelerate to 230 KCAS)
- P: "Flaps Up"
- CP: "Flaps are Up"
- E: "Loadmasters Post Drop Checklist"
- L: "Completed"
- E: "Door Arming Switch"
- P: "Off"
- E: "Red Light Switch"
- CP: "Off"
- E: "Pressurization"
- P: "Off"
- E: "Post Drop Checklist-Completed"

### Turn Prep

- N: "5 miles to turn"
- N: "Heading 151T"
- N: "Altitude 3000"

### 1424z .....19 (Z (FaytApp.Pope.aiff))

- FCI: "082 PH", 151 NH", "240 TAS", "→", 5 sec delay, "E", "151 NH"
- Lead: "Fayetteville App, Veda 10 flight back with you, climbing to 4000'
- FAY: "Veda 10 flight radar contact, climb and maintain 4000. Cleared to Pope as filed."
- Lead: "Climb and, maintain 4000, Veda 10, cleared to Pope."

\*\*\* SWAT RATING FOR RUN-IN AND DROP EVENTS 2ND DROP

\*\*\* SWAT RATING FOR RECOVERY EVENTS FOR 2ND DROP

### Turn Prep

- N: "5 miles to turn"
- N: "Heading 071T"
- N: "Altitude 4000"

### 1427z .....20 (A)

- FCI: "151 PH", 071 NH", "240 TAS", "←", 5 sec delay, "E", "071 NH"

### Range Control (**RngCntrl.Scores.aiff**)

- Number passes
  - Clear of DZ
  - Drop scores
- Lead: "Luzon CCT, Veda 10 flight done for the day, ready to copy scores"
- Range: "Veda 10 flight, on your first pass, Veda 11 scored a PI; Veda 12, 160 yards at 3 o'clock; Veda 13, 170 yards at 9 o'clock. On the second pass, Veda 11 50 yards at 2 o'clock; Veda 12, 160 yards at 3 o'clock; Veda 13, 170 yards at 9 o'clock "
- Lead: "CCT Veda 10 flight copy all"
- Fay: "Change to my frequency 133.0"
- Lead: "Fayetteville Veda 10 flight up 133.0"

### Combat Exit Checklist (Called for by Pilot)

- P: "Crew, Combat Exit Checklist"
- CP, N, E, S, L: "Acknowledged"
- E: "Observers"
- P: "Cleared to Reposition"
- E: "Battle Damage Assessment"
- CP, P, N, E, S, L: "Complete"
- Simulate rest of checklist complete

### Turn Prep

- N: "5 miles to turn"
- N: "Heading 343T"
- N: "Altitude 4000"

1437z .....21 (D)

- FCI: "071 PH", 343 NH", "240 TAS", "←" 5 sec delay, "E", "343 NH"
- Wingmen move to SKE inline for SKE arrival

### Descent Checklist (Called for by Pilot)

- E: "Altimeters"
- CP, P, N: "29.88"
- E: "Radar"
- P, N: "On"
- E: "Crew Briefing"
- P: "Completed" (Pilot briefs)
- E: "Radar Altimeter"
- P, N: "On/Set"
- E: "Thrust Reverse Limiter"
- CP: "Set"
- E: "Continuous Ignition"
- P: "On"
- E: "Seat Belt Switch"
- P: "On"
- E: "Seat Belt and Shoulder Harness"
- CP, P: "Adjusted"
- E: "Descent Check - Completed"

### Approach Checklist (Called for by Pilot)

- E: "Crew Briefing"
- P: "Completed"
- E: "Radar"
- P, N: "On" (as required)

E: "Continuous Ignition"  
P: "On"  
E: "Approach Check - Completed"

**Fayetteville App (FaytApp.11955.aiff)**

Fay: "Veda 10 flight change to my frequency 119.55"  
Lead: "Fayetteville Approach, Veda 10, flight of three, 4000"  
App: "Veda 10, radar contact, descend and maintain 2000, Pope altimeter now 29.86"  
Lead: "Veda 10 flight, descend 2000, altimeter 29.86"  
FCI: "020 ALT", "986 BAR"

**Turn Prep**

N: "5 miles to turn"  
N: "Heading 258T"  
N: "Altitude 2000"

**1442z .....22 (E (PopeTower.Contact.aiff))**

- FCI: "343 PH", "258 NH", "200 IAS". "←", 5 sec delay, "E", "258 NH"  
App: "Veda 10 Flight, maintain present heading, cleared ILS, contact Pope Tower"

**Before Landing Checklist (Called for by Pilot)**

E: "Landing Gear Warning Horn Cut-Out Switch"  
CP: "Normal"  
E: "Landing Gear"  
CP: "Down"  
P: "Down and Centered"  
E: "Command Markers"  
CP, P: "Set"  
E: "Brake Pressure and Release Light"  
CP: "Normal and On"  
E: "Spoilers"  
CP: "Closed and Armed"  
E: "ADI Select Switch"  
CP, P: "Normal"  
E: "Before Landing Check Completed"

**1444z .....23 (I (PopeTower.ILS23.aiff))**

- Intercept ILS final
  - Maintain 160 KCAS until POB NDB
- Lead: "Pope Tower, Veda 11 six miles out, gear down, ILS 23 Pope"  
Tower: "Veda 11, cleared to land"  
• 12,000' minimum spacing, 16,000' desired from lead  
Tower: "Veda 12, winds calm, cleared to land"

**1449z .....24 (Pope)**

- ILS Approach

\*\*\* AFTER LANDING, SWAT RATINGS FOR APPROACH

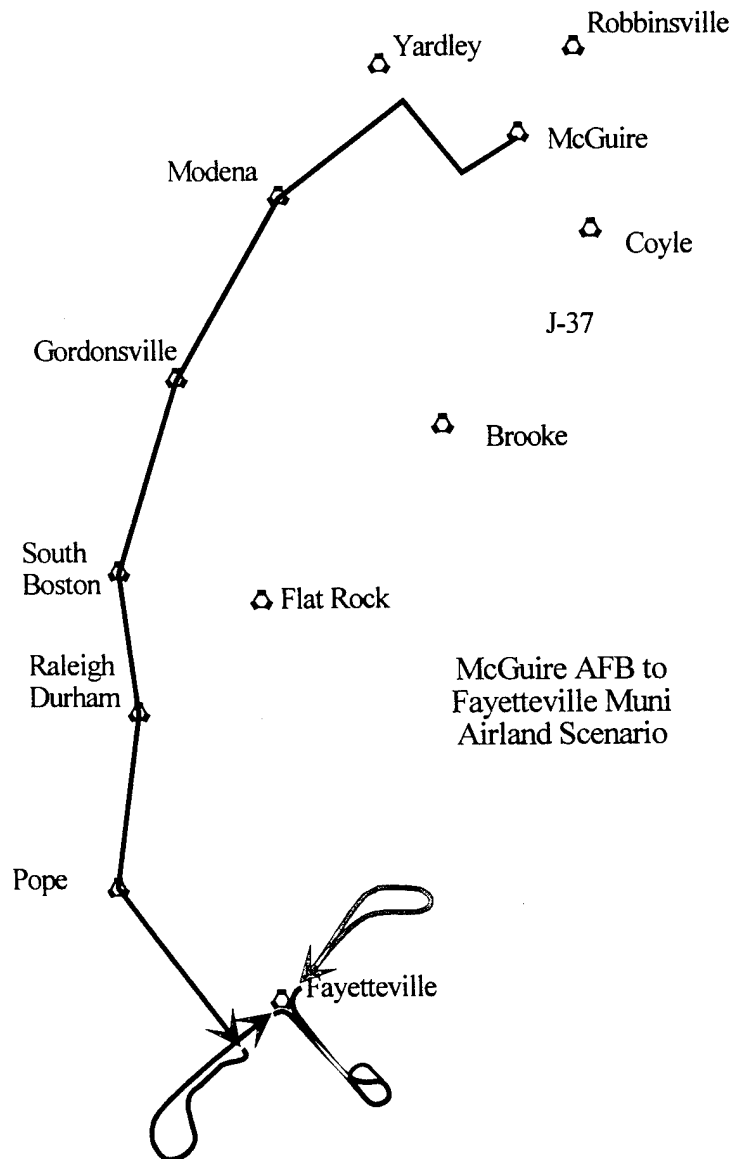
\*\*\* SWAT RATINGS FOR ENTIRE MISSION EVENTS

\*\*\* SWAT RATINGS FOR PROJECTED MISSION IF FLOWN REAL WORLD

**Airland Scenario**  
**McGuire AFB to Fayetteville**  
**429NM, 1+23, FL310, .74 Mach**

General. The mission profile consists of Modena Two Standard Instrument Departure (SID) from RWY 24, McGuire AFB (WRI), transitioning to the high altitude airway system at Modena (MXE). The mission proceeds via J75 to Gordonsville (GVE), INS direct South Boston (SBV), INS direct Raleigh-Durham (RDU), INS direct Pope (POB), direct DOONE (GR) for the NDB RWY 4 at Fayetteville Regional/Grannis Field. The NDB will terminate in a Missed Approach (as published), two turns in holding at GLANDS intersection, followed by a VOR RWY 22 full stop. Both Approaches will be flown using ICAO 45/180 procedure as per AFM 51-37.

**NOTE:** Time permitting, a part task analysis of the operability of the PFD metric format will be conducted. This will consist of one or two approaches with altitudes, elevations, and distances in meters/km.



## McGuire AFB

### Pre-Flight

- The pilot will set up the cockpit for a RWY 24 departure from McGuire AFB. When ready, the pilot will listen to ATIS information.

- PRIMARY FLIGHT CONFIGURATION**

ADI: ATT  
HSI: HDG  
FD: MAG  
ALT: FT  
BARO: IN

**NAV SELECT**

PTR1: TAC1 (GXU)  
PTR2: TAC2 (ARD)  
ATT REF: INS1  
HDG REF: INS1  
AP/FD: LNAV  
CMD/FPA: ?  
FPA: 0.0

- SECONDARY CONFIGURATION**

MAP: RADAR OFF  
TACAN ON  
RNG 25/50  
WND/DRFT BOTH

**DISPLAY CONTROL**

CDS: NORM  
DPU SEL: 1  
DAMU CNTRL: P  
HANDOFF: OFF  
OUTBRD: SFD  
INBRD: PFD

- Copilot Selects ATIS frequency 110.6 or 270.1

ATIS: "McGuire AFB information \_\_\_\_\_, time \_\_\_\_55Z. Weather better than 5000 and 5, winds calm altimeter 29.92. McGuire AFB landing and departing RWY 24. Advise on initial contact you have information \_\_\_\_\_"

- Copilot selects Clearance Delivery Frequency 135.2 or 335.8.

CP: "McGuire Clearance, VEDA 10, IFR to Fayetteville, clearance on request."

Clearance: "VEDA 10, Clearance available, advise when ready to copy."

CP: "VEDA 10 is ready to copy."

Clearance: "VEDA 10, cleared as filed to Fayetteville Regional Airport. Maintain FL230, expect FL310 ten minutes after departure. Departure control frequency 120.25 or 363.8, SQUAWK 3210."

CP: "VEDA 10 cleared to Fayetteville Regional Airport. Maintain FL230, expect FL310 ten minutes after departure. Departure control frequency 120.25 or 363.8, SQUAWK 3210."

Clearance: "VEDA 10, contact McGuire Ground Control on 121.8 or 375.8 when ready to taxi."

CP: "VEDA 10, Ground Control on 121.8 or 375.8 good day."

- Pilot sets Airspeed Command Marker to Go/Rotate speed
- Altitude Command Marker to 6000 feet
- Altitude Alert to 230.
- Pointer 1 to McGuire (GXU)
- Pointer 2 to Yardley (ARD).

### Taxi

CP: "McGuire Ground Control, VEDA 10, ready to taxi with clearance and the numbers."

GND: "VEDA 10, taxi RWY 24, monitor Tower on 119.8 or 255.6 and advise when ready for takeoff."

CP: "Veda 10"

P: "Before Takeoff Checklist"

### Before Takeoff Checklist

E: "Brakes"  
P: "Checked"  
E: "Flight Instruments"  
CP, P: "Checked"  
E: "Altimeters"  
CP, P: "29.92"  
E: "Flaps"  
CP: "Set for takeoff"  
E: "Spoilers"  
CP: "Closed and disarmed"  
E: "Stabilizer, Rudder, and Aileron Trim"  
CP, P: "Set"  
E: "Thrust Reverse Limiter"  
CP: "Set"  
E: "Crew Briefing"  
P: "Completed" (after briefing departure)  
E: "FSAS/INS 1 and 2"  
CP, P: "Programmed and set"  
E: "Radios, Radar, and Radar Altimeter"  
CP, P: "Set"  
E: "Yaw damper"  
CP: "On"  
E: "Warning Lights"  
CP, P: "Checked"  
E: "Before Takeoff Check complete"

### Lineup

CP: "Ground VEDA 10, going to Tower."  
• Copilot selects Ground Control on 121.8 or 375.8.  
CP: "McGuire Tower, VEDA 10, number 1, ready for takeoff."  
Tower: "VEDA 10, winds calm, cleared for takeoff."  
CP: "VEDA 10, copies cleared for takeoff."  
P: "Line-Up Checklist"

## Lineup Checklist

E: "Spoilers"  
CP, P: "Closed and Armed"  
E: "IFF"  
CP: "Set"  
E: "Continuous Ignition"  
CP: "On" (as required)  
E: "Engine Anti-Ice"  
CP: "Off" (as required)  
E: "Anti-Collision/Strobe Lights"  
CP: "Set"  
E: "Pitot Heat and Temp Probe De-Ice"  
CP: "On"  
E: "Angle of Attack De-Ice"  
CP: "On"  
E: "Takeoff Light"  
P: "Checked"  
E: "Lineup Check - Completed"

## RELEASE SIMULATOR

### Takeoff

- Pilot advances power to takeoff EPR
- Release brakes and accelerate to Go/Rotate speed  
CP: "Go"
- Positive rate of climb  
P, CP: "Gear up"
- Accelerate to minimum flap retract speed  
P, CP: "Flaps up"
- Tower: "Veda 10 contact McGuire Departure Control"  
CP: "Veda 10 going to Departure"
- Copilot changes to 120.25  
CP: "Departure, Veda 10 passing \_\_\_\_\_, climbing to 6000"  
Dep: "VEDA 10, radar contact, climbing to 6000."  
P: "After Takeoff Climb Checklist"

### After Takeoff, Climb Checklist

E: "Spoilers"  
CP: "Closed and Disarmed"  
E: "Landing Gear Warning Horn Cut-Out Switch"  
CP: "Off"  
E: "Exterior Lights" (strokes off)  
CP: "Extended and On" (as required)  
E: "No Smoking Switch"  
CP: "Off" (as required)  
E: slight delay then, "After Takeoff, Climb Check - Completed"



### **Standard Instrument Departure (SID)**

- Pilot flies the ARD R172 after using the DAMU SWAP function and set course 352.
- Copilot tunes in Modena
- Pilot selects MXE as Pointer #2 NAVAID.
- Passing ARD 172/017 fix, Pilot sets Altitude Command Marker to FL230.
- At NAGGS (**WAYPOINT 2**) Pilot selects Modena (MXE) as Primary NAV utilizing DAMU SWAP function and set course 259.
- Copilot tunes in Gordonsville
- Pilot sets Gordonsville (GVE) as Pointer #2 NAVAID.

**\*\*\* AFTER CROSSING WAYPOINT 2: SWAT SCORE FOR DEPARTURE EVENTS**

### **20NM inbound to MXE (Modena - Waypoint 3)**

- Dep: "VEDA 10, Contact Washington Center on 132.55."  
CP: "VEDA 10 going to Washington on 132.55."
- Copilot selects Washington Center frequency 132.55 or 279.6.  
CP: "Washington Center, VEDA 10, with you passing \_\_\_\_\_ for FL230, requesting higher."
- Wash: "VEDA 10, Radar Contact, climb and maintain FL310."  
CP: "VEDA 10, passing \_\_\_\_\_ for FL310."
- Pilot sets Altitude Alert to FL310.
  - Sets MXE 240R outbound course.
  - Changes range on Secondary Flight Display Format from Takeoff/Departure range (25 or 50 NM) to Climb/Cruise range (150 or 300NM).

### **Modena (Approximately 70 miles outbound from MXE) - Waypoint 3**

- Wash: "VEDA 10, contact Washington Center now on 135.2."  
CP: "VEDA 10, 135.2, good day."
- Selects Washington Center frequency 135.2.  
CP: "Washington Center, VEDA 10 with you FL310."
- Wash: "VEDA 10, radar contact, maintain FL310."  
P: "Cruise Checklist"

### **Cruise Checklist (expect when 31,000 feet and level)**

- E: "Cabin Altitude and Oxygen Quantity"  
CP: "2000 Feet, 20 Liters"  
E: "Anti-Ice/De-Ice"  
P: "Off" (as required)  
E: "Continuous Ignition"  
P: "On" (as required)  
E: "Seat Belt Switch"  
P: "On"  
E: "Altimeter"  
CP, P: "29.88"  
E: "Radar"  
P: "On and tuned" (as required)  
E: "Cruise Check - Completed"

### **SYSTEM DEMONSTRATIONS (CONOP CONFIG) BETWEEN WAYPOINT 3 (after reach FL310 & Cruise Checklist completed), AND GORDONSVILLE (Waypoint 5)**

TACAN / VOR FAIL WHEN SIGNAL LOST  
METERS / BARO MODES (M/ MB)

EXPANDED HSI  
TRK-UP / TRUE MODES WHEN IN INS  
SFD OPTIONS  
TACAN DISPLAYS  
RADAR AND RANGE SETTINGS

### Offset Waypoint (Waypoint 4)

**APPROX. 10 NM INBOUND TO GORDONSVILLE (Waypoint 5), SIMULATE CP  
DAMU FAIL WHEN IN CONOP CONFIG** (Access the copilot's DAMU, and repeat pilot's  
PFD and SFD)

DISPLAY CONTROL MENU

DAMU CNTRL: CP  
OUTBRD: SFD REPEAT  
INBRD: PFD REPEAT  
DAMU CNTRL: P

**\*\*\*UPON COMPLETION, SWAT SCORE FOR DAMU FAIL EVENTS**

### Gordonsville (Waypoint 5)

Wash: "All aircraft, this is Washington Center with convective SIGMET Charlie effective time \_\_\_\_\_ Z. A line of  
thunderstorms extending from \_\_\_\_\_ to \_\_\_\_\_ to moving \_\_\_\_\_ degrees at \_\_\_\_\_ knots, tops to \_\_\_\_\_  
feet. 1 inch hail and moderate to severe turbulence reported in clouds. Contact flight watch for additional  
information.

- Selects SFD RADAR OVERLAY.
  - **SECONDARY FLIGHT CONTROL DISPLAY CONFIGURATION**

**MAP: RADAR ON.**

- Pilot selects Gordonsville (GVE) as primary Nav utilizing SWAP function and sets course 226.
- Set South Boston (SBV) as Pointer #2.
- Select INS as Pointer #1 at Gordonsville (GVE). and proceeds direct to SBV.
- Passing GVE Pilot sets Raleigh-Durham as pointer #2.

### Approximately 20NM outbound from Gordonsville (Waypoint 5)

Wash: "VEDA 10, contact Washington Center on 118.75"

CP: "VEDA 10, 118.75, good day"

- Copilot selects Washington frequency 118.75 or 377.1  
CP: "Washington Center, VEDA 10, FL310."  
Wash: "VEDA 10, Radar contact, maintain FL310."

### Approximately 45NM inbound to South Boston (Waypoint 6)

- Pilot briefs approach into Fayetteville
- sets Airspeed Marker to Approach Speed
- Sets Altitude Command Marker to MDA.  
P: "Descent Check"

**\*\*\*45 NM INBOUND TO S. BOSTON, SWAT SCORE FOR CRUISE EVENTS**

### Descent Checklist

E: "Altimeters"  
CP, P: "29.92"  
E: "Radar"  
P: "On"  
E: "Crew Briefing"  
P: "Completed"

E: "Radar Altimeter"  
P: "On/Set"  
E: "Thrust Reverse Limiter"  
CP: "Set"  
E: "Continuous Ignition"  
P: "On"  
E: "Seat Belt Switch"  
P: "On"  
E: "Seat Belt and Shoulder Harness"  
CP, P: "Adjusted"  
E: "Descent Check - Completed"

### **Approaching South Boston**

Wash: "VEDA 10, Descend and maintain FL230."

CP: "VEDA 10, departing FL310 for FL230."

- Pilot sets Altitude Alert to FL230.
- Over SBV selects RDU as primary Nav (VOR) utilizing the DAMU SWAP function.
- Copilot tunes in Pope (POB)
- Pilot sets POB as Pointer #2.

Wash: "VEDA 10, Contact Washington Center on 124.05 or 307.0."

CP: "VEDA 10 Washington now 124.05"

- Copilot selects Washington Center Frequency 124.05.

CP: "Washington Center , VEDA 10 FL230."

Wash: "VEDA 10, descend pilot's discretion, maintain 10,000. Cross RDU at or below 15,000. RDU altimeter 29.92."

CP: "VEDA 10, out of FL230 for 10,000, altimeter 29.92."

- Pilot sets Altitude Alert to 10,000.
- Select SFD to Expanded HSI
- SECONDARY FLIGHT DISPLAY CONFIGURATION  
**HSI: WND/DRFT: WND, DRFT or BOTH**

### **Raleigh Durham (Waypoint 7)**

- Pilot sets POB as Primary Nav Utilizing DAMU SWAP function.
- Sets DOONE (GR) or Fayetteville (FAY) as Pointer #2.  
Wash: "VEDA 10, contact Washington Center on 135.2 or 348.65. Report level 10,000."  
CP: "Washington on 135.2, report 10 thousand, VEDA 10"
- Copilot selects Washington Center Frequency 135.2 or 348.65.  
CP: "Washington Center, VEDA 10 out of \_\_\_\_\_ for 10,000."  
Wash: "VEDA 10, descend and maintain 3000. Proceed direct Fayetteville."  
CP: "VEDA 10, descending to 3000, direct Fayetteville."
- Pilot sets 3000 in Altitude Alert
- Sets Pointer #1 to FAY or GR (whichever is not in PTR #2). If FAY is set to PTR #1, then proceed direct, if GR is set PTR #1 then execute DAMU SWAP function and then proceed direct.  
P: "Approach Checklist"

### **Approach Checklist**

- E: "Crew Briefing"
- P: "Completed"
- E: "Radar"
- P: "On" (as required)
- E: "Continuous Ignition"
- P: "On"
- E: "Approach Check - Completed"

### **20NM inbound to Pope (Waypoint 8)**

- Wash: "VEDA 10, Contact Fayetteville Approach on 133.0 or 295.0."  
CP: "Fayetteville 133.0, Veda 10"
- Selects Fayetteville Approach Control frequency 133.0 or 295.0  
CP: "Fayetteville Approach VEDA 10, level 3000, direct Fayetteville."  
Fay: "VEDA 10, Radar contact, Fayetteville weather; ceiling 600 broken visibility 2 miles, with fog and light drizzle, winds 270 at 5 kts, altimeter 29.92, ILS RWY 04 out of service. Expect NDB RWY 04 full stop."  
CP: VEDA 10, copies all, altimeter 29.92."  
Fay: "VEDA 10, Cleared NDB RWY 04."  
CP: "VEDA 10, cleared approach."

## NDB RWY 04 Fayetteville

- Pilot sets Altitude Alert to 2200 (will not alert due to 2500 foot threshold)
- Fly 218 bearing outbound (PTR2, BDHI, or can execute SWAP and use PTR1.)  
CP: "VEDA 10 departing 3000 for 2200."  
Fay: "VEDA 10, roger, report procedure turn inbound."  
CP: "VEDA 10 WILCO."
- Slows below 200 KCAS  
P, CP: "Flaps approach"
- Set HDG Marker for 173 degrees (45 degree heading change for course reversal)
- Set HDG Marker for 335 degrees (180 degree heading change to re-intercept course inbound)
- Set 038 course inbound (Fly 038 BRG inbound).  
CP: "Fayetteville Approach, VEDA 10 procedure turn inbound."  
Fay: "VEDA 10 Contact Fayetteville Tower on 118.3 or 348.6."  
CP: "VEDA 10 going to tower."
- Copilot selects Tower Frequency 118.3 or 348.6.  
P, CP: "Gear down"  
P: "Before Landing Checklist"

## Before Landing Checklist

- E: "Landing Gear Warning Horn Cut-Out Switch"
- CP: "Normal"
- E: "Landing Gear"
- CP: "Down"
- P: "Down and Centered"
- E: "Command Markers"
- CP, P: "Set"
- E: "Brake Pressure and Release Light"
- CP: "Normal and On"
- E: "Spoilers"
- CP: "Closed and Armed"
- E: "ADI Select Switch"
- CP, P: "Normal"
- E: "Before Landing Check Completed"

## Fayetteville Muni

- P, CP: "Flaps, Landing."
- CP: "Fayetteville Tower, VEDA 10 NDB inbound, gear down."
- Tower: "VEDA 10, check gear down, winds 270 at 7 knots cleared to land RWY 04."
- CP: "VEDA 10 is gear down, cleared to land."

\*\*\* AROUND PILOT REQUEST FOR FLAPS LANDING OR GEAR DOWN, SWAT  
SCORE FOR APPROACH EVENTS UP TO THIS POINT

CP: "Hundred above" (Minimum descent altitude), "Minimums"  
CP: "Airfield not in sight"  
P: "Go around"

- Pilot sets Go Around EPR  
P, CP: "Flaps approach"
- Copilot sets flaps approach  
P, CP: "Gear up"
- Copilot raises gear  
P, CP: "Flaps up"
- Copilot retracts flaps

### Missed Approach

- CP: "VEDA 10, executing Missed Approach."  
Tower: "VEDA 10, contact Fayetteville Approach on 133.0 or 295.0."  
CP: "VEDA 10, going to departure."
- Select Fayetteville Departure Control frequency 133.0 or 295.0.  
CP: "Fayetteville Departure VEDA 10 with you executing published missed approach."
  - Pilot executes Missed Approach
  - Selects FAY as primary Nav utilizing DAMU SWAP function and sets course 311)
  - Sets pointer #2 to Florence (FLO) (Sets HDG MKR to 057 or 237 for cross radial (optional) ).  
Fay: "VEDA 10, Radar Contact. Climb and maintain 3000, Proceed direct GANDS and hold. State your intentions."  
CP: "VEDA 10 climbing to 3000, request two turns in holding followed by the VOR RWY 22 full stop at Fayetteville."  
Fay: "VEDA 10 approved as requested. Report Departing GANDS."  
CP: "VEDA 10 WILCO."
  - Pilot sets Altitude Alert to 3000.
  - Sets Airspeed Command Marker to 200 KCAS.

### GANDS

#### AT HOLDING PATTERN, SIMULATE INS FAILURE.

#### \*\*\* SWAT SCORES FOR INS FAIL CORRECTION

- Enter holding, complete two turns,
  - Pilot briefs VOR RWY 22 approach
  - Changes Altitude Command Marker to 540
- CP: "Fayetteville Approach, VEDA 10, departing GANDS level 3000."  
FAY: "VEDA 10, cleared VOR RWY 22 report procedure turn inbound."  
CP: "VEDA 10, copies cleared approach, WILCO."

## **VOR RWY 22 Fayetteville**

- Pilot sets outbound course 019.  
CP: "Fayetteville Approach VEDA 10 departing 3000 for 2000 procedure turn outbound."  
FAY: "VEDA 10, roger."  
P, CP: "Flaps approach"
- Copilot sets flaps to approach.  
P, CP: "Gear down"
- Copilot lowers gear.  
P: "Before Landing Checklist"

### **Before Landing Checklist**

- E: "Landing Gear Warning Horn Cut-Out Switch"
- CP: "Normal"
- E: "Landing Gear"
- CP: "Down"
- P: "Down and Centered"
- E: "Command Markers"
- CP, P: "Set"
- E: "Brake Pressure and Release Light"
- CP: "Normal and On"
- E: "Spoilers"
- CP: "Closed and Armed"
- E: "Before Landing Check Completed"

### **Outbound**

- Set HDG Marker to 064 (45 degree heading change for course reversal)
- Set HDG Marker to 244 (180 degree heading change to re-intercept course inbound)
- Set inbound course 199.  
CP: "Fayetteville Approach, VEDA 10 departing 2000 for 1100, procedure turn inbound."  
FAY: "VEDA 10, contact Fayetteville Tower on 118.3 or 269.2."  
CP: "VEDA 10 going to Tower."
- Copilot selects Fayetteville Tower Frequency 118.3 or 269.2  
CP: "Fayetteville Tower, VEDA 10 is with you VOR inbound."  
Tower: "VEDA 10 check gear down, winds calm, cleared to land RWY 22."  
CP: "VEDA 10 is gear down, cleared to land."
- Pilot lands the aircraft

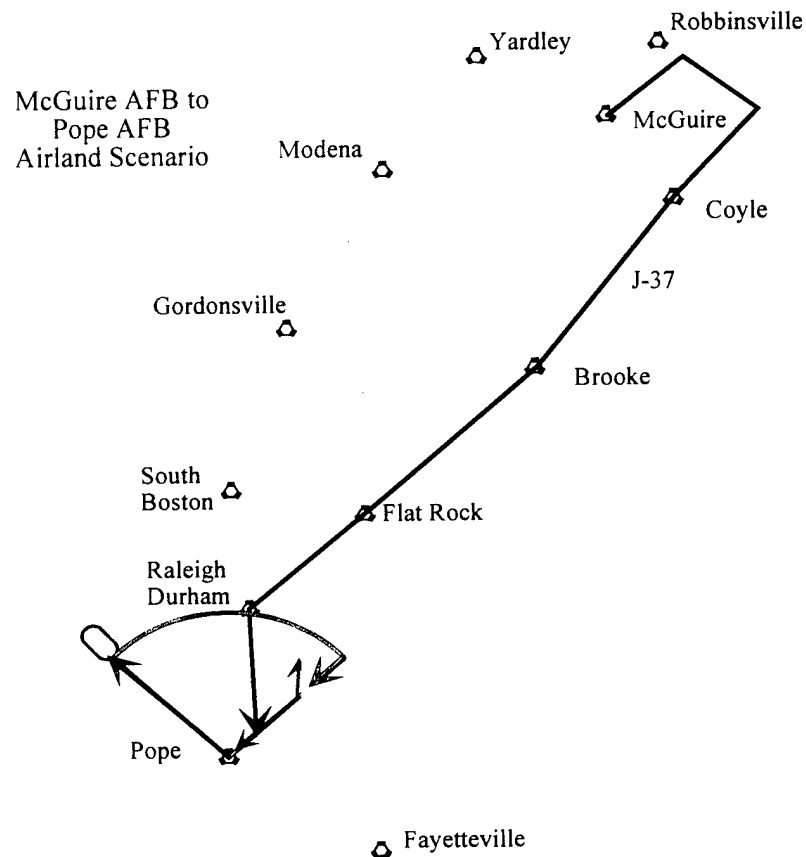
**\*\*\*AFTER LANDING, SWAT SCORES FOR 2ND APPROACH EVENTS**

**\*\*\*SWAT SCORES FOR ENTIRE MISSION**

**\*\*\*SWAT SCORES FOR PROJECTED REAL-WORLD MISSION**

**Airland Scenario**  
**McGuire AFB to Pope AFB**  
**431NM, 1+23, FL310, .74MACH**

General. Mission Profile consists of Cressi Two Standard Instrument Departure (SID) from RWY 06, McGuire AFB (WRI), transitioning to the high altitude airway system at Coyle (CYN). The mission proceeds via J37 to Brooke (BRV), INS direct Flat Rock (FAK), INS direct Raleigh-Durham (RDU), INS direct Pope (POB), for the NDB RWY 23 at Pope AFB. The NDB will terminate in a Missed Approach direct AWGUS INTX, two turns in holding at AWGUS intersection, followed by a TAC RWY 23 full stop. The NDB approach will be flown using ICAO 45/180 procedure as per AFM 51-37.





## McGuire AFB

### Pre-Flight

- THE PILOT WILL SET UP THE COCKPIT FOR A RWY 06 DEPARTURE FROM MCGUIRE AFB. WHEN READY, THE PILOT WILL LISTEN TO ATIS INFORMATION.

#### PRIMARY FLIGHT CONFIGURATION

ADI: ATT  
HSI: HDG  
FD: MAG  
ALT: FT  
BARO: IN

#### NAV SELECT

PTR1: TAC1 (GXU)  
PTR2: TAC2 (ARD)  
ATT REF: INS1  
HDG REF: INS1  
AP/FD: HDG  
CMD/FPA: ?  
FPA: 0.0

- SECONDARY CONFIGURATION

MAP: RADAR OFF  
TACAN ON  
RNG 25/50  
WND/DRFT BOTH

#### DISPLAY CONTROL

CDS: NORM  
DPU SEL: 1  
DAMU CNTRL: P  
HANDOFF: OFF  
OUTBRD: SFD  
INBRD: PFD

- Copilot Selects ATIS frequency 110.6 or 270.1  
ATIS: "McGuire AFB information \_\_\_\_\_, time \_\_\_\_55Z. Weather better than 5000 and 5, winds calm altimeter 29.92. McGuire AFB landing and departing RWY 6. Advise on initial contact you have information \_\_\_\_\_."
- Copilot selects Clearance Delivery Frequency 135.2 or 335.8.  
CP: "McGuire Clearance, VEDA 10, IFR to Fayetteville, clearance on request."  
Clearance: "VEDA 10, Clearance available, advise when ready to copy."  
CP: "VEDA 10 is ready to copy."  
Clearance: "VEDA 10, cleared as filed to Pope AFB. Maintain FL230, expect FL310 ten minutes after departure. Departure control frequency 120.25 or 363.8, SQUAWK 3210."  
CP: "VEDA 10 cleared to Pope AFB. Maintain FL230, expect FL310 ten minutes after departure. Departure control frequency 120.25 or 363.8, SQUAWK 3210."  
Clearance: "VEDA 10, contact McGuire Ground Control on 121.8 or 375.8 when ready to taxi."  
CP: "VEDA 10, Ground Control on 121.8 or 375.8 good day."
- Pilot sets Airspeed Command Marker to Go/Rotate speed
- Altitude Command Marker to 5000 feet
- Altitude Alert to 230.
- Pointer 1 to McGuire (GXU)
- Pointer 2 to Robbinsville (RBV).

### Taxi

- CP: "McGuire Ground Control, VEDA 10, ready to taxi with clearance and the numbers."  
GND: "VEDA 10, taxi RWY 06, advise Tower on 119.8 or 255.6 and when ready for takeoff."  
CP: "Veda 10"  
P: "Before Takeoff Checklist"

### Before Takeoff Checklist

- E: "Brakes"  
P: "Checked"  
E: "ADI Select and Air Delivery Switches"  
CP: "Normal"

P: "Normal and On"  
 E: "Flight Instruments"  
 CP, P: "Checked"  
 E: "Altimeters"  
 CP, P: "29.92"  
 E: "Flaps"  
 CP: "Set for takeoff"  
 E: "Spoilers"  
 CP: "Closed and disarmed"  
 E: "Stabilizer, Rudder, and Aileron Trim"  
 CP, P: "Set"  
 E: "Thrust Reverse Limiter"  
 CP: "Set"  
 E: "Crew Briefing"  
 P: "Completed" (after briefing departure)  
 E: "FSAS/INS 1 and 2"  
 CP, P: "Programmed and set"  
 E: "Radios, Radar, and Radar Altimeter"  
 CP, P: "Set"  
 E: "Yaw damper"  
 CP: "On"  
 E: "Warning Lights"  
 CP, P: "Checked"  
 E: "Before Takeoff Check complete"

## Lineup

- CP: "Ground VEDA 10, going to Tower."
- Copilot selects Ground Control on 121.8 or 375.8.
- CP: "McGuire Tower, VEDA 10, number 1, ready for takeoff."
- Tower: "VEDA 10, winds calm, cleared for takeoff."
- CP: "VEDA 10, copies cleared for takeoff."
- P: "Line-Up Checklist"

## Lineup Checklist

E: "Spoilers"  
CP, P: "Closed and Armed"  
E: "IFF"  
CP: "Set"  
E: "Continuous Ignition"  
CP: "On" (as required)  
E: "Engine Anti-Ice"  
CP: "Off" (as required)  
E: "Anti-Collision/Strobe Lights"  
CP: "Set"  
E: "Pitot Heat and Temp Probe De-Ice"  
CP: "On"  
E: "Angle of Attack De-Ice"  
CP: "On"  
E: "Takeoff Light"  
P: "Checked"  
E: "Lineup Check - Completed"

## RELEASE SIMULATOR

### Takeoff

- Pilot advances power to takeoff EPR
- Release brakes and accelerate to Go/Rotate speed  
CP: "Go"
- Positive rate of climb  
P, CP: "Gear up"
- Accelerate to minimum flap retract speed  
P, CP: "Flaps up"
- Tower: "Veda 10 contact McGuire Departure Control"  
CP: "Veda 10 going to Departure"
- Copilot changes to 120.25  
CP: "Departure, Veda 10 passing \_\_\_\_\_, leveling 5000"
- Dep: "VEDA 10, radar contact."  
P: "After Takeoff Climb Checklist"

### After Takeoff, Climb Checklist

E: "Spoilers"  
CP: "Closed and Disarmed"  
E: "Landing Gear Warning Horn Cut-Out Switch"  
CP: "Off"  
E: "Exterior Lights" (strokes off)  
CP: "Extended and On" (as required)  
E: "No Smoking Switch"  
CP: "Off" (as required)  
E: slight delay then, "After Takeoff, Climb Check - Completed"

### Standard Instrument Departure (SID)

- Pilot flies the RBV R122 as Primary Nav utilizing DAMU SWAP function and sets course 302.
- Pilot selects CYN as Pointer #2 NAVAID.
- Passing 5000 foot restriction, Pilot sets Altitude Command Marker to FL230.
- Over Dixie (**Waypoint 2**) selects CYN as Primary NAV utilizing DAMU SWAP function and sets course 226
- Copilot tunes in Brooke (BRV)
- Pilot sets (BRV) as Pointer #2 NAVAID.

### AFTER CROSSING DIXIE (**Waypoint 2**)

#### \*\*\* SWAT RATINGS FOR DEPARTURE EVENTS

### Outbound Coyle (**Waypoint 3**)

- Dep: "VEDA 10, Contact Washington Center on 132.55."
- CP: "VEDA 10 going to Washington on 132.55."
- Copilot selects Washington Center frequency 132.55 or 279.6.  
CP: "Washington Center, VEDA 10, with you passing \_\_\_\_\_ for FL230, requesting higher."
- Wash: "VEDA 10, Radar Contact, climb and maintain FL310."
- CP: "VEDA 10, passing \_\_\_\_\_ for FL310."
- Pilot sets Altitude Alert to FL310.
  - Sets CYN 236R outbound course.
  - Changes range on Secondary Flight Display Format from Takeoff / Departure range (25 or 50 NM) to Climb/Cruise range (150 or 300NM).

### Approximately 70 miles outbound from Coyle

- Wash: "VEDA 10, contact Washington Center now on 135.2."
- CP: "VEDA 10, 135.2, good day."
- Selects Washington Center frequency 135.2.  
CP: "Washington Center, VEDA 10 with you FL310."
- Wash: "VEDA 10, radar contact, maintain FL310."
- P: "Cruise Checklist"

### Cruise Checklist

- E: "Cabin Altitude and Oxygen Quantity"
- CP: "2000 Feet, 20 Liters"
- E: "Anti-Ice/De-Ice"
- P: "Off" (as required)
- E: "Continuous Ignition"
- P: "On" (as required)
- E: "Seat Belt Switch"
- P: "On"
- E: "Altimeter"
- CP, P, N: "29.88"
- E: "Radar"
- P, N: "On and tuned" (as required)
- E: "Cruise Check - Completed"

### SYSTEM DEMONSTRATIONS (CONOP CONFIG) BETWEEN WAYPOINT 3 (after reach FL310 and Cruise Checklist completed), AND (WAYPOINT 5) BROOKE

DEMONSTRATION OF TACAN/VOR FAILURE WHEN SIGNAL IS LOST  
METERS / BARO MODES (M/MB)

EXPANDED HSI  
HDG -UP / TRUE MODES (WHEN IN INS)  
SFD OPTIONS

TACAN STATION DISPLAYS  
MAP RADAR AND RANGE SETTINGS

- Over NALES intersection (**Waypoint 4**), Pilot selects Brooke (BRV) as primary Nav utilizing SWAP function and sets course 256.
- Set Flat Rock (FAK) as Pointer #2.
- Select INS as Pointer #1 at Brooke (BRV).
- Sets Raleigh-Durham as pointer #2.

Wash: "All aircraft, this is Washington Center with convective SIGMET Charlie effective time \_\_\_\_\_ Z. A line of thunderstorms extending from \_\_\_\_\_ to \_\_\_\_\_ to moving \_\_\_\_\_ degrees at \_\_\_\_\_ knots, tops to \_\_\_\_\_ feet. 1 inch hail and moderate to severe turbulence reported in clouds. Contact flight watch for additional information.

- Selects SFD RADAR OVERLAY.

SECONDARY FLIGHT CONTROL DISPLAY CONFIGURATION  
MAP: RADAR ON.

**APPROX. 10 NM INBOUND TO BROOKE (Waypoint 5), SIMULATE DAMU FAIL (CDS CONFIG)** Access the copilot's DAMU, and repeat pilot's PFD and SFD)

DISPLAY CONTROL MENU  
DAMU CNTRL: CP  
OUTBRD: SFD REPEAT  
INBRD: PFD REPEAT  
DAMU CNTRL: P

**\*\*\* SWAT RATINGS FOR DAMU FAIL EVENTS**

**Approximately 20NM outbound from Brooke (Waypoint 5)**

Wash: "VEDA 10, contact Washington Center on 118.75"

CP: "VEDA 10, 118.75, good day"

- Copilot selects Washington frequency 118.75 or 377.1  
CP: "Washington Center, VEDA 10, FL310."

Wash: "VEDA 10, Radar contact, maintain FL310."

**\*\*\* APPROX. 30 NM INBOUND TO FLAT ROCK (WAYPOINT 6), SWAT RATINGS FOR CRUISE EVENTS**

## Flat Rock (Waypoint 6)

- Pilot briefs approach into Fayetteville
- sets Airspeed Marker to Approach Speed
- Sets Altitude Command Marker to MDA.
  - P: "Descent Check"

### Descent Checklist

- E: "Altimeters"
- CP, P: "29.92"
- E: "Radar"
- P: "On"
- E: "Crew Briefing"
- P: "Completed"
- E: "Radar Altimeter"
- P: "On/Set"
- E: "Thrust Reverse Limiter"
- CP: "Set"
- E: "Continuous Ignition"
- P: "On"
- E: "Seat Belt Switch"
- P: "On"
- E: "Seat Belt and Shoulder Harness"
- CP, P: "Adjusted"
- E: "Descent Check - Completed"

Wash: "VEDA 10, Descend and maintain FL230."

CP: "VEDA 10, departing FL310 for FL230."

- Pilot sets Altitude Alert to FL230.
- Selects RDU as primary Nav (VOR) utilizing the DAMU SWAP function.
- Copilot tunes in Pope (POB)
- Pilot sets POB as Pointer #2 (TAC or NDB).
  - Wash: "VEDA 10, Contact Washington Center on 124.05 or 307.0."
  - CP: "VEDA 10 Washington now 124.05"
- Copilot selects Washington Center Frequency 124.05.
  - CP: "Washington Center , VEDA 10 FL230."
- Wash: "VEDA 10, descend pilot's discretion, maintain 10,000. Cross RDU at or below 15,000. RDU altimeter 29.92."
- CP: "VEDA 10, out of FL230 for 10,000, altimeter 29.92."
- Pilot sets Altitude Alert to 10,000.
- Select SFD to Expanded HSI

- **SECONDARY FLIGHT DISPLAY CONFIGURATION**

**HSI:** WND/DRFT: WND, DRFT or BOTH

### **Raleigh Durham (Waypoint 7)**

- Pilot sets POB (TAC or NDB) as Primary Nav Utilizing DAMU SWAP function.
  - Sets POB (TAC or NDB) as Pointer #2 (Depending on PTR1 selection).
- Wash: "VEDA 10, contact Washington Center on 135.2 or 348.65. Report level 10,000."
- CP: "Washington on 135.2, report 10 thousand, VEDA 10"
- Copilot selects Washington Center Frequency 135.2 or 348.65.
- CP: "Washington Center, VEDA 10 out of \_\_\_\_\_ for 10,000."
- Wash: "VEDA 10, descend and maintain 3000. Proceed direct Pope."
- CP: "VEDA 10, descending to 3000 direct POB."
- Pilot sets 3000 in Altitude Alert
  - Pilot select ATIS frequency 132.3 for Pope weather.
- ATIS: "Pope AFB information \_\_\_\_\_, time \_\_\_\_55Z. Ceiling 600 broken visibility 2 miles with fog and light drizzle, winds calm altimeter 29.92. ILS out of service, expect NDB full stop. Pope landing and departing RWY 23. Advise on initial contact you have information \_\_\_\_\_."
- P: "Approach Checklist"

### **Approach Checklist**

- E: "Crew Briefing"
- P: "Completed"
- E: "Radar"
- P, N: "On" (as required)
- E: "Continuous Ignition"
- P: "On"
- E: "Approach Check - Completed"

### **30NM inbound to Pope**

- Wash: "VEDA 10, Contact Fayetteville Approach on 133.0 or 295.0."
- CP: "Fayetteville 133.0, Veda 10"
- Selects Fayetteville Approach Control frequency 133.0 or 295.0
- CP: "Fayetteville Approach VEDA 10, level 3000, direct Pope with the numbers."
- FAY: "VEDA 10, Radar contact, maintain 3000, cleared NDB RWY 23 at Pope. In the event of Missed Approach, climb RWY HDG to 1000 feet then turn right direct AWGUS and hold. Maintain 3000."
- CP: VEDA 10, copies cleared approach."

### NDB RWY 23 Pope

- Pilot sets Altitude Alert to 1700 (will not alert due to 2500 foot threshold)
- Fly 049 BEARING outbound.  
CP: "VEDA 10 departing 3,000 for 1700."  
FAY: "VEDA 10, roger, report procedure turn inbound."  
CP: "VEDA 10 WILCO."
- Slows below 200 KCAS  
P, CP: "Flaps approach"
- Sets Air Speed Marker to Approach Speed
- Set HDG Marker for 004 degrees (45 degree heading change for course reversal)
- Set HDG Marker for 184 degrees (180 degree heading change to re-intercept course inbound)
- Set 229 course inbound (Fly 229 BRG inbound)  
CP: "Fayetteville Approach, VEDA 10 procedure turn inbound."  
Fay: "VEDA 10 Contact Fayetteville Tower on 118.3 or 348.6."  
CP: "VEDA 10 going to tower."
- Copilot selects Tower Frequency 118.3 or 348.6.  
P, CP: "Gear down"  
P: "Before Landing Checklist"

### Before Landing Checklist

- E: "Landing Gear Warning Horn Cut-Out Switch"
- CP: "Normal"
- E: "Landing Gear"
- CP: "Down"
- P: "Down and Centered"
- E: "Command Markers"
- CP, P: "Set"
- E: "Brake Pressure and Release Light"
- CP: "Normal and On"
- E: "Spoilers"
- CP: "Closed and Armed"
- E: "Before Landing Check Completed"

### Pope Tower

- P, CP: "Flaps, Landing."
- CP: "Pope Tower, VEDA 10 NDB inbound, gear down."
- TOWER:** "VEDA 10, check gear down, winds 270 at 7 knots cleared to land RWY 23."
- CP: "VEDA 10 is gear down, cleared to land."

**\*\*\*AROUND PILOT'S REQUEST FOR FLAPS LANDING OR GEAR DOWN, SWAT RATINGS FOR APPROACH EVENTS UP TO THIS POINT**



- CP: "Hundred above" (Minimum descent altitude), "Minimums"
- CP: "Airfield not in sight"
- P: "Go around"
- Pilot sets Go Around EPR
- P, CP: "Flaps approach"
- Copilot sets flaps approach
- P, CP: "Gear up"
- Copilot raises gear
- P, CP: "Flaps up"
- Copilot retracts flaps

### Missed Approach

- CP: "VEDA 10, executing Missed Approach."
- Tower: "VEDA 10, contact Fayetteville Approach on 133.0 or 295.0."
- CP: "VEDA 10, going to departure."
- Select Fayetteville Departure Control frequency 133.0 or 295.0.
- Pilot executes Missed Approach
- Set Altitude Command Marker to 3000
- Set Airspeed Command Marker to Holding Airspeed
- Select POB (TAC) as primary Nav utilizing DAMU SWAP function (Set Holding course 150)
- CP: "Fayetteville Departure VEDA 10 with you right turn direct AWGUS."
- FAY: "VEDA 10, Radar Contact. Copy climbing to 3000, direct AWGUS state your intentions."
- CP: "VEDA 10 request two turns in holding followed by the TAC RWY 23 full stop."
- FAY: "VEDA 10 approved as requested. Report Departing AWGUS."
- CP: "VEDA 10 WILCO."

### AWGUS

#### AT HOLDING PATTERN, SIMULATE INS FAILURE.

#### \*\*\* SWAT RATINGS FOR INS FAIL CORRECTION

- Enter holding, complete two turns
- Pilot briefs TAC RWY 23 approach
- Changes Altitude Command Marker to 640
- CP: "Fayetteville Approach, VEDA 10, departing AWGUS out of 3000 for 2000."
- FAY: "VEDA 10, cleared TAC RWY 23 report POB 042R inbound."
- CP: "VEDA 10, cleared approach, WILCO."
- Pilot set Altitude Alert to 2000

### TAC RWY 23 Pope

- Pilot sets inbound course 222.
- Set HDG Command Marker for lead radial (optional)
- CP: "Fayetteville Approach, VEDA 10 departing 2000 for 1500, POB 042R inbound."
- FAY: "VEDA 10, roger."
- P, CP: "Flaps approach"
- Copilot sets flaps to approach.
- P, CP: "Gear down"
- Copilot lowers gear.
- P: "Before Landing Checklist"

### Before Landing Checklist

- E: "Landing Gear Warning Horn Cut-Out Switch"
- CP: "Normal"
- E: "Landing Gear"

CP: "Down"  
P: "Down and Centered"  
E: "Command Markers"  
CP, P: "Set"  
E: "Brake Pressure and Release Light"  
CP: "Normal and On"  
E: "Spoilers"  
CP: "Closed and Armed"  
E: "Before Landing Check Completed"

### **Final Approach, Pope**

- FAY: "VEDA 10, contact Pope Tower on 135.025 or 291.1."  
CP: "VEDA 10 going to Tower."  
• Copilot selects Fayetteville Tower Frequency 135.025 or 291.1  
CP: "Pope Tower, VEDA 10 is with you TAC inbound."  
Tower: "VEDA 10 check gear down, winds calm, cleared to land RWY 23."  
CP: "VEDA 10 is gear down, cleared to land."  
• Pilot lands the aircraft

\*\*\* AFTER LANDING, SWAT RATINGS FOR 2ND APPROACH EVENTS

\*\*\* SWAT RATINGS FOR ENTIRE MISSION

\*\*\* SWAT RATINGS FOR PROJECTED REAL-WORLD MISSION

**APPENDIX F**  
**FUNCTIONAL SPECIFICATION**

# FUNCTIONAL SPECIFICATION FOR THE C-141 PRIMARY FLIGHT DISPLAY

## 1.0 SCOPE

**1.1 Scope.** This document provides the functional description, detailed design description, design rationale, and lessons learned for the design of the draft standard for electronic head-down primary flight displays (PFD). The design is based on electronic PFD development work performed in support of the C-141 Control/Display System (CDS) upgrade program. It was developed through a series of reviews by the Joint Cockpit Office (JCO) Flight Symbolology Development Group (FSDG) and the C-141 Autopilot Working Group (AWG); the baseline format was described in the C-141 CDS (Revision A). Once defined, the PFD was exercised in a part-task simulation to determine if performance was "at least as good as" or better than the current C-141 design and the T-1 format (a reference format selected by the FSDG). Several design changes were identified during the simulation, and were implemented by the design team. The updated symbolology has been evaluated in a full mission context. Changes made to this design based on the results of this evaluation are described in this document.

**1.2 Format.** The format of this document is patterned after Military Standard, Aircraft Display Symbolology (MIL-STD-1787B), particularly section 4. However, the format used here is optimized for providing a detailed description of the design, and to provide useful guidance and rationale information to be used during the development of a standard, rather than being optimized for tailoring requirements to a specific aircraft. In the current document, the discussion of each functional requirement is divided into three parts:

- a. Functional Requirement - Describes, at a top level, the intended function of the symbolology or component, but does not provide a detailed design description.
- b. Design Rationale - Top level information on the source of the design, and reasons why the particular implementation was selected.
- c. Design Guidance - Detailed description of the symbolology and its mechanization.
- d. Lessons Learned - Summaries of experience with the described or alternate symbolology designs.

## 2.0 REFERENCED DOCUMENTS

**2.1** Unless otherwise indicated, the documents specified herein are referenced solely to provide supplemental technical data.

### 2.1.1 Government documents

- a. Concept of Operation for the All Weather Flight Control System in the C-141 Cockpit (Revisions A and B)
- b. MIL-STD-1787B (Draft) Aircraft Display Symbolology
- c. U.S. Air Force Guide Specification, AFGS-87213B, Displays, Airborne, Electronically/Optically Generated
- d. MAC Pamphlet 55-34 SKE/ZM Air Delivery System (AN/APN-169C and AN/TPN-27A) Operator's Guide
- e. T.O. 1C-141B-1 Flight Manual C-141B
- f. AFM 51-37 Flying Training, Instrument Flying
- g. AFR 60-16 General Flight Rules

### **3.0 DEFINITIONS, ABBREVIATIONS, AND ACRONYMS**

- 3.1 ADI - Attitude Director Indicator
- 3.2 AFGS - Air Force Guide Specifications
- 3.3 AFM - Air Force Manual
- 3.4 AGL - Above Ground Level
- 3.5 AOA - Angle of Attack
- 3.6 AWG - Autopilot Working Group
- 3.9 CAS - Command Airspeed
- 3.10 CDI - Course Deviation Indicator
- 3.11 CDM - Climb/Dive Marker
- 3.12 CDS - Control / Display System
- 3.13 CRT - Cathode Ray Tube
- 3.14 DAMU - Display Avionics Management Unit
- 3.15 DME - Distance Measuring Equipment
- 3.16 EADI - Electronic Attitude Director Indicator
- 3.17 EHSI - Electronic Horizontal Situation Indicator
- 3.18 FSDG - Flight Symbolology Development Group
- 3.19 FL - Flight Level
- 3.20 FOV - Field of View
- 3.21 FPM - Flight Path Marker
- 3.22 fpm - feet per minute
- 3.23 HDG - Heading
- 3.24 HSI - Horizontal Situation Indicator
- 3.25 HUD - Head-Up Display
- 3.26 Hz - Hertz
- 3.27 ILS - Instrument Landing System
- 3.28 INS - Inertial Navigation System

- 3.29 JCO - Joint Cockpit Office
- 3.30 LCD - Liquid Crystal Display
- 3.31 LAC - Longitudinal Acceleration Cue
- 3.32 MAG - Magnetic
- 3.33 MIL STD - Military Standard
- 3.34 mr - milliradians
- 3.35 NAV - Navigation
- 3.37 PFD - Primary Flight Display
- 3.38 Rev - Revision
- 3.39 SKE - Station Keeping Equipment
- 3.40 T.O. - Technical Order
- 3.41 TRK - Track
- 3.42 TRU - True
- 3.43 TR - Technical Report
- 3.43 VVI - Vertical Velocity Indicator

## **4.0 FUNCTIONAL REQUIREMENTS**

**4.1 Information Content of the Primary Flight Display Page.** The displays shall present the information needed for all instrument flight maneuvers and operational maneuvers to include takeoff, navigation, instrument flight, cargo deployment, and landing. Additionally, the information presented shall conform to the instrument flight requirements of the AFR-60-16 and to requirements to be published in MIL-STD-1787B (Draft) regarding required flight information for specific phases of flight. In general, symbols and symbol formats shall be designed and integrated with an emphasis on enhancing the pilot's spatial orientation, situational awareness, and transfer of information to the operator while minimizing operator workload and the potential for misinterpretation.

### **DESIGN GUIDANCE**

The following components are displayed on a 6 x 8 inch display area:

- \*Electronic Attitude Direction Indicator (EADI)
- \*Electronic Horizontal Situation Indicator (EHSI)
- \*Airspeed Scale
- \*Altitude Scale
- \*Vertical Velocity Indicator (VVI)

The overall format is depicted in Figure 4-1. The details of these components will be provided in subsequent paragraphs.

### **DESIGN RATIONALE**

This design was primarily developed through a cooperative effort between Wright Laboratory, the JCO, the C-141 AWG and the results of the part-task mission evaluation. The C-141 CDS document served as a design baseline. This baseline design was reviewed from the perspective of PFD requirements and C-141 operational requirements. Where possible, the design was made to be consistent with the current C-141. This was done to minimize negative transfer of training for pilots transitioning to the new CDS system, or for those flying a mixed fleet. A part-task simulation evaluation was conducted on the proposed design, in which a variety of design deficiencies were identified. Changes were made to the proposed design based on these results. The updated design is currently being evaluated in a full mission context.

### **LESSONS LEARNED**

In the part-task evaluation and full mission evaluation, the display was found to provide equal or superior performance to the current C-141 and the T-1 primary flight displays. However, a variety of minor improvements were desired by the test subjects. The implementation of these recommendations are discussed in subsequent paragraphs.



Figure 4-1. Primary Flight Display



**4.2 Standard symbols.** Symbols described under Section 4.2 shall have the geometry shown in the Figure 4-s accompanying each paragraph. All stroke widths shall be between 0.6 mm and 1 mm, unless otherwise specified. Alphanumeric symbol sizes used in the format shall conform with AFGS-87213, unless otherwise specified.

### DESIGN GUIDANCE

In the C-141, the PFD format will be presented on a 6 inch by 8 inch LCD display a pixel density of 80 per inch. For evaluation purposes, the PFD format was implemented on a 6 inch by 8 inch area of a large color CRT. This CRT had a vertical pixel density of 91.76 per inch and a horizontal pixel density of 85.6 per inch. Stroke widths reflect the CRT implementation. All symbol sizes are appropriate for a 30 inch viewing distance. Use the following formula to calculate required symbol sizes for alternate viewing distances:  $\text{Size in degrees} = \arctan(\text{symbol size} / \text{viewing distance})$ . The alphanumeric sizes will be either: Medium (4.25 mm high x 2.54 mm wide) or Large (5.66 mm high x 2.80 mm wide), as specified.

### DESIGN RATIONALE

These values are based on alphanumeric sizes selected by the AWG and comply with AFGS-87213B, which take into account both viewing distance and pixel density. Symbol sizes can be reduced if a higher pixel density or shorter viewing distance is achieved. It is desirable to make all strokes at least 2 pixels wide, so that symbology remains legible in the event of LCD line failures.

### LESSONS LEARNED

TBD

#### 4.2.1 Aircraft and Reference Symbology

**4.2.1.1 Electronic Attitude Director Indicator (EADI).** The EADI shall serve as the primary flight control reference. Aircraft attitude (aircraft pitch and bank) and flight director information, shall be provided on the Attitude Director Indicator (ADI). Climb-dive information shall be available if selected by the pilot. The ADI shall provide an immediately discernible attitude reference and information required for recovery from unusual attitude recovery conditions. Pitch information shall be provided at all times (Figure 4-2).

### DESIGN GUIDANCE

On the proposed C-141 format, the EADI is located in the top half of the PFD. The center of the EADI is 71 mm from the left edge and 147 mm from the bottom edge of the display page. It provides a vertical field of view (FOV) totaling 45 degrees and a horizontal FOV approaching  $\pm 15$  degrees. The entire display is outlined with a solid white line. Any area above the horizon is represented by cyan to indicate "sky" and any area below the horizon line is represented by brown, indicating "ground". The display is earth stabilized in both the pitch and roll axes, although the EADI movement is not necessarily scaled one-to-one with real world movement in the pitch axis. When the ghost horizon is displayed (i.e. true horizon is out of the EADI FOV) the area between the "ghost horizon" and edge of the display's outline is shaded in either blue or brown, to show direction to the "sky" or "ground", as appropriate. The basic symbology provided by the C-141 EADI includes the Climb-Dive Marker (CDM), a miniature aircraft symbol, an airspeed deviation cue, pitch and bank steering bars, a pitch scale, and bank indicator. All of this information is displayed within the EADI's FOV. Each of the symbology elements are discussed in greater detail in the following sections.

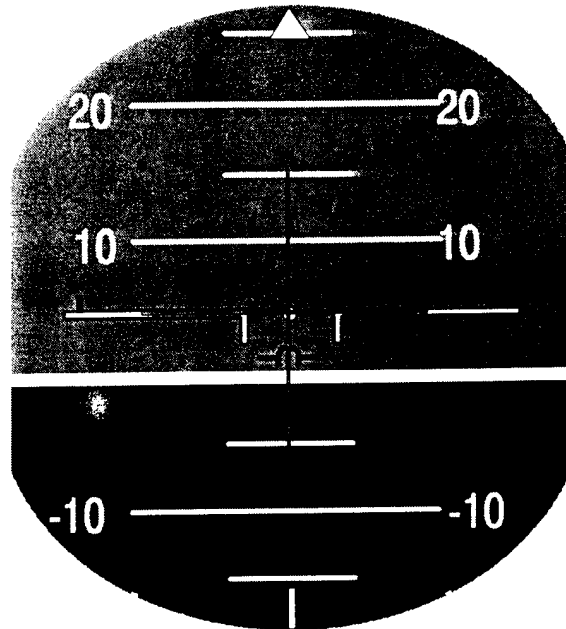


Figure 4-2. Electronic Attitude Direction Indicator.

## DESIGN RATIONALE

The basic format of the EADI is similar to a traditional electromechanical ADI and is based on the CDS Rev. A design. The horizontal FOV was chosen to be large enough to contain the maximum flyable drift angle for the C-141. The vertical FOV was chosen to be consistent with the current T-1 format. The color coding conventions and symbol sizes were selected to facilitate symbol discriminability and minimize clutter.

## LESSONS LEARNED

In the original proposed design, the PFD had two operating modes available for selection: Attitude Mode and Climb-Dive Mode. In the Attitude Mode, a traditional attitude indicator format was displayed. The miniature aircraft symbol served as the primary control symbol and as the point of reference for movement of the pitch scale. In the Climb-Dive Mode, the display was earth stabilized in the roll axis, but reflected actual aircraft climb-dive angle in the vertical axis. In this mode, the CDM served as the primary control reference, and as the point of reference for the movement of the climb-dive scale. Although performance for the two modes was comparable, potential safety issues were identified. Specifically, concern was raised that the display may be misinterpreted in extreme conditions (e.g. stall conditions), where climb-dive showed level flight or a dive condition, and the miniature aircraft symbol showed a high pitch angle (i.e. angle of attack is large). Since the part-task evaluation did not explore these conditions in detail, the FSDG recommended that further research be accomplished before using the Climb-dive mode as a primary flight display.

In the part task evaluation, large symbol sizes, wide stroke widths and insufficient color coding usage were considered to cause increased display clutter, particularly during ILS approaches. Appropriate changes were made for the current design. The general layout and design of the EADI was highly rated by the subject pilots in the C-141 full mission simulation.

4.2.1.1.1 **Climb-Dive Marker (CDM).** The CDM shall display the current climb-dive angle when read against the pitch scale (Figure 4-3). If the aircraft's climb-dive angle requires the CDM be positioned outside the limits of the display's FOV, the CDM shall be confined to the edge of the display FOV and flash at a rate of 3-5 Hertz (Hz). The climb-dive marker shall be considered as a secondary control reference.

#### DESIGN GUIDANCE

The center of the CDM is located 71 mm from the left of the display page. The line width of the CDM is 3 pixels. The CDM symbol is colored black and is horizontally fixed in the center of the pitch scale, but moves vertically to present angle of pitch against the pitch scale. The CDM can be selected, deselected, or replaced by the flight path marker, as desired by the pilot. However, the CDM and FPM can never be displayed simultaneously.

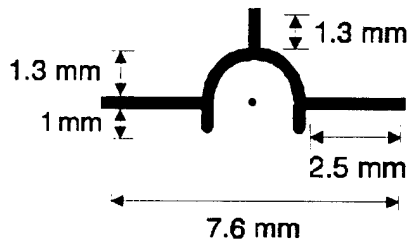


Figure 4-3. Climb-Dive Marker.

The following set of equations position the CDM. When positioning the CDM, a positive azimuth angle is to the right of the aircraft reference point and a positive elevation angle is above the aircraft reference point.

$uA$  = Velocity X Body Axis (positive along aircraft axis)

$vA$  = Velocity Y Body Axis (positive out right wing)

$wA$  = Velocity Z Body Axis (positive down)

$$FPM_{az} = \frac{180 \tan^{-1}\left(\frac{vA}{uA}\right)}{\pi}$$

$$FPM_{el} = \frac{180 \tan^{-1}\left(\frac{wA}{uA}\right)}{\pi}$$

$\phi$  = Aircraft Roll Angle (positive right wing down)

$$VV_{el} = FPM_{el} \times \cos\phi - FPM_{az} \times \sin\phi$$

The CDM's position relative to the aircraft reference point is defined in the following equations:

$$\alpha = \text{Aircraft Angle Of Attack}$$

$$CDAMAZ = 0.0$$

$$CDAMEL = VVEL \cos \phi - \alpha \sin^2 \phi + CDAMQ$$

## DESIGN RATIONALE

The CDM originates from the CDS Rev. A, in which a FPM was used to show aircraft climb/dive. The FSDG recommended replacing the original FPM symbol with the CDM that was developed for the Head-Up Display (HUD). The flash coding was incorporated to warn the pilot that the displayed climb-dive angle is inaccurate (out of field of view of the display). The symbol shape and dynamics were selected to be similar to the standardized HUD format. The black color and small size of the symbol was selected to decrease EADI clutter and aid in discrimination from the larger, white primary control symbol (miniature aircraft symbol). The size of the CDM is identical to the flight path marker, to emphasize their roles as the secondary control references.

## LESSONS LEARNED

In the part task simulation, the size of the CDM was based on Mil-STD-1787B requirements. The size used in the standard HUD assumes that the symbol will be used as a primary control reference and is much larger than the current C-141 design. The symbol was white when used as a secondary control reference, and black when used as a primary control reference. The findings showed that the size, color and dynamics of the CDM, particularly when used as a secondary control reference, added clutter to the EADI and caused distraction. Some subjects also confused the primary and secondary control symbols during the evaluation. The CDM was highly rated by subject pilots during the full mission evaluation.

**4.2.1.1.2 Miniature Aircraft Symbol.** The miniature aircraft symbol shall be fixed in the center of the ADI to show aircraft pitch when read against the pitch scale. (Figure 4-4).

## DESIGN GUIDANCE

The symbol is colored white with a black border and fixed in the center of the EADI, 71 mm from the left edge and 147 mm from the bottom of the display page. The miniature aircraft symbol has a line width of 2 mm. The dot located in the of the symbol has a radius of 2 mm.

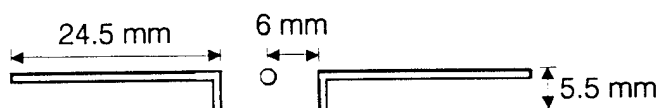


Figure 4-4. Miniature Aircraft Symbol.

## DESIGN RATIONALE

Two different symbols were originally proposed for providing aircraft pitch information (CDS Rev. A). Displaying a single primary control reference symbol, the miniature aircraft, was recommended by the FSDG to minimize confusion and improve standardization. The redesign of this miniature aircraft symbol from that of a "flying W" to a "shallow T" symbol is a result of the EADI implementation, in which both the CDM and the miniature aircraft symbologies are displayed against the same scale. The broken miniature aircraft allows the simultaneous display of these two symbols without an occlusion of either. The color of the symbol was selected to reduce clutter within the EADI and aid its discriminability from other symbols.

## LESSONS LEARNED

The miniature aircraft symbol was well received by operational pilots participating in the part-task evaluation. However, its stroke width was reduced, and the black highlight was added to help improve symbol discriminability and reduce clutter within the EADI. The current miniature aircraft symbol was highly rated during the C-141 full mission evaluation.

**4.2.1.1.3 Flight Path Marker (FPM).** The Flight Path Marker (FPM) shall indicate the actual flight path of the aircraft when read against the pitch scale (Figure 4-5). The FPM shall be free to move both vertically and horizontally within the EADI FOV. If the actual flight path requires the positioning of the FPM outside the limits of the display FOV, the FPM shall be confined to the edge of the EADI FOV and flash at a rate of 3-5 Hz.

## DESIGN GUIDANCE

The line width used to present this symbology is 3 pixels. This symbol is colored black. Vertical scaling is defined by the EADI FOV and horizontal scaling shows 15 degrees drift left and right of center. The CDM or FPM may be selected or neither symbol may be displayed. This symbol will not be included on the C-141 PFD due to Inertial Navigation System (INS) hardware limitations.

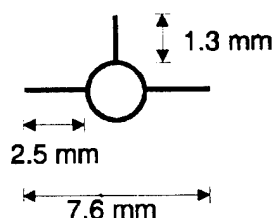


Figure 4-5. Flight Path Marker.

The following set of equations position the FPM.

$$FPM_{az} = \frac{180 \tan^{-1}\left(\frac{v_d}{u_d}\right)}{\pi}$$

$$FPM_{el} = \frac{180 \tan^{-1}\left(\frac{w_d}{u_d}\right)}{\pi}$$

## DESIGN RATIONALE

The FPM was not part of the original CDS (Rev. A). Its addition was recommended by the FSDG and accepted by the AWG. The flash coding was incorporated to warn the pilot that the displayed flight path angle is inaccurate (out of field of view of the display). As a result of the part-task mission evaluation, the color of the FPM was changed to black and the size was reduced to decrease clutter and aid in discrimination from the primary control symbol. The size of the CDM is identical to the flight path marker, to emphasize their roles as secondary control references.

## LESSONS LEARNED

Without proper training, the FPM can be difficult to interpret.

**4.2.1.1.4 Pitch Scale.** The pitch scale shall serve as the reference scale for the CDM, the FPM, and the miniature aircraft symbol (Figure 4-6). The scale in conjunction with the symbols, shall display aircraft climb-dive angle, flight path angle, and pitch angle. The pitch scale shall move dynamically within the limits of the EADI FOV. When the true horizon representation is within the EADI FOV, it shall be a solid line. When the true horizon representation exceeds the EADI FOV, the line shall become dashed ("ghosted") and shall stay fixed on a position in the axis of aircraft pitch while the rest of the pitch scale continues to move in this axis. The pitch scale shall always remain earth stabilized in the roll axis.

## DESIGN GUIDANCE

The pitch scale consists of a set of parallel solid white lines of varying lengths and spacing. The pitch scale lines are spaced at 5 degree intervals. The scale line lengths are as follows: the 5 degree lines are 13.5 mm in length, and the 10 degree lines are 35 mm in length. Beyond -30 and +30 degrees, the ends of the lines are angled 30 degrees away from the horizon (Figure 4-7). Throughout the entire pitch scale, the 10 degree lines are labeled on both ends. Below the horizon line, negative signs (-) precede the numeric labels. All numbers are centered vertically on the pitch scale lines. The horizon line is slightly thicker than the other pitch scale lines, and extends across the full width of the EADI. When the horizon line exceeds the EADI FOV and becomes "ghosted", it is displayed 8 mm from the edge of the EADI. However, the horizon line remains earth stabilized in the roll axis, and rotates around the edge of the EADI in response to aircraft bank.

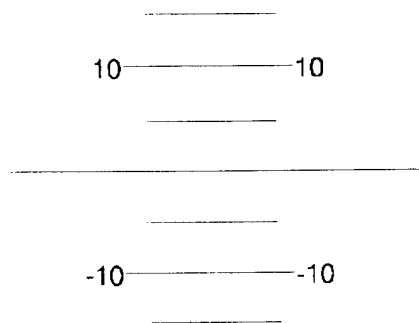


Figure 4-6. Pitch Scale.

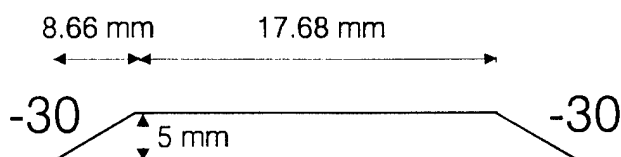


Figure 4-7.  $\pm 30$  Degree And Beyond Articulated Climb/Dive Bars.

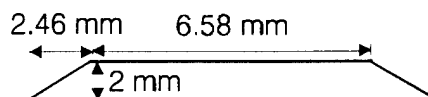


Figure 4-8.  $\pm 35$  Degree And Beyond Articulated

## DESIGN RATIONALE

The original CDS (Rev. A) design did not contain articulated pitch scale lines or the "ghost horizon" concept. The articulated lines were based upon the standard HUD work, in which they were found to provide an intuitive, global cue of direction to the horizon. The pitch scaling was selected to be consistent with the T-1.

## LESSONS LEARNED

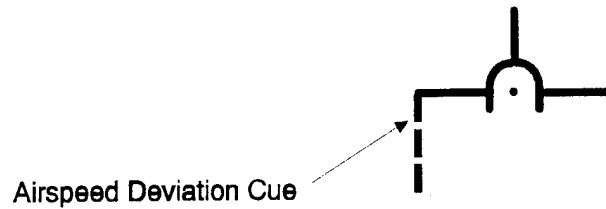
An expanded scale (30 degrees total), and 2.5 degree pitch lines, were originally proposed by the AWG. During the part-task simulation, the pilots commented that the scale provided greater precision than was necessary, and tended to exaggerate the display's response to control inputs. Also, some pilots expressed difficulty adapting to the expanded scale, probably because it differed significantly from the 80 degree FOV provided in the electromechanical C-141 displays. Based on these findings, the FOV was increased to match that used in the T-1. Also, several pilots recommended removing the 2.5 degree pitch lines to help reduce clutter.

During the full mission simulation, pilots once again commented that using the scale was "uncomfortable," since it was still expanded compared with the C-141. Most pilots felt that they would adapt to the display with additional experience, and no changes were recommended.

**4.2.1.1.5 Airspeed Deviation Cue.** The airspeed deviation cue shall indicate deviation from the aircraft's commanded airspeed (Figure 4-8). The symbol shall be a dashed line that extends vertically from the left "wing" of the miniature aircraft symbol in the EADI. If the actual airspeed is greater than the commanded airspeed, the dashed line shall extend above the wing. If the actual airspeed is less than the commanded airspeed, the line shall extend downward.

## DESIGN GUIDANCE

Each segment represents a 5 knot deviation from the commanded airspeed. A maximum of six segments are displayed to indicate a maximum airspeed deviation of 30 knots. As airspeed deviation changes, the segments shall be lengthened and shortened in a continuous fashion (partial segments are drawn, as required). The segments are drawn with a line width of 3 pixels and measure 3 mm in length, with a space of 1 mm between adjacent segments. The airspeed deviation cue is over-written by all symbols, with the exception of the pitch/climb-dive scale. This symbol is only displayed when ILS mode is selected.



*Figure 4-8. Airspeed Deviation Cue.*

## DESIGN RATIONALE

The cue was part of the baseline (CDS Rev. A) design. The scaling of the dashes was chosen by the AWG and reflects procedures to fly at airspeeds in 5 knot increments over the commanded value at different points in the approach.

## LESSONS LEARNED

TBD

**4.2.1.1.6 Bank Indicators.** The bank pointer and scale shall indicate aircraft bank (Figure 4-9). The bank indicator shall be a moving pointer, fixed-scale design, positioned at the bottom of the EADI. The pointer shall be earth stabilized and shall provide an indication of aircraft bank when read against the bank scale. The bank scale shall contain tic marks at 0, 10, 20, 30, and 60 degree intervals. It shall also have dots as reference marks at the 45 degree positions. An additional sky pointer, along with an abbreviated scale, shall be provided at the top of the EADI ball.

## DESIGN GUIDANCE

All tick marks are drawn in white and completely outside of the EADI. The 10, 20, and 60 degree tic marks on the bottom scale are 3 mm long by 0.5 mm wide. The 60 degree tick marks located on the top scale are also 3 mm long by 0.5 mm wide. The 0 and 30 degree tick marks on both the top and bottom scales are 4 mm long by 1 mm wide. White reference dots 2 mm in diameter are placed on both the top and bottom scales at the 45 degree positions. The bank pointers, are considered as high priority and are written over by only the CDM, the miniature aircraft symbol, and the FPM.



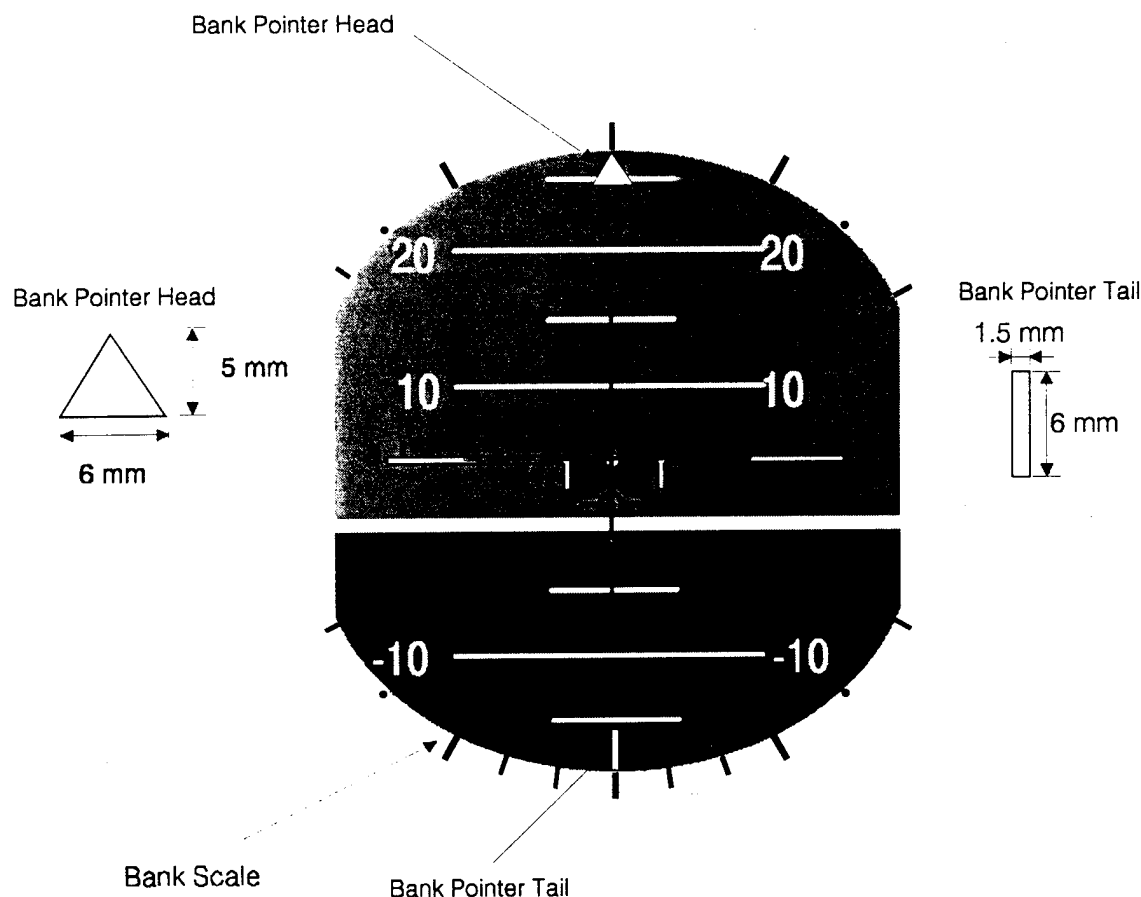


Figure 4-9. Bank Indicators.

## DESIGN RATIONALE

The orientation of the bank pointer (pointing upward) was originally recommended by the FSDG to comply with MIL-STD-1787B, and with the philosophy that a PFD should not contain ground-pointing arrows. The bottom bank scale design was re-position outside of the EADI as a result of the part-task simulation, to help improve readability. An abbreviated scale at the top of the display was added by the AWG to maintain consistency with the current C-141 bank indicators.

## LESSONS LEARNED

The scale used during the part-task evaluation was drawn inside of the EADI ball and tended to be washed out by other symbology (e.g. the pitch scale). Moving the scale to the outside of the ball resulted in better readability. Pilots commented during the full mission simulation that they would prefer the more traditional triangle shaped bottom bank pointer. While the current design did not appear to degrade performance, a more traditional shape should be considered for the head-down standard.

**4.2.1.1.7 Pitch and Bank Steering Bars.** The pitch and bank steering bars shall indicate the amount and direction of the flight director roll and pitch steering error, respectively, when read against the miniature aircraft symbol (Figure 4-10). In addition to providing ILS pitch and bank steering commands, the bank steering symbol shall be used to display command to course, command to heading, and bank steering for Station Keeping Equipment (SKE), depending on the mode selected.

## DESIGN GUIDANCE

These symbols are located and move dynamically within the limits of the EADI. The bank steering bar is fixed vertically in the center of the EADI, but is free to move in the horizontal direction to indicate commanded steering. The pitch steering bar is fixed in the horizontal direction but free to move in the vertical direction to indicate commanded pitch angle. The bank and pitch steering bars are 38 mm long, 0.8 mm wide and colored yellow with a black outline. For the bank steering bar, the maximum deflection is 17.5 mm left and right from the center of the EADI. For the pitch steering bar, the maximum deflection is 17.5 mm above and below the center of the EADI. For the command to course mode, the maximum bank steering bar deflection represents 30 degrees, except when Inertial Navigation System (INS) is selected. When INS is selected, the maximum commanded bank angle is a function of altitude. Below 10,000 ft, the deflection represents 23 degrees maximum; between 10,000 ft and Flight Level (FL) 250, the deflection represents 15-20 degrees; and above FL 250, the bank steering bar deflection represents 15 degrees maximum. In command to heading mode, the bank steering bar commands a turn to the heading marker on the EHSI. For SKE, the bank steering bar represents the selected cross-track flight path offset as follows:  $\pm 1000$  ft full scale when track offset is set between 1000 and 4000 ft;  $\pm 2000$  ft full scale when the track offset is set between 5000 and 9000 ft; and  $\pm 4000$  ft full scale when track offset is set between 10,000 and 24,000 ft. The desired cross-track position can be set right or left, zero too 4900 ft in 100 ft increments. When centered, the bank steering bar represents ownship offset. The maximum deflection of the bank bar in SKE mode is the same as above. The pitch and bank steering bars overwrite all EADI symbology except for the miniature aircraft symbol, CDM, and FPM.

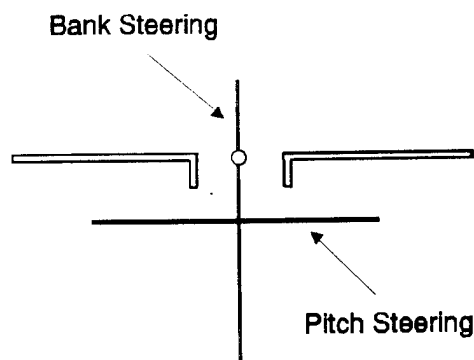


Figure 4-10. Pitch and Bank Steering Bars.

## DESIGN RATIONALE

The design of the pitch and bank steering bars follow the same convention that has been widely used in Air Force aircraft for many years. The yellow color with a black outline was chosen to maximize visibility against the blue and brown sky and ground colors in the ADI. The shorter, narrower bars were chosen to reduce clutter.

## LESSONS LEARNED

The design was found to be generally acceptable in the part-task mission evaluation, although the bars tended to obscure the miniature aircraft symbol. The width was reduced based on findings of the part-task mission. The design was found to be acceptable in the full mission evaluation

**4.2.1.1.8 Single Cue Flight Director.** The single cue flight director shall provide pitch and bank commanded steering information (Figure 4-11). The symbol shall move laterally and vertically within the EADI ball to indicate commanded bank and pitch respectively. It shall be a selectable alternative to the pitch and bank steering bars only when both pitch and bank steering information are available (i.e. ILS).

## DESIGN GUIDANCE

This yellow filled circle is selectable as an alternative to the dual cue bars only when both pitch and bank steering information are available. The maximum deflection of the single cue flight director is 17.5 mm in any direction from the center of the EADI. This symbol is overwritten by the CDM, miniature aircraft symbol, and FPM, but will overwrite all other EADI symbology. The single cue flight director is a C-141 design specific symbol and will not be part of the future head-down standard.



*Figure 4-11. Single Cue Flight Director.*

## DESIGN RATIONALE

The design of the symbol has not changed from the original CDS (Rev. A) except that it is now only selectable when both pitch and bank command steering are available. Since it is an integrated cue, it would provide erroneous information if either pitch nor bank steering were not available.

## LESSONS LEARNED

This symbol was not exercised in the part task or full mission simulation. However, evaluation work accomplished in support of the standard HUD format development showed less precise performance with slightly reduced workload compared to dual cue flight directors.

**4.2.1.1.9 Rising Runway.** The rising runway indicator shall display localizer deviation and radar altitude during landing (Figure 4-12). The rising runway shall be placed on the EADI ball and shall be designed to fit within the miniature aircraft symbol.

## DESIGN GUIDANCE

The white lines on the rising runway indicator are 1 mm in width. At 180 ft AGL, the symbol appears at the bottom of the EADI and rises toward the miniature aircraft symbol as aircraft altitude decreases. It intersects

with the primary control reference (either miniature aircraft symbol or climb-dive marker) at aircraft touchdown. The symbol extends to the reference tic mark on the expanded localizer scale and remains aligned with it at all times to show lateral deviation from the desired flight path. The indicator is not shown when radar altitude is above 180 ft. The rising runway is a C-141 design specific symbol and will not be part of the future head-down standard.

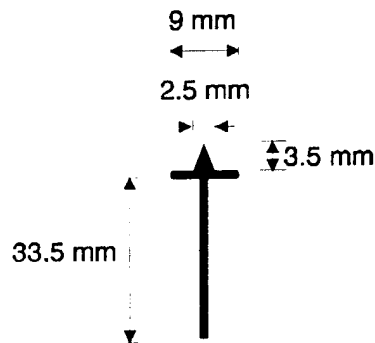


Figure 4-12. Rising Runway.

## DESIGN RATIONALE

The decision to incorporate the rising runway symbology was originally made by the AWG. The design was based on the mechanical rising runway currently provided in the C-141.

## LESSONS LEARNED

TBD

**4.2.1.1.10 Glideslope Deviation Indicator.** The glideslope indicator shall be used in conjunction with the glideslope scale to indicate the magnitude and direction of deviation from the desired glideslope. The glideslope deviation shall be determined by reading the position of the moving pointer relative to the stationary scale (Figure 4-13). The glideslope pointer shall move in response to aircraft deviation from the desired glidepath. As the aircraft "flies" below glideslope, the pointer shall rise toward the top of the scale. The pointer shall move toward the bottom of the scale to show above glideslope conditions. This information shall be displayed when in ILS mode only.

## DESIGN GUIDANCE

The glideslope deviation scale is comprised of five white dots 2 mm in diameter (except the center dot), spaced 10 mm apart (center to center), arranged and centered vertically at the left edge of the EADI. The center dot of the glideslope scale is 3 mm in diameter and is located 32 mm from the left edge and 147 mm from the bottom of the display. A white "G" (3.5 mm high and 2.5 mm wide) enclosed in a five-sided figure (5 mm high and 5 mm wide) resembling an arrow serves as the glideslope deviation indicator. The arrow tip is 2 mm in length. The maximum deflection of the glideslope deviation indicator is determined by the height of the glideslope window at some distance from the localizer, based on a projection angle of 1 through 1.8 degrees at the localizer.

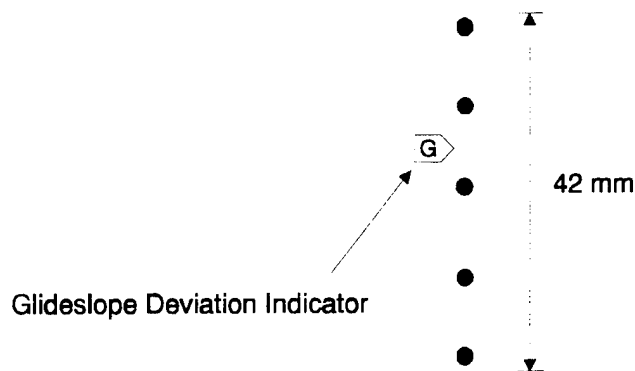


Figure 4-13. Glideslope Deviation Indicator.

### DESIGN RATIONALE

The design of the glideslope indicator is based on traditional electromechanical glideslope indicators.

### LESSONS LEARNED

The glideslope indicator was well-received in the part-task evaluation and the full mission simulation.

**4.2.1.1.11 Station Keeping Equipment (SKE) Altitude Offset.** When in SKE mode, the Station Keeping Equipment (SKE) altitude offset shall display relative vertical position of the lead aircraft to the follower aircraft to the right of the EADI. The display shall use a “fly-to” design (Figure 4-15). It shall be positioned near other altitude related information.

### DESIGN GUIDANCE

The SKE altitude offset display consists of a scale and a pointer. The scale is composed of a 3 mm by 3 mm square at the center and four black dots with a white outline arranged in a vertical manner, two above and two below the square. The dots are 2 mm in diameter and spaced 9 mm apart, center to center. The pointer is a black diamond symbol with a 1mm yellow outline, 4 mm high by 4 mm wide, with the far right edge centered on and overlaying the scale. The vertical offset scale can be set to display  $\pm 1000$  ft full scale or  $\pm 5000$  ft full scale for the zero offset condition. For the first case, each vertical dot represents 500 ft of deviation above or below the desired altitude. The index can be set to display 0 through 2900 ft, in 100 ft increments. The SKE Altitude Offset is a C-141 design specific symbol and does not apply to the future head-down standard.

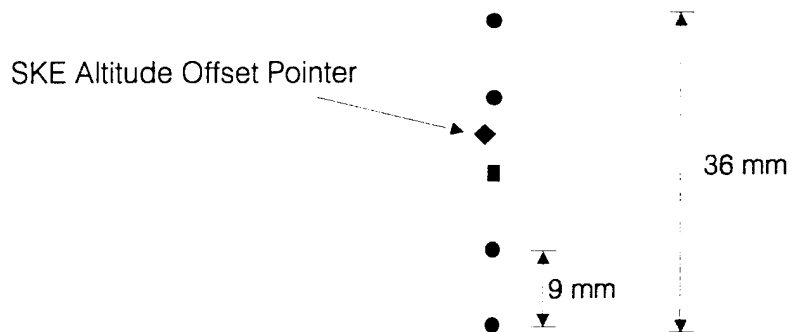


Figure 4-15. Station Keeping Equipment Altitude Offset.

## DESIGN RATIONALE

The SKE altitude offset display design was implemented according to MAC Pamphlet 55-34, SKE/ZM Air Delivery System (AN/APN-169C and AN/TPN-27A) Operators Guide and is similar to what currently exists in the C-141. Color coding was applied to make the pointer more prominent and show its relationship to other SKE information.

## LESSONS LEARNED

This symbol was not used in the part-task evaluation. During the full mission simulation, the pointer and scale were both colored white. Pilots had difficulty reading the information due to tight placement, poor contrast and clutter. As a result, the color of the SKE altitude offset pointer was changed to yellow, and the size of the pointer was increased.

**4.2.1.1.12 Station Keeping Equipment (SKE) Relative Range Indicator (RRI).** When in SKE mode, the Station Keeping Equipment (SKE) Relative Range Indicator (RRI) shall display relative longitudinal spacing of the lead aircraft to the follower aircraft (Figure 4-16). The display shall use a “fly-to” design and be placed on the left side of the EADI.

## DESIGN GUIDANCE

The SKE RRI display consists of a scale, scale text, and an ownship representation. The scale is composed of a 3 mm by 3 mm square at the center and four white dots with a black outline arranged in a vertical manner, two above and two below the square. The dots are 3 mm in diameter and spaced 9 mm apart, center to center. The ownship representation is an yellow airplane silhouette, 10 mm long, 6 mm wide at the “wing”, and 3 mm wide at the “tail”, with the far right edge placed 1mm from the center and overlaying the scale. The line width of the ownship representation is 1mm. The RRI scale can be set to display any desired longitudinal spacing between 0 and 24,000 ft at the index. The scale always displays a range of 1000 ft “too close” through 1000 ft “too far back”, based on the desired separation between lead aircraft and follower aircraft. The SKE RRI is a C-141 design specific symbol and does not apply to the future head-down standard.

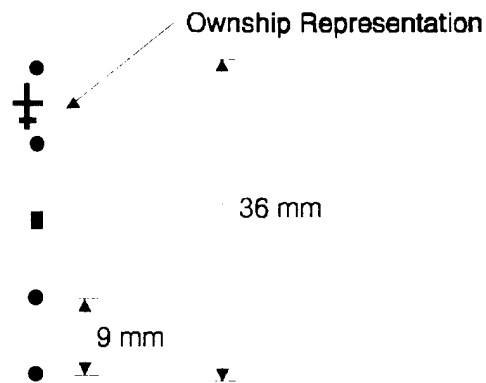


Figure 4-16. Station Keeping Equipment Relative Range Indicator.

### DESIGN RATIONALE

The SKE RRI offset display design was implemented according to MAC Pamphlet 55-34, SKE/ZM Air Delivery System (AN/APN-169C and AN/TPN-27A) Operators Guide. Due to mechanical limitations, the current electromechanical RRI was limited to a range of +1000 and -750 feet. This limitation did not exist in the electronic version; therefore the range in the electronic version was increased to +1000 and -1000 feet. Colors and placement were selected to minimize clutter and optimize distinctiveness of individual symbols.

### LESSONS LEARNED

In the design tested in the full mission simulation, the aircraft symbol and scale were white, and the word “range” was drawn vertically between the airspeed scale and ADI. Pilots had difficulty reading the scale due to the tight placement of and lack of distinctiveness between the symbols. As a result, the labeling used to distinguish the RRI was removed.

**4.2.1.2 Electronic Horizontal Situation Indicator (EHSI).** The Electronic Horizontal Situation Indicator (EHSI) shall serve as the primary navigation control reference. The information provided by the EHSI shall include heading, course, bearing, ground track, reference heading, course deviation, and range (Figure 4-17). The information presented shall depend on the requirements of the different modes of operation.

### DESIGN GUIDANCE

On the proposed C-141 PFD, the EHSI is located in the bottom half of the PFD page. The center of the EHSI is 71 mm from the left edge and 45 mm from the bottom edge of the display unit. It is positioned slightly left of center to maintain alignment with the EADI ball. It consists of a full circular compass rose card that rotates in response to aircraft heading changes. The basic symbology provided by the EHSI includes a course arrow, course deviation indicator, bearing pointers, a to-from indicator, heading references, and a magnetic or ground track symbol. A lubber line, against which the compass rose scale is read, and a digital heading readout window are displayed at the top center of the EHSI.

The EHSI displays either heading or ground track, depending on the mode of operation. For each mode, magnetic, true, or grid heading may be selected. When displaying heading, the default mode, a small cross is placed on the compass rose scale to indicate the ground track and the EHSI shows either magnetic, true, or grid heading. When displaying ground track, a “TRK” annunciation is displayed to the left of the digital readout and a small diamond is drawn on the compass scale to indicate heading. A “MAG”, “TRU”, or “GRID”

annunciation is displayed to the immediate right of the digital heading readout for either mode, indicating which option is selected.

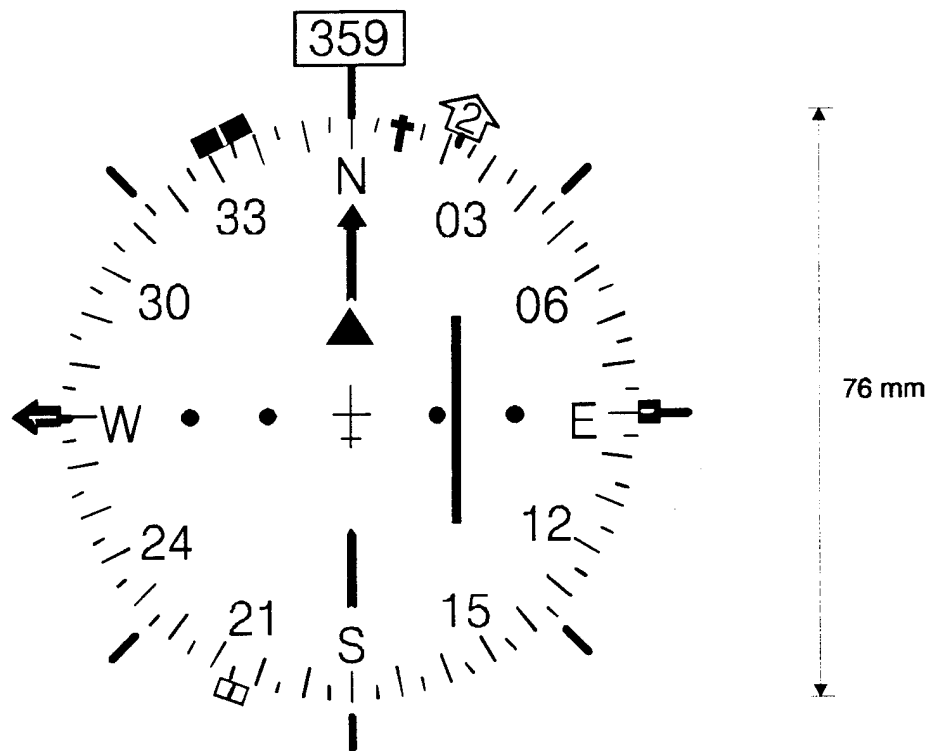


Figure 4-17. Electronic Horizontal Situation Indicator.

#### DESIGN RATIONALE

Significant changes were made to the CDS (Rev A) baseline design based on FSDG recommendations and discussions at the AWG meetings. The original design presented a truncated compass with alphanumeric scale markings on the outside and the bearing pointers on the inside. The EHSI design was changed to more closely resemble the current electromechanical version: the compass rose was shown in full, the alphanumeric scale markings were moved inside and the bearing pointers were moved outside the compass rose. In addition, tic marks were added at 45 degree intervals to the outside of the compass rose. In the heading mode, heading is read below the upper lubber line. When the EHSI is in the ground track mode, wind corrected course is read below the upper lubber line.

#### LESSONS LEARNED

The general layout and design of the EHSI was highly rated by the subject pilots in the C-141 part-task evaluation and the full mission simulation.

**4.2.1.2.1 Course Arrow.** The course arrow shall indicate selected course. The course arrow shall consist of a head and tail and be displayed on the interior of the EHSI (Figure 4-18). The head and tail shall be aligned with



each other but are separated to allow space for the course deviation indicator. The head shall always indicate selected course when read against the EHSI compass rose and the tail shall always be aligned with the reciprocal of the selected course. Upon manual course selection, the course arrow shall appear in the EHSI and shall remain fixed relative to the compass rose, rotating as the compass rose rotates.

#### DESIGN GUIDANCE

The course arrow is green and has a line width of 1.5 mm. The course arrow head is 5 mm wide and 3 mm high.

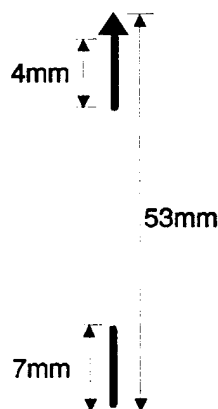


Figure 4-18. Course Arrow.

#### DESIGN RATIONALE

The design of the course arrow is similar to that used in traditional HSI's.

#### LESSONS LEARNED

The course arrow was well-received by the subject pilots in the part-task evaluation and full mission simulation.

**4.2.1.2.2 Course Deviation Indicator (CDI).** The Course Deviation Indicator (CDI) shall display direction and magnitude of deviation from the course when read against the course arrow and aircraft symbol. The CDI shall be composed of a CDI pointer and a CDI scale (Figure 4-19). The CDI scale shall be located in the center of the EHSI. The CDI shall rotate around the EHSI aircraft symbol such that the CDI pointer remains parallel with the course arrow and the CDI scale remains perpendicular to the course arrow at all times. The CDI shall rotate independent of the compass rose when the course is being manually set. Once the course is set, the CDI shall remain fixed relative to the compass rose and shall rotate with the compass rose in response to aircraft heading changes. The CDI pointer shall move laterally within the limits of the compass rose scale to indicate deviation from selected course.

#### DESIGN GUIDANCE

The CDI is colored green and consists of a CDI pointer (1.5 mm in width) that moves relative to four dots (1 mm radius) which comprise the CDI scale. The dots are spaced 10 mm apart (center to center) in a line that remains perpendicular to the course arrow at all times. The maximum deflection of the CDI pointer represents

a deviation from the selected course greater than 10 degrees. Each dot on the scale represents 5 degrees of deviation. In ILS mode, full scale deflection differs with the width of the localizer course (3 - 6 degrees) and each dot is scaled accordingly. When INS mode is selected as the source, each dot represents 1.5 miles deviation from the course. In the Airdrop mode, the sensitivity if the EHSI CDI increases by a factor of 10 (from 1.5 nautical miles per dot to 0.15 nautical miles per dot). The CDI can only be driven from the source associated with bearing pointer one. The course deviation indicator is the highest priority symbol on the EHSI and overwrites the CDI scale, to-from indicator, and aircraft symbol.

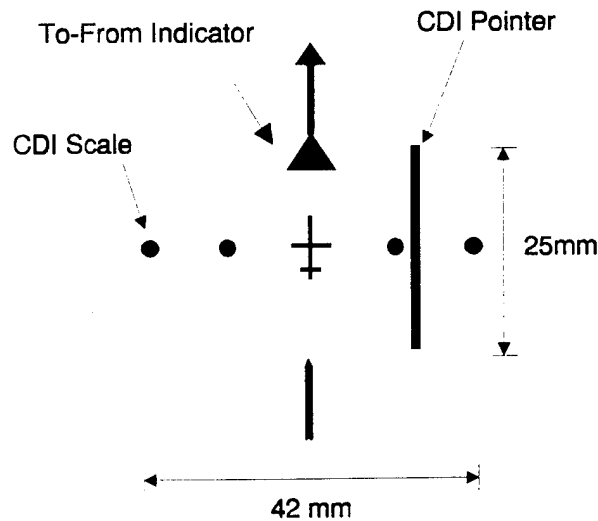


Figure 4-19. Course Deviation Indicator.

## DESIGN RATIONALE

The basic design of the CDI a direct translation of the traditional course deviation indicator. The CDI scale was expanded and the color of the CDI was changed to green to indicate its relationship to bearing pointer one, as recommended by the AWG.

## LESSONS LEARNED

No difficulties in using the CDI scale were reported during either of the simulation testings.

**4.2.1.2.3 To-From Indicator.** The to-from indicator is a triangular shaped pointer that shall be placed in line with the course arrow either in front of or behind the EHSI aircraft symbol (Figure 4-20). It shall always occupy a place in the gap between the head and tail of the course arrow. When indicating a "to" condition, it shall point toward the course arrow head and shall be placed in front of the aircraft symbol. When showing a "from" condition, it shall point toward the course arrow tail and shall be placed behind the aircraft symbol. Once the course is selected, the to-from indicator shall rotate with the compass rose. When a navigation station is crossed, the to-from indicator shall flip from its position in front of the aircraft symbol to a position behind the aircraft symbol and shall point to the tail of the course arrow.

## DESIGN GUIDANCE

The to-from indicator is located on the interior portion of the EHSI compass rose in the gap between course arrow head and tail and is colored green. In all cases, it is 18.5 mm from the center of the EHSI compass rose. The to-from indicator is overwritten by the CDI symbology.

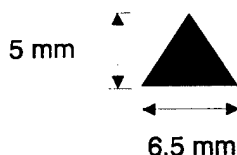


Figure 4-20. To-From Indicator.

## DESIGN RATIONALE

Although the current design is a direct translation of a traditional to-from indicator, the design has undergone two changes from its original form as described in CDS (Rev. A). Both changes were recommended by the FSDG and accepted by the AWG. First, the symbol was enlarged. Secondly, it was remechanized such that it flips from the head to the tail of the course arrow and reverses its orientation when the navigation station is crossed. This is an improvement from the original design, in which the to-from indicator occupied a single space and simply changed orientation. The color of the to-from indicator was changed to green to indicate its relationship to bearing pointer one, as recommended by the AWG.

## LESSONS LEARNED

TBD

**4.2.1.2.4 Compass Rose Scale.** The compass rose shall be the primary reference scale on the EHSI. When read with reference to a variety of symbols, it shall display selected heading, actual heading, ground track, selected course, and bearing (Figure 4-21). The 0, 90, 180, and 270 degree positions shall be labeled with "N", "E", "S", and "W", respectively. On the remainder of the scale, numeric labels shall be provided every 30 degrees. The compass rose shall be driven by the aircraft navigation data and shall rotate around the EHSI aircraft symbol at its center to show actual aircraft heading or ground track, depending on the selected mode.

## DESIGN GUIDANCE

The compass rose forms the central portion of the EHSI and is located in the bottom half of the PFD page. The center of the compass rose is 71 mm from the left edge and 45 mm from the bottom edge of the display unit. It consists of a white, full circular scale that has major tic marks 4 mm in length every 10 degrees and minor tic marks 2 mm in length every 5 degrees. On the outside of the scale, tic marks 6 mm in length and 2 pixels wide, are provided every 45 degrees to be used as references for various navigation maneuvers. The upper lubber line is 8 mm in length and 2 pixels wide. The compass tick marks are written over by all other symbology that is presented or referenced to the scale. In the implementation for the part-task evaluation, the alphanumeric labels did not rotate with the compass; rather they retained their proper relationship to the scale, but always remained upright.

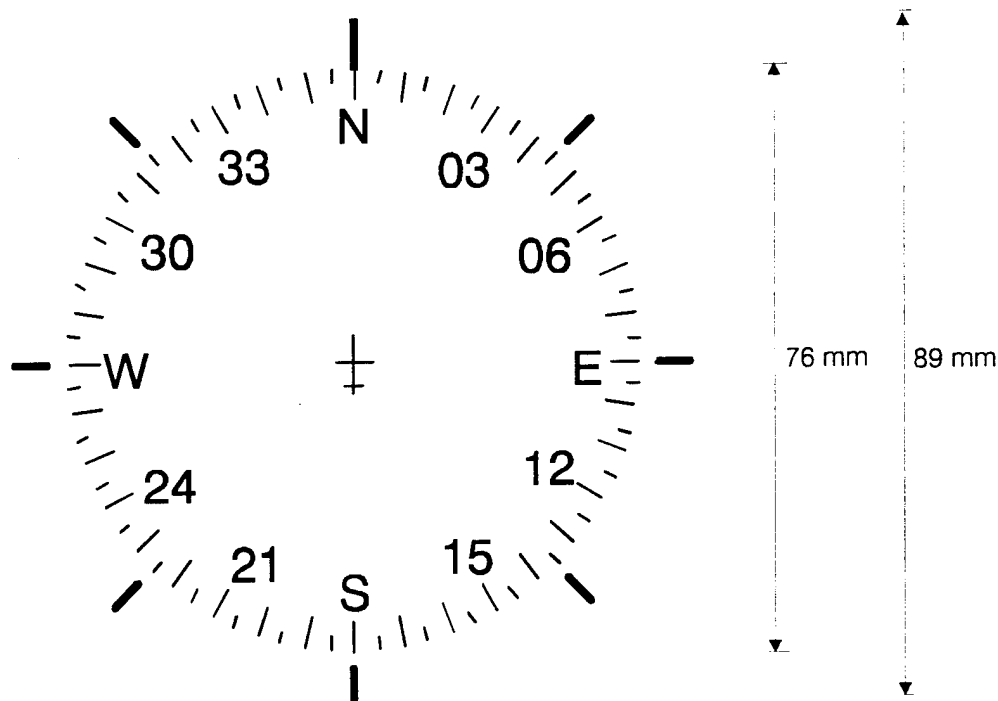


Figure 4-21. Compass Rose.

## DESIGN RATIONALE

In its original form (CDS Rev. A), the bottom portion of the compass rose was truncated and the scale alphanumerics were presented on the outside of the scale. In the current design, the full compass rose is displayed and the alphanumerics have been moved to the inside. In addition, the 45 degree tic marks were added around the outside of the compass rose. Based on FSDG recommendations and discussions within the AWG, these EHSI changes were made to enhance its similarity to the current electromechanical Horizontal Situation Indicator (HSI). As a result of the full mission simulation, the index lines were enlarged in length and the upper lubber line was extended downward to meet the compass rose so that they would not be obscured by the bearing pointers.

## LESSONS LEARNED

No criticisms of the scale were received in the part-task evaluation. During the full mission simulation pilot's commented that the index lines on the EHSI were obscured by the bearing pointers in certain situations making the instrument difficult to read.

**4.2.1.2.5 Aircraft Symbol.** The aircraft symbol shall represent ownship position with respect to the navigation situation (i.e. bearing pointers, heading, and course deviation). It shall be drawn at the center of the EHSI such that the "fuselage" line is aligned with the vertical central axis of the compass rose and the "wing" line shall be aligned with the horizontal central axis of the EHSI (Figure 4-22). The symbol shall be stationary at all times.

## DESIGN GUIDANCE

The intersection of the "wing" and "fuselage" is located 71 mm from the left edge and 45 mm from the bottom edge of the display, coinciding with the exact center of the compass rose. The lines used to construct this white

symbol are 2 pixels in width. The "tail" of the aircraft symbol is located 7 mm from the "nose" of the aircraft symbol. The aircraft symbol is a low priority element and is overwritten by the CDI.

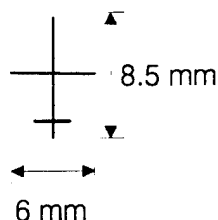


Figure 4-22. Aircraft Symbol.

### DESIGN RATIONALE

The aircraft symbol is an electronic representation of a traditional aircraft symbol.

### LESSONS LEARNED

The symbol was well-received by the subject pilots in the part-task evaluation and full mission evaluation.

**4.2.1.2.6 Heading Marker.** A "captain's bar" shaped symbol shall be used to provide a reference to the desired heading on the compass rose scale (Figure 4-23). Once manually set, the heading marker shall be stabilized to its position on the scale, and shall move as the scale rotates in response to aircraft heading changes. The

### DESIGN GUIDANCE

This symbol is located on the outer portion of the compass rose and is colored magenta with a white center lubber line. This symbol has a line width of 1 pixel. In the command to heading mode, the heading marker is overwritten by all other EHSI symbology except for the bearing pointers.

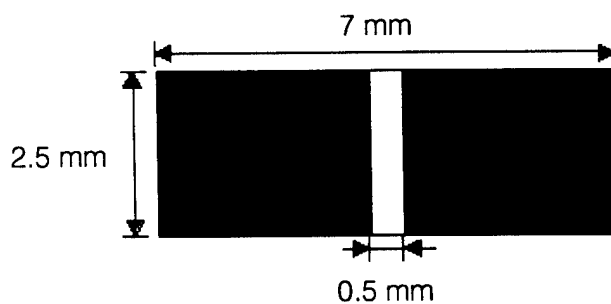


Figure 4-23. Heading Marker.

## DESIGN RATIONALE

This style of heading marker has been widely used in electromechanical Horizontal Situation Indicators. Colors were selected to maximize legibility of the reference line. The heading marker was mechanized to overwrite the bearing pointers in heading mode, so that the highest priority information in this mode was always visible.

## LESSONS LEARNED

Originally an "M" shaped symbol was proposed as the heading marker in CDS Rev. A. Operational pilots who participated in the part-task evaluation reported that the "M" shaped heading marker was difficult to read against the compass rose scale. As a result, it was designed as a captains bar design with a black reference line in the center; it was mechanized to always be overwritten by the bearing pointers. During the full mission simulation, pilots felt that the black reference line was not sufficiently distinct and comments indicated that the heading marker should overwrite the bearing pointers.

**4.2.1.2.7 Bearing Pointers.** The bearing pointers shall display the relative bearing to the selected navigation aid. Two bearing pointers shall be provided. Each pointer shall consist of a head and tail, which are displayed at opposite sides of the scale (i.e. separated by 180 degrees). The two bearing pointers shall be provided on the outside portion of the compass rose (Figure 4-24), shall be designed such that they do not degrade the readability of the compass rose scale, and shall be visually distinct from one another. Both shall rotate around the circumference of the compass rose scale based on the aircraft position relative to the navigation station.

## DESIGN GUIDANCE

Bearing pointer one is filled in and labeled with a number "1"; its tail is also filled in, but not labeled. Bearing pointer one and its associated information is colored green. Bearing pointer two is slightly larger, drawn in an outline style with a line width of 2 pixels, and labeled with a number "2". Bearing pointer two and its associated information is colored cyan. The label text located within the bearing pointers is 3 mm wide by 4 mm high. Both bearing pointers have a lubber line 0.8 mm wide extending from their base to provide a reference point for reading against the compass rose scale. The tails of the bearing pointers each contain a vertical line through their centers measuring 2.6 mm. The line width in the center of bearing pointer two is 1 mm. Portions of the bearing pointers overwrite the scale, track cross/heading diamond, and 45 degree tic marks. When a bearing pointer overlays a 45 degree tic mark, part of the tic mark is still visible. When associated with ground navigation aids, both bearing pointers indicate the magnetic bearing from the aircraft to the selected ground station. Bearing pointer one shows drift angle (i.e. the same information as the ground track "cross") when it is associated with either INS one or INS two. Bearing pointer two is not driven by either INS. When in ILS mode, the appropriate bearing pointer is removed from the display. A representation of bearing pointer 1 and its associated information is presented to the left of the EHSI. A representation of bearing pointer 2 and its associated information is presented to the right of the EHSI.

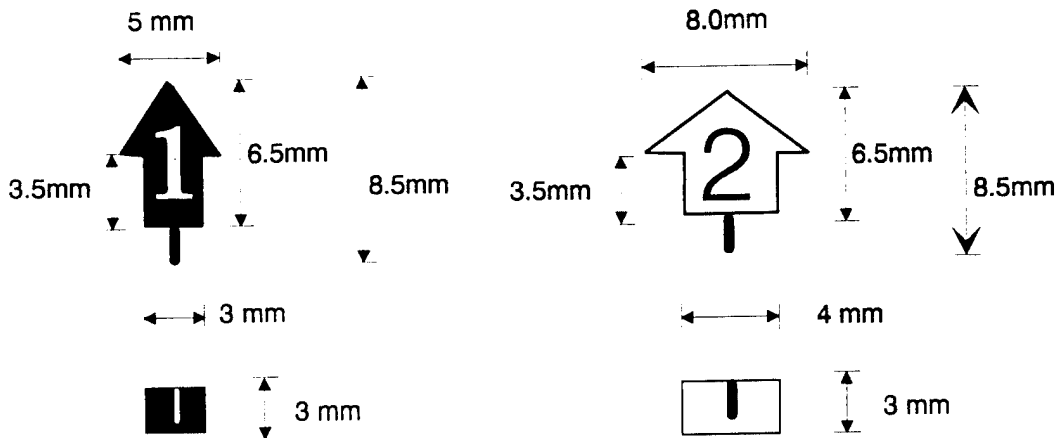


Figure 4-24. Bearing Pointers.

## DESIGN RATIONALE

The designs were selected to be visually distinct and to maximize readability against the HSI compass rose.

## LESSONS LEARNED

The bearing pointer designs were well-received by the participating subject pilots in the C-141 part-task simulation and the full mission simulation.

**4.2.1.2.8 Course Readout.** The course readout shall provide a digital readout of selected course (Figure 4-25). It shall be positioned in close proximity to the HSI and shall be color coded to show its relationship to the course arrow.

## DESIGN GUIDANCE

The course readout consists of the medium green font abbreviation "CRS" and the actual selected course. The bottom left-hand corner of the "CRS" annunciator is located 5 mm from the left edge and 26.5 mm from the bottom of the display. The bottom left-hand corner of the actual course value is located 5 mm from the left edge and 20 mm from the bottom of the display.

CRS  
268

Figure 4-25. Course Readout

## DESIGN RATIONALE

The AWG decided to present course information on the left side of the EHSI. The intent was to group similar information and to provide room for future design enhancements.

## LESSONS LEARNED

Operational pilots participating in a part-task evaluation and the full mission simulation commented that the nontraditional placement of the course information disrupted their normal scan pattern. While the current design did not appear to degrade performance, placement in a more traditional location should be considered for the head-down standard.

**4.2.1.2.9 Distance Readout.** The distance readout shall indicate distance to the selected navigation aid to the nearest tenth of a mile (Figure 4-26) and shall provide an indication that distance information is invalid.

## DESIGN GUIDANCE

The distance readouts are placed immediately above the station identifier information for each bearing pointer. The center reference of bearing 1 head is located 14 mm from the left edge and 55 mm from the bottom of the display. The center reference of bearing 2 head is located 138 mm from the left edge and 55 mm from the bottom of the display. Below each bearing pointer 1 head the center reference of the source 1 is located 14 mm from the left edge and 48.5 mm from the bottom of the display. Below each bearing pointer 2 head the center reference of the source 2 is located 138 mm from the left edge and 48.5 mm from the bottom of the display. The center reference of the actual distance 1 value is located 14 mm from the left edge and 65 mm from the bottom of the display. The center reference of the actual distance 2 value is located 138 mm from the right edge and 65 mm from the bottom of the display. The distance 1 value consists of green medium font and distance 2 value consists of cyan medium font.



*Figure 4-26. Distance Readouts*

## DESIGN RATIONALE

The annunciators for distance one and two were placed such that they were aligned horizontally on the display based on a recommendation from the AWG. The location of the distance information (for bearing pointer 1) was chosen to be consistent with traditional HSI designs.

## LESSONS LEARNED

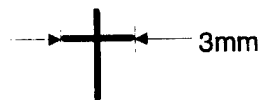


An alternative design was tested in the part-task evaluation which consisted of the annunciation "DIST" and a numerical value below it. These readouts were placed to the left and lower left of the HSI. Operational pilots participating in the part-task evaluation commented that the placement of the distance information disrupted their normal scan pattern. As a result, the annunciation "DIST" was removed and the distance readout for bearing pointer 1 was moved to the upper left corner of the HSI. The distance readouts were well-received by the subject pilots during the full mission simulation.

**4.2.1.2.10 Ground Track Cross.** The ground track cross shall be overlaid on the compass rose scale to indicate ground track when the EHSI is in heading mode (Figure 4-27). This symbol shall move along the compass scale in response to changes in aircraft ground track. The difference between heading and ground track shall be interpreted as drift angle.

#### DESIGN GUIDANCE

The ground track cross symbol is white and is 4 mm high with the wing placed 2.5 mm from the bottom of the symbol. The line width used to construct this symbol is 3 pixels. Ground track is always displayed in the same units that are selected for the entire EHSI (eg. true or magnetic). The ground track cross overwrites the compass scale tic marks and are overwritten by portions of the bearing pointers and heading marker. This symbol is aligned with bearing pointer one when bearing pointer one is being driven by either INS one or INS two.



*Figure 4-27. Ground Track Cross*

#### DESIGN RATIONALE

The original CDS (Rev. A) used a diamond instead of a cross for a ground track symbol with the cross symbol used to indicate heading when in track mode. The AWG agreed to reverse these representations so that the cross now illustrated ground track and the diamond showed heading. The rationale was that the cross (a "T" shape) was a more intuitive symbol for ground track.

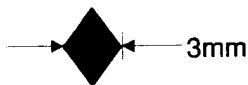
#### LESSONS LEARNED

TBD

**4.2.1.2.11 Heading Diamond.** The heading diamond shall be a diamond shaped symbol overlaid on the compass rose scale, indicating heading when the EHSI is in track mode marker (Figure 4-28). The heading diamond shall move along the compass rose scale in response to changes in the aircraft heading.

#### DESIGN GUIDANCE

Aircraft heading is always displayed in the same units that are selected for the entire EHSI (eg. true or magnetic). The heading diamond is white and 4 mm high. This symbol overwrites the compass rose scale and tic marks but is overwritten by portions of the bearing pointers and the heading.



*Figure 4-28. Heading Diamond*

## DESIGN RATIONALE

The original CDS (Rev. A) used a diamond instead of a cross for a ground track symbol with the cross symbol used to indicate heading when in track mode. The AWG agreed to reverse these representations so that the cross shows ground track and the diamond shows heading.

## LESSONS LEARNED

TBD

**4.2.1.3 Airspeed Scale.** The airspeed scale shall provide calibrated airspeed in both vertical tape and digital formats (Figure 4-29), and shall provide a graphic indication of commanded airspeed. The airspeed information shall be placed on the left side of the EADI to maintain consistency with the standard "T" instrument arrangement. The displayed range of airspeeds shall be compatible with aircraft requirements. The airspeed scale shall move vertically in response to aircraft speed changes to provide a trend indication to the pilot. A digital readout, presented with a rolling counter type format, shall provide a presentation of airspeed at the center of the vertical tape. The scale and digital readout shall be designed for facilitate ease and accuracy of interpretation.

## DESIGN GUIDANCE

On the proposed C-141 PFD, the airspeed scale is white with a gray background and is displayed to the left of the EADI ball. The scale numbers are in the large font and are 5 mm from the left edge of the display and the center of the scale is aligned with the primary control reference symbol on the EADI. The height of the tape is 83 mm. The scale displays a range of 100 kts (50 kts above and below actual airspeed) and is incremented in 20-knot intervals. Major tic marks, 6 mm long, are presented at every 20-knot interval (16.4 mm apart) and minor tic marks, 3 mm long, are displayed at every 10-knot interval. A digital readout window in a rolling-drum format, drawn with a line width of 2 pixels, and centered vertically with respect to the airspeed scale, is provided. The background of the this window is colored in black. The right edge of the digital readout window is placed 22 mm from the left edge of the display and 147 mm from the bottom of the display. All scale information (tic marks, numeric labels, and digital readout) overwrites the command preset and autothrottle speed setting.

CMD 157

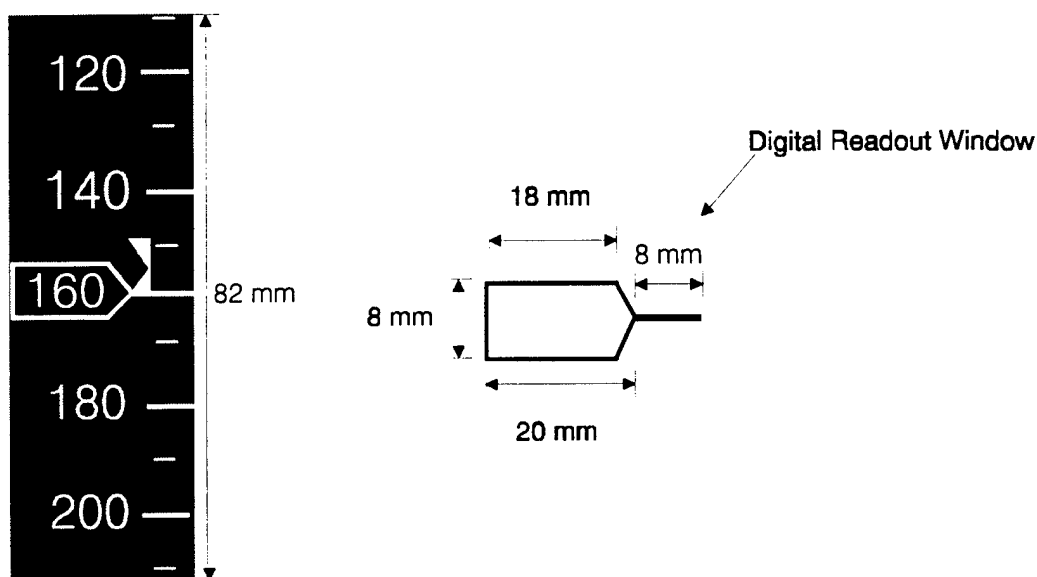


Figure 4-29. Airspeed Scale.

### DESIGN RATIONALE

The airspeed scale was designed with the intent of providing high precision as well as good trend information. The direction of scale numbering was selected to be a “fly-to” design, and is consistent with the current C-141 format. A shaded background was placed behind the scale to aid in its discernability from other display components and to reduce perceived clutter.

### LESSONS LEARNED

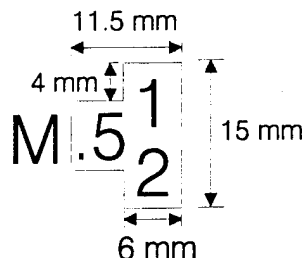
During both the part-task full mission simulation, pilots had difficulty obtaining trend information from the both the digital readout and the moving scale, and commented that the digital readout blocked a significant portion of the scale. The continuous movement of the digital readout was found to cause distraction and the precise nature of the display has the potential to induce workload. During the full mission simulation, pilot’s commented that they would prefer to have the 200 kts increment highlighted to provide additional trend information.

**4.2.1.3.1 Mach Readout.** The mach readout shall provide a digital readout of mach number and a warning when the mach limit is being approached. It shall be placed immediately below the airspeed digital readout box. The mach readout shall consist of the letter “M” followed by a 3-digit readout (Figure 4-30).

### DESIGN GUIDANCE

The “M” is 94 mm from the top edge of the display and 5 mm from its left edge. The center of the far left edge of the mach readout window is located 11 mm from the left edge and 94 mm from the bottom edge of the display. The mach readout window displays two significant digits. For the first significant digit, only one value is presented. For the second digit, the window is expanded vertically to show a range of two digits. All

digits are presented in the large font. The "counter" scrolls up as mach increases. In normal conditions, the readout is white. As mach increases, the color changes as follows: 1) when mach exceeds .78, the window and readout is displayed in yellow; 2) when mach exceeds .80, the window is displayed in red and the readout is displayed in yellow; and 3) when mach exceeds .825, both the window and the readout are displayed in red.



*Figure 4-30. Mach Readout.*

## DESIGN RATIONALE

At the recommendation of the AWG, the expanded window was added around the mach digital readout to improve trend information. The color coding of caution and warning conditions and 2-digit precision were also AWG recommendations.

## LESSONS LEARNED

In the part-task simulation, the mach readout provided 3 digits of precision. Pilots felt this was too precise and added unnecessary clutter to the PFD. In the original design the mach readout window was only displayed above a speed of .4. During the full mission simulation, pilots requested that the mach indicator be displayed at all times since it can be used for "rule of thumb" techniques such as estimating turn radius. They also commented that they missed having a mach command marker.

**4.2.1.3.2 Ground Speed Readout.** The ground speed readout shall provide a digital readout of the ground speed (Figure 4-31).

## DESIGN GUIDANCE

It consists of white "GS" abbreviation followed by a digital value presented in medium font. The ground speed readout is placed immediately below the mach readout window, 5 mm from the left edge and 10 mm from the bottom edge of the display. Any digits that change at a rate of three digits per second, or greater, are temporarily replaced by zeros.

**GS 180**

*Figure 4-31. Ground Speed Readout.*

## DESIGN RATIONALE

The design provides a straightforward indication of ground speed. As a result of the full mission simulation, the ground speed readout was moved to provide a better cross-check of the display.

## LESSONS LEARNED

Operational pilots, performing simulated maneuvers with this display configuration, commented that alternative positions should be considered for the ground speed readout and that reference groundspeed should be available. Pilots commented during the full mission simulation that the course readout should be moved to the lower left corner of the display to aid in the display cross-check.

**4.2.1.3.3 Command Airspeed Preset.** The command airspeed preset shall provide both a digital readout of the commanded airspeed, and a graphic indication of commanded airspeed on the scale itself (Figure 4-32).

## DESIGN GUIDANCE

For the proposed C-141 design, the command airspeed preset consists of a "bowtie" symbol placed on the airspeed scale and a digital representation that is placed immediately above the airspeed scale (Figure 4-31). Once selected, the bowtie remains fixed relative to the scale and moves with the scale. If the commanded airspeed is not in the range of the airspeeds shown by the scale, a partial bowtie shall be presented at either the top or bottom of the scale to indicate that the command airspeed is below or above the currently displayed range. The digital readout is accompanied by the label "CMD". The command airspeed bowtie is placed on the airspeed scale such that bowtie is horizontally centered with respect to the largest scale tic marks. The digital presentation of the command airspeed is located immediately above the airspeed scale, 2 mm from the left and 191 mm from the bottom of the display and is composed of numbers presented in medium font. All command airspeed preset information is colored magenta. All symbols overwrite the command airspeed preset bowtie, but a portion of the bowtie is always visible on the right portion of the scale.

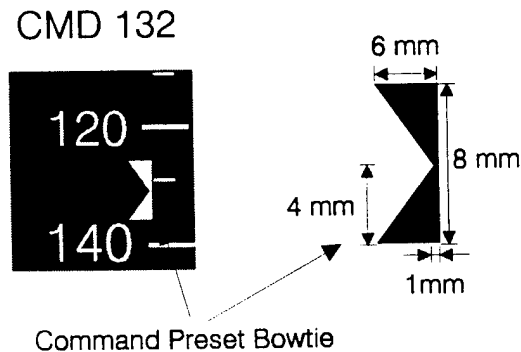


Figure 4-32. Command Airspeed Preset.

## DESIGN RATIONALE

The digital presentation was positioned to reduce its potential confusion as part of the scale. The bowtie symbol was chosen to minimize conflict with scale tic marks and the digital readout box. Also, the bowtie has a "lock and key" fit with the digital readout box when commanded airspeed is obtained.

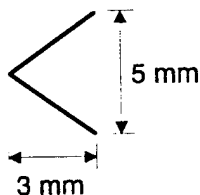
## LESSONS LEARNED

In the original proposed design, a command bar rather than a bowtie was used. Pilot comments indicated that the digital readout blocked a significant portion of the bar as commanded airspeed was approached. During the full mission evaluation, pilots commented that there was a lack of positive identification of the set airspeed due to the lack of contrast and prominence of the command marker. While the design did not appear to affect pilot performance, an alternative format should be considered for the head-down standard.

**4.2.1.3.4 Autothrottle Airspeed Caret.** The autothrottle airspeed caret shall display target airspeed whenever the autothrottles and "speed-on pitch" are engaged, but otherwise, shall not be shown (Figure 4-33).

## DESIGN GUIDANCE

The autothrottle airspeed caret is a magenta symbol resembling the mathematical "less than" symbol pointing toward the scale that moves along the right side of the airspeed scale. When in the default mode, it displays the current airspeed. The autothrottle airspeed caret is drawn with a line width of 3 pixels. The autothrottle airspeed caret is a C-141 design specific symbol and does not apply to the future head-down standard.



*Figure 4-33. Autothrottle Airspeed Caret.*

## DESIGN RATIONALE

The autothrottle system was not used in the part-task simulation or the full mission simulation.

## LESSONS LEARNED

TBD

**4.2.1.4 Altitude Scale.** The altitude scale shall provide aircraft altitude information in both vertical scale and digital readout formats (Figure 4-34). The airspeed information shall be placed on the right side of the EADI to maintain consistency with the standard "T" instrument arrangement. The displayed range of altitudes shall be compatible with aircraft requirements. The altitude scale shall move vertically in response to aircraft altitude changes. The center of the scale shall be aligned with the primary control symbol in the center of the EADI. The scale and digital readout shall be designed for facilitate ease and accuracy of interpretation.

## DESIGN GUIDANCE

For the proposed C-141 format, the altimeter tape is located on the far right side of the PFD and is aligned vertically with the EADI ball. The scale is white with a gray background, provides a total range of 2000 ft (1000 ft above and below the actual altitude) and is numbered in 500 ft increments. Major tic marks, 6 mm in length, are displayed every 500 ft and minor tic marks 3 mm in length are displayed every 100 ft. The major tic marks are spaced 20.5 mm apart with the minor tic marks centered between them. The larger numbers are placed at the top of the scale to provide a “fly-to” design. A digital readout window provided in rolling-drum format, drawn with a line width of 2 pixels, and centered vertically with respect to the altitude scale is provided. When any digit changes at a rate of three digits per second, or faster, a zero temporarily replaces that digit. The hundreds, tens, and ones digits are drawn with a 2 pixel line width; the remaining digits are drawn with a 3 pixel line width. The resolution of the digital readout is in tens of feet. An annunciation for the unit of altitude is provided immediately below the vertical tape, and is either “FT” or “METERS”. These annunciators will be 126 mm from the left edge of the display and 100 mm from the bottom edge of the display. Additionally, when the altimeter is scaled to meters, the letter “M” is displayed between each of the numeric labels. Finally, the tape will be re-scaled such that the rate of movement is identical to that when in feet mode. All scale information (tic marks, numeric labels, and digital readout) overwrites the command preset and the radar altimeter indicator.

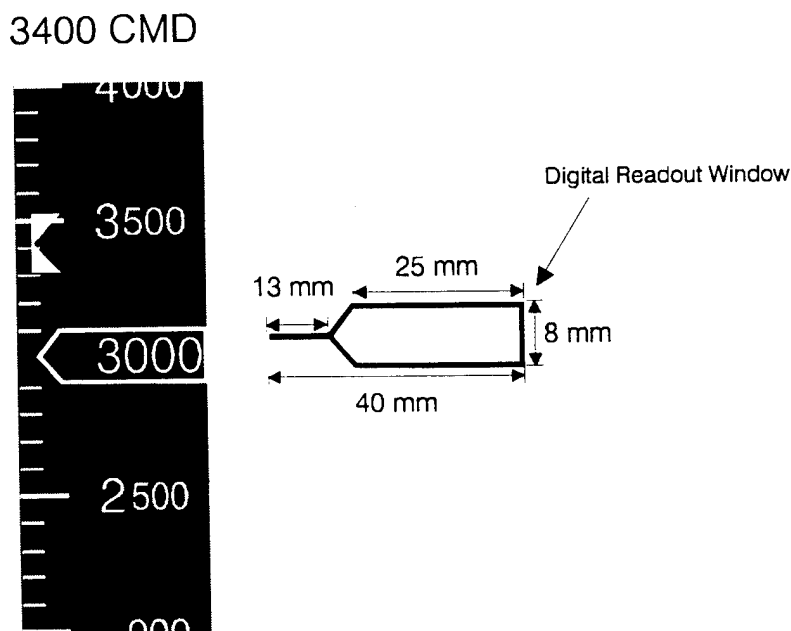


Figure 4-34. Altitude Scale.

## DESIGN RATIONALE

This design has changed significantly from the CDS. The AWG chose the 2000 foot range to facilitate anticipation of level-off altitudes during rapid descents or penetrations. They also chose to provide the resolution of the digital readout to 10 feet. The direction of scale numbering was selected to be a “fly-to” design, and is consistent with the current C-141 format.. The FSDG recommended replacing any digit changing

at a rate of three digits per second with a zero in order to improve readability in dynamic conditions. The "METERS" annunciation and "M" placed between the scale labels were added to provide a positive indication of the current units mode to the pilot. A shaded background was placed behind the scale to aid in its discernability from other display components and to reduce perceived clutter

## LESSONS LEARNED

During the part-task simulation and full mission simulation, pilots had difficulty obtaining trend information from the both the digital readout and the moving scale, and commented that the digital readout blocked a significant portion of the scale. The continuous movement of the digital readout was found to cause distraction and the precise nature of the display has the potential to induce workload. During the full mission simulation, pilots suggested to scroll the digits in 20 ft increments or to move the altitude scale numbers to far right and extend lines. The subjects also suggested to consider a different altitude scale or to consider changing to a traditional vernier scale. These alternatives should be considered for the head-down standard.

**4.2.1.4.1 Radar Altitude.** The radar altitude indicator shall provide Above Ground Level (AGL) altitude on the primary flight display (Figure 4-35). It shall be designed to provide both high precision and clear trend information.

## DESIGN GUIDANCE

Above Ground Level (AGL) Altitude provides radar altitude in both analog and digital fashion (Figure 4-34). The digital form is placed inside a box and is labeled with "AGL". The analog form shall be of the thermometer type and presented on the altitude scale. The analog thermometer symbol is a white ribbon, 3 mm wide, with a triangular shaped platform positioned at the top. The sides of the triangular platform measure 4 mm and 8.5 mm. The thermometer ribbon appears at the bottom of the altitude scale at 1000 ft. The difference between the top of the thermometer ribbon and the center of the tape scale is the ground elevation. As the thermometer ribbon approaches the center of the tape scale, the AGL altitude approaches zero. The digital readout of AGL is presented in a box measuring 7 mm by 20 mm with the label "AGL". The digital readout will scroll in the same direction as that of the baro altimeter. The label, presented in large font is positioned 116 mm from the left and 80 mm from the bottom edge of the display. The center of the left edge of the digital box is located 131 mm from the left and 82 mm from the bottom edge of the display.



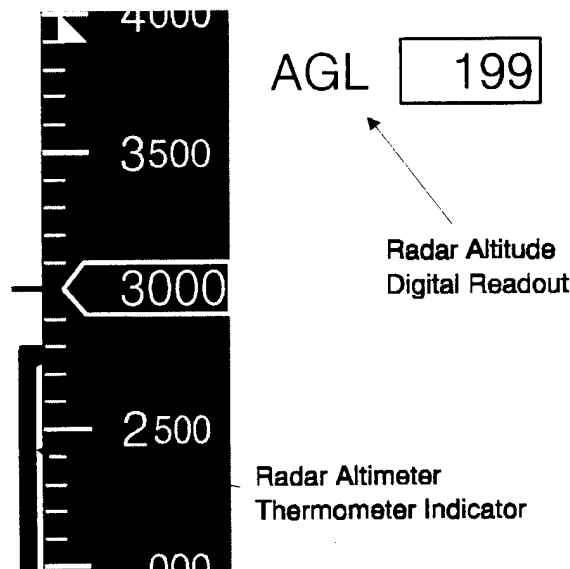


Figure 4-35. Above Ground Level Altitude Indication.

#### DESIGN RATIONALE

Both a digital and analog presentation is provided in order to meet the requirements for high precision and good trend information. As a result of the full mission simulation, the scroll direction of the radar altitude digital readout was changed to match that of the baro altimeter to eliminate some of the distraction.

#### LESSONS LEARNED

Pilots participating in the part-task mission simulation and the full mission simulation commented that the radar altitude digital readout did not provide adequate trend information and that the rapidly changing digital readout was distracting. They also commented that the radar altimeter thermometer indicator obscured the altitude tape, making it harder to read and suggested a different location. During the full mission evaluation, pilots suggested that the scroll direction of the radar altitude digital readout match that of the baro altimeter to help eliminate distraction on the display. However, the current design should not degrade the pilot's performance to safely operate the aircraft.

**4.2.1.4.2 Command Altitude Preset.** The command altitude preset shall provide both a digital readout of the commanded altitude, and a graphic indication of commanded airspeed on the scale itself (Figure 4-36).

#### DESIGN GUIDANCE

The command altitude preset consists of a "bowtie" shaped symbol that is placed on the altitude scale and a digital readout (Figure 4-35). Once selected, the bowtie remains fixed relative to the scale and moves with the scale. If the command altitude is not in the current range shown by the scale, a partial bowtie is presented at either the top or bottom of the scale, as appropriate. The digital value is accompanied by the label "CMD".

The command altitude bowtie is placed on the altitude scale such that the bowtie is horizontally centered with respect to the largest scale tic marks. The bottom left edge of the digital presentation is located 118 mm from the left edge and 191 mm from the bottom of the display and is composed of medium font numbers. All command altitude preset information is colored magenta. Normally, the digital readout is shown in feet. The units will switch to meters when the altimeter is shown in meters.

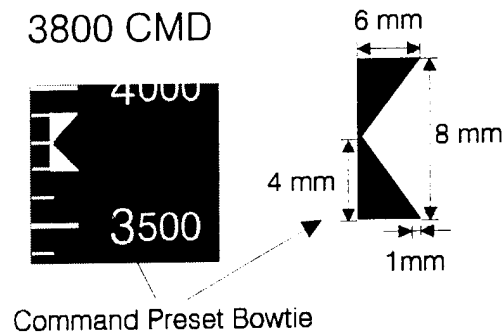


Figure 4-36. Command Altitude Preset.

## DESIGN RATIONALE

The digital presentation was positioned to reduce its potential confusion as part of the scale. The bowtie symbol was chosen to minimize conflict with scale tic marks and the digital readout box. Also, the bowtie has a “lock and key” fit with the digital readout box when commanded altitude is obtained.

## LESSONS LEARNED

In the original proposed design, a command bar rather than a bowtie was used. Pilot comments indicated that the digital readout blocked a significant portion of the bar as commanded altitude was approached. During the full mission evaluation, pilots commented that there was a lack of positive identification of the set altitude due to the lack of contrast and prominence. While the design did not appear to affect pilot performance, an alternative format should be considered for the head-down standard.

**4.2.1.4.2 Baro Altimeter Setting.** The baro altimeter setting shall be presented on the primary flight display (Figure 4-37).

## DESIGN GUIDANCE

The baro altimeter setting is a white digital readout positioned 91 mm from the bottom left edge and 126 mm from the bottom of the display. The values are drawn with the medium font.

## 29.83

*Figure 4-37. Baro Altimeter Setting.*

### DESIGN RATIONALE

The placement was found to be acceptable in the part-task evaluation. During the full mission simulation, pilots suggested that the baro altimeter setting be moved to the far right to aid a easy cross-check of the display. Although improvement is possible, the current design did not degrade the pilot's capability to safely operate the aircraft.

### LESSONS LEARNED

TBD

**4.2.1.4.3 Alert Altitude.** The alert altitude shall be presented in digital form on the primary flight display. It shall be pilot selectable and shall change according to manual selections made on the reference set panel. (Figure 4-38).

### DESIGN GUIDANCE

The alert altitude is white digital readout placed at the lower right corner of the PFD, approximately 110 mm from the left edge and 5 mm from the bottom of the display. The medium font is used to draw the alert altitude readout.

ALRT 2500

*Figure 4-38. Alert Altitude.*

### DESIGN RATIONALE

This information was added to the display by the recommendation of the AWG. While the information is available elsewhere in the cockpit, crosscheck efficiency is improved by including it in the pilot's prime visual signal area.

### LESSONS LEARNED

The original placement of the alert altitude readout (below the radar altimeter readout) was found to be unfavorable by pilots participating in the part-task evaluation. Pilots participating in the full mission simulation rated the alert altitude readout as acceptable.

**4.2.1.5 Vertical Velocity Indicator.** The vertical velocity indicator shall indicate rate of climb or descent in feet per minute (fpm) using a vertical scale format (Figure 4-39). It shall be placed between the EADI ball and the altimeter scale. The vertical velocity shall be determined by reading the position of the thermometer type indicator against the left side of the scale.

## DESIGN GUIDANCE

On the proposed C-141 PFD, the vertical velocity indicator is positioned 114 mm from the left edge and 147 mm from the bottom of the display. The center of the scale is aligned with the primary control symbol on the EADI. A 2.5 mm wide thermometer indicator grows and shrinks continuously from the zero point in response to changes in aircraft climb and descent rate. The scale normally provides a total range of 3000 fpm, with numeric labels at 0, -1000, and 1000 fpm. Each numeric label is constructed using the medium size font. When vertical velocity reaches 1500 fpm, a boxed "1.5" label is added to the scale. The boxed digit is offset 3 mm to the left of the scale. The numbers presented in the boxes are drawn using the medium font. As vertical velocity exceeds 1500 fpm, the digital readout in the box changes to show up to 9.9 x 1000 fpm to the nearest 100 fpm. Major tic marks 4 mm in length are drawn to the right of the vertical scale and are provided at 0, 1.0, 1.5 x 1000 fpm. Each major tick mark is spaced 11 mm apart. Minor tick marks 2.5 mm in length are provided every 100 fpm.

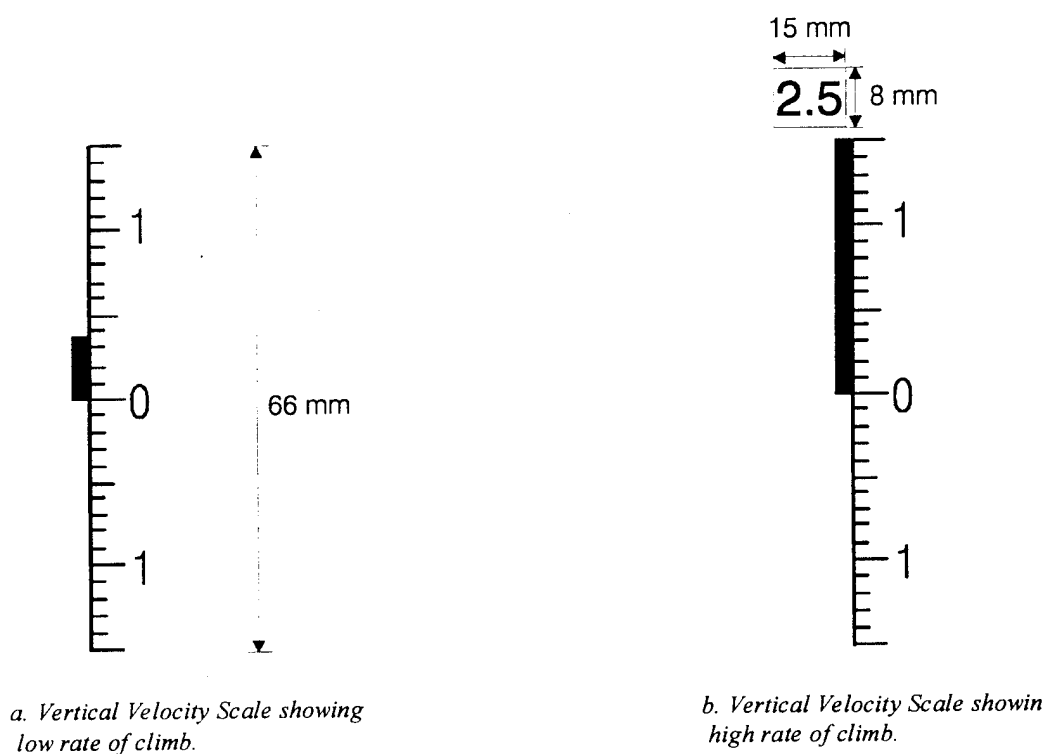


Figure 4-39. Vertical Velocity Indicator.

## DESIGN RATIONALE

In general, the design is very similar to the current C-141 VVI, except that a thermometer style indicator is used instead of a moving pointer caret. The thermometer scale was thought to improve the prominence of the display and to improve the trend indication.

### **LESSONS LEARNED**

The VVI was one of the highest rated items in the C-141 part-task evaluation. During the full mission simulation, pilots preferred that the digits of the VVI digital readout scroll rather than "click" to provide better trend information. Although improvement is possible, the current design did not degrade the pilot's capability to safely operate the aircraft.