ASC-TR-94-5026



# KC-135 COCKPIT MODERNIZATION STUDY PHASE 1 EQUIPMENT EVALUATION

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July, 1994

FINAL REPORT FOR Jan 94 - May 94



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# REPORT DOCUMENTATION PAGE

*Form Approved*
*OMB No. 0704-0188*



| 1. AGENCY USE ONLY (Leave blank) | 2. REPORT DATE | 3. REPORT TYPE AND DATES COVERED |
|---|---|---|
| | JUL 94 | FINAL 02/01/94--05/31/94 |

**4. TITLE AND SUBTITLE**
KC-135 IMPROVED COCKPIT STUDY
PHASE 1 EQUIPMENT EVALUATION

**5. FUNDING NUMBERS**

**6. AUTHOR(S)**
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**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**
Crew Staion Evaluation Facility
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**8. PERFORMING ORGANIZATION REPORT NUMBER**
ASC-TR-94-5026

**9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**
Crew Systems Branch
Aeronautical Systems Center
Air Force Materiel Command
Wright-Patterson AFB, OH 45433-7126
ASC/ENSC, Attn: Capt Ehrhart (513)255-4258

**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
ASC-TR-94-5026

**11. SUPPLEMENTARY NOTES**

**12a. DISTRIBUTION/AVAILABILITY STATEMENT**
APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION IS UNLIMITED

**12b. DISTRIBUTION CODE**

**13. ABSTRACT** *(Maximum 200 words)*

Future KC-135 missions will require significant increases in aircraft flexibility to respond to the Air Force vision of "Global Reach, Global Power." Such flexibility typically translates into advanced avionics systems and system capabilities; however, a large percentage of the avionics sytems currently installed on the KC-135 are late 1950s and 1960s technology which has degraded the efficiency, reliability, maintainability and safety of the KC-135 mission. Strategic Air Command (SAC), now Air Mobility Command (AMC) issued a statement of need (SON, 1987) addressing the need to modernize the KC-135 cockpit avionics to attend to these problems. This report documents the evaluation of the Phase 1 modification plan as proposed by HQ/AMC. The evaluation of the reduced crew consisted of a comparison of crew workload and performance across three missions - Minot, Castle and McChord. Based on crew workload, safety of flight issues and crew interviews, study results did not support the two-person (No Nav) cockpit, given the Phase 1 modifiactions. Based on these results, the CSEF recommended that the feasibility of the Phase 1 modification plan be re-assessed prior to installation into the KC-135. Recommendations are based upon using the final design, identical in system capabilities, as evaluated at the Crew Station Evaluation Facility.

**14. SUBJECT TERMS**
KC-135, Crew Workload, Crew Reduction, Phase 1 Cockpit

**15. NUMBER OF PAGES**
94

**16. PRICE CODE**

| 17. SECURITY CLASSIFICATION OF REPORT | 18. SECURITY CLASSIFICATION OF THIS PAGE | 19. SECURITY CLASSIFICATION OF ABSTRACT | 20. LIMITATION OF ABSTRACT |
|---|---|---|---|
| UNCLASSIFIED | UNCLASSIFIED | UNCLASSIFIED | UL |

## TABLE OF CONTENTS

**TABLE OF CONTENTS (CONT'D)**

APPENDICES

## LIST OF FIGURES

## EXECUTIVE SUMMARY

Recent world events have proven that future KC-135 missions will require significant increases in aircraft flexibility to respond to the Air Force vision of "Global Reach, Global Power." Such flexibility typically translates into advanced avionics systems and system capabilities; however, a large percentage of the avionics systems currently installed on the KC-135 are late 1950s and early 1960s technology which has degraded the efficiency, reliability, maintainability and safety of the KC-135 mission. Strategic Air Command (SAC), now Air Mobility Command (AMC) issued a Statement of Need (SON, 1987) addressing these very problems.

The KC-135 Improved Cockpit Program describes a systematic, time phased avionics integration plan which utilizes modification blocks (Mod Blocks) that will ensure all avionics upgrades are installed in a manner optimizing future upgrades. This integration plan emphasizes the use of modern technologies while maintaining commonality with other Air Force weapon systems.

The introduction of this technology will upgrade the KC-135 avionics that have significantly higher levels of reliability and maintainability, thereby reducing life cycle costs and increasing mission efficiency. The use of a fully integrated avionics system can also support increases in mission management efficiency and automation, simplified crew interfaces, enhanced navigation methods and reductions in overall crew workload. Accordingly, the reduction of the current crew (pilot, copilot, navigator, boom operator) to that of a crew with no navigator may be possible, resulting in additional savings in manpower costs.

During initial test and evaluation, the Crew Station Evaluation Facility demonstrated the feasibility of a two person conceptual cockpit. This design was demonstrated using full mission simulation with operational aircrews; each aircrew flew three different missions with varying levels of difficulty and workload. Performance data, subjective questionnaires and oral responses were collected. In the current study, Phase 1 modifications were implemented and evaluated.

The crews flew five different missions. These missions were generic examples of missions flown during day-to-day tanker operations to include both air refueling and cargo hauling sorties. The missions ranged from 2 hours to 3 1/2 hours in duration depending on crew reaction and decisions. In addition, mission difficulty was manipulated through the use of weather, maintenance problems and a variety of mission changes to evaluate performance across a variety of workload situations. The crews began their missions by completing the necessary preflight and interior inspection checklists and remained in the simulator until mission completion.

Results showed that workload, when compared to the reference aircraft, was significantly higher for the two-man Phase 1 cockpit. The most notable of these results was that workload in the Phase 1 cockpit was believed (as measured by crewmember responses) to be significantly higher than those encountered in the existing aircraft due to the removal of the navigator from the crew.

In addition, results of the Subjective Workload Assessment Technique (SWAT), the Subjective WORkload Dominance (SWORD) technique, the mission questionnaires, objective performance data and crew debriefings consistently support the following results:

1. The mission difficulty yielded expected results. The Minot mission was the easiest, followed by the Castle mission, and the McChord 2 mission was seen as more difficult than the McChord 1 mission

2. Most crewmembers felt that a minimally qualified two-man crew (new A/C and an average CP) could not have successfully completed the harder of the sample missions flown, given the Phase 1 system capabilities.
3. Increased workloads for the two-man crew were encountered during the inflight replanning, random refueling, navigation and radar tasks. Since these workloads were so far outside the desired range, system familiarity and training alone may not reduce workload to the levels needed to guarantee mission success.

The findings of this study do not support the two-person (No Nav) Phase 1 cockpit, given the planned equipment modifications. Of the missions flown, only the most basic missions (Minot and McChord 1 - which did not include any mission or timing changes, weather or receiver problems) were flown safely and with acceptable crew workload. Recommendations for system modification cannot be linked to the most basic missions, but rather, must be tied to a more realistic sampling of missions actually flown - which includes mission changes. These unforeseen changes are where the workload was the highest and, consequently, where the navigator is of the greatest use to the crew. The findings of this study indicate that the two-person (No Nav) cockpit has a significant number of safety of flight problems; workload levels for the two-man crew were significantly higher in the Phase 1 conceptual cockpit when compared to the version of the KC-135 currently flown due to the removal of the navigator. The conclusions listed above are based upon using the Phase 1 design, identical in system capabilities; any changes to this design must be analyzed in detail to accurately measure their effects on crew workload. The key to the eventual success of this program lies in the utilization of modifications discussed in previous reports and the proper implementation of those modifications in future KC-135 cockpits.

## INTRODUCTION

Future KC-135 missions will require significant increases in aircraft flexibility to respond to the Air Force vision of "Global Reach, Global Power." Such flexibility typically translates into advanced avionics systems and system capabilities; however, a large percentage of the avionics systems currently installed on the KC-135 are late 1950s and early 1960s technology which has degraded the efficiency, reliability, maintainability and safety of the KC-135 mission. Strategic Air Command (SAC), now Air Mobility Command (AMC) issued a Statement of Need (SON, 1987) addressing this shortfall and the need to modernize the KC-135 cockpit avionics.

The long-range goal of the Improved Cockpit Program is to develop a systematic, time phased avionics integration plan by means of modification blocks (Mod Blocks) that will ensure all avionics upgrades are installed in a manner that will optimize future upgrades. This integration plan also emphasizes the use of modern technologies while maintaining similarity with other Air Force weapon systems.

The introduction of modern technology will upgrade the KC-135 with avionics that have significantly higher levels of reliability and maintainability, thereby reducing life cycle costs and increasing mission efficiency. A fully integrated avionics system can also support increases in mission management efficiency and automation, simplified crew interfaces, enhanced navigation methods and reductions in overall crew workload. Accordingly, the reduction of the current crew (pilot, copilot, navigator, boom operator) to that of a crew with no navigator may be possible, resulting in additional savings in manpower costs.

The possibility of KC-135 crew reduction has been addressed several times in the past. Geiselhart, Schiffler, and Ivey (1976) reviewed task analysis documents and performed flight tests in an effort to determine the necessity of the four-person crew. With dual Inertial Navigation Systems (INS's) installed aboard a test aircraft, they concluded that workload was too excessive to eliminate the navigator; a four person crew was necessary.

Previous efforts have shown that crew reduction can be accomplished effectively. Schiffler, Geiselhart, and Griffin (1978) used flight tests to demonstrate that the C-141 aircrew could be reduced from a crew of five to a crew of four (by removing the navigator) without any significant mission degradation. In 1981, Barbato, Sexton, Moss, and Brandt studied the avionics requirements needed to successfully accomplish the KC-135 mission. Their study incorporated state-of-the-art systems and yielded the information requirements Madero, Barbato, and Moss (1981) used in full mission simulation to conclude that the KC-135 mission could be successfully accomplished by a three person crew. More recent studies have shown that with the proper avionics integration, removal of the navigator from the crew may be possible. Ehrhart, Kriss, Emerson and Hughes (1993) studied the functional and information requirements of a reduced crew and studied them in full mission simulation. Their results showed that the use of leading edge technology would allow for the removal of the navigator from the crew on standard CONUS missions, but that on in-theater or contingency operations, more detailed analyses were required. Although these studies indicate mixed results, more recent efforts indicate that the key to the success of a three-person crew is contingent upon the use of leading edge technology in the automation of tasks and the modernization of cockpit displays.

## PREVIOUS CSEF TASKING

The Crew Station Evaluation Facility (CSEF) managed and operated by the Aeronautical Systems Center's Crew Systems Branch (ASC/ENSC) conducts real time engineering simulation evaluation in support of weapons systems development. The System Program Office (SPO) uses the CSEF as an engineering tool to quantitatively and qualitatively analyze flight crew workload and performance as a function of crew size, cockpit configuration and operational mission demands.

As part of the KC-135 Cockpit Modernization Program, a Memorandum of Agreement (MOA) between the Directorate of Bomber and Tanker Programs (ASD/SDB) and the CSEF was signed in October 1990. The CSEF was tasked to explore the feasibility of crew reduction by developing an advanced cockpit design, to include avionics upgrades, and then demonstrate the effectiveness of that design in a full mission simulation environment. The results of this tasking were documented in a three volume report labeled Volume 1, Function Analysis Phase, Volume 2, Cockpit Design Phase and Volume 3, the Test and Evaluation Phase. Additionally, a separate report entitled KC-135 Cockpit Modernization Study and Crew Reduction Feasibility Demonstration documented follow-on studies on the performance of a reduced crew in both CONUS and wartime operations. These phases were separate efforts conducted to identify items of interest such as workload bottlenecks and safety critical tasks.

## Function Analysis Phase

The primary focus of the Function Analysis phase was to complete a function analysis of the KC-135 mission in order to recommend and provide a basis for function reallocation that could be effectively supported by a two-man crew configuration. The function analysis and reallocation was accomplished in three steps.

The first step consisted of mission decomposition resulting in detailed listing of all tasks performed by the KC-135 flight crew. With the task listing completed, a detailed functional analysis was conducted during the second step. The functional analysis expanded upon the task listing by identifying information requirements, control requirements and performance criteria for each task. With a thorough understanding of the functional requirements, reallocation of the navigator's tasks was accomplished in the final step.

Through the use of the Modified-Cooper Harper questionnaire, potential high workload segments were identified and highlighted as candidates for automation. Additional information was gathered via literature searches, questionnaires, interviews and observation. As a result of this phase, function redistribution and cockpit automation concepts were established and were used as a requirements baseline for the cockpit design team to develop a two-crewmember flight deck. (Ward, et al., 1991)

## Cockpit Design Phase

The focus of the Cockpit Design Phase was to design a two-person conceptual cockpit, eliminating the navigator station. The design effort used the requirements baseline established during the function analysis phase with additional input from subject matter experts throughout the design process. With user requirements a major concern, vendors of Control Display Units (CDUs) and advanced avionics computers were consulted to ensure leading edge technology was integrated into the CSEF cockpit.

Several design reviews were held at which time user representatives reviewed design concepts and prototypes. The final design incorporated a CDU modified by the CSEF and tailored to meet the specific needs of the KC-135 mission. In addition, a remote readout unit, radar control panel, electronic flight instruments, and a digital warning, caution and advisory panel were included. (Barnaba, et al., 1992)

## Test and Evaluation Phase - Study 1

During the Test and Evaluation Phase, the CSEF began feasibility demonstrations of the two person conceptual cockpit developed during the design phase. This design was demonstrated using full mission simulation with operational aircrews. Each aircrew flew four different missions with varying levels of difficulty and workload. Performance data, subjective questionnaires and oral responses were collected. The ultimate objective of this phase was to validate the functional requirements established during Phase 1 to determine whether the cockpit was designed such that workload was kept at manageable levels in order to ensure mission success. (Rueb, et al., 1992)

## Test and Evaluation Phase - Study 2

Due to the lessons learned during the Persian Gulf War, HQ AMC expressed new concerns that the demands of combat missions (i.e., multiple timing and mission changes, area saturation and degraded navigational aids in wartime areas of operation) may justify the continued need for the naviga' ,r on the KC-135 flight deck. As a result, the CSEF was tasked to re-integrate the navigator station into a modernized cockpit and 1) assess the acceptability of the modernized navigator station and 2) reevaluate the feasibility of the two-man cockpit concept. Drawing upon information gathered during the first three phases of the CSEF Cockpit Modernization effort, a modernized navigator station was developed to support the reallocation of navigator functions back to the navigator. This advanced navigator suite was then demonstrated in full mission simulation using operational aircrews.

In the end, a navigator station was developed which supported all navigator activities. At the same time, no functional capability was removed from the pilot/copilot station as defined by the Phase 2 design concept. This approach allowed for the use of the simulator in both two-man and three-man configurations.

With the design complete, crews were brought in for data collection. During this effort, each aircrew flew seven different simulation missions with varying levels of workload. Crew performance data as well as subjective measures and verbal feedback were collected.

# CURRENT CSEF TASKING

This volume describes the method and results of the test and evaluation of the proposed Phase 1 modification to the KC-135. In order to remove the navigator from the proposed Phase 1 cockpit, CSEF personnel had previously compiled a comprehensive task listing to include all functional and control requirements of the navigator. In addition, interviews with and questionnaires from navigators were used to develop a listing of equipment needed to accomplish the navigator's duties at the pilot station. Phase 1 design modifications were proposed and integrated for testing.

This design was implemented at the request of Air Mobility Command Headquarters for preliminary test and evaluation as a stepping stone toward a fully automated KC-135 cockpit. As a result, the CSEF was tasked to integrate the Phase 1 cockpit into it's simulator and 1) assess the acceptability of the proposed Phase 1 modifications and 2) reevaluate the feasibility of the two-man cockpit concept. Crews were then brought in for data collection. During this effort, each aircrew flew four different simulation missions with varying levels of workload. Crew performance data as well as subjective workload data and verbal feedback were collected. Additional cockpit design recommendations, lessons learned and other considerations were presented to help guide SPO engineers and program managers in defining the requirements for KC-135 upgrades, especially those involving crew reduction.

# METHOD

## Subjects

A total of 8 KC-135 crews (Pilots, Copilots, and boom operators) were used in this study. They were operational crews from various air bases (Active Duty) throughout the United States. All crew members were current and qualified in their respective crew positions. One crew was qualified in all versions of the KC-135 (E,R,Q), and seven crews were qualified in the KC-135R. Overall KC-135 hours ranged from 387 to 3900 and averaged 1428.6. Total flying time ranged from 585 to 4500 and averaged 1960.3. The average time since the last KC-135 flight was 10.5 days.

# Simulation Test Bed

## Crew Station Evaluation Facility

The study was performed at the CSEF, an Air Force simulation facility managed and operated by the Aeronautical Systems Center in the Crew Systems Branch at Wright-Patterson AFB. The facility supports System Program Offices in their acquisition engineering through pilot vehicle interface evaluations using man-in-the-loop simulation. Currently, the CSEF has the capability to perform full and part mission simulations for a variety of aircraft including the KC-135, F-16, F-22 and T-38.

## KC-135 Simulator

The KC-135 simulator (shown in Figures 1 and 2) flown during the simulated missions is equipped with two wide angle collimating windows that provided a panoramic outside scene capable of supporting the Night Visual System (NVS). A Digital Equipment Corporation (DEC) PDP 11/35 computer used a number of databases to simulate various night visual scenes for the NVS. This provided the subjects with a realistic visual scene used during the takeoff and landing phases of flight. The KC-135 simulator cockpit was designed using the instrumentation as required by HQ/AMC . Modifications based upon preliminary quick-looks and subjective inputs were implemented to improve performance and reduce workload. The software package contained all flight, engine, atmosphere, weight and balance modules, a dictionary of all KC-135 data variable and several other data pools for the KC-135A model aircraft. In addition, a Defense Mapping Agency terrain database was fed into a Gould Sel 87 computer. The computer then compared simulator position with the DMA database to compute the aircraft elevation displayed by the radar altimeter and to show the radar picture displayed on the pilot and navigator station radar.

## Computer Complex

The simulator was connected to a series of computer systems, each with a vital role in the control of the overall realism of the KC-135 cockpit. The computer complex included a Gould Series 32/7780, a Gould concept 32/8780, two PDP 11/34, three PDP 11/35 and several Silicon graphics Iris work stations. The Silicon Graphics Work Stations hosted both the ADI/HSI instrument displays and the experimenter's console displays.

## Experimenter's Console

The experimenter's console, also referred to as the Console Operator Station (COS), included a complete intercom system for up to four test engineers/observers and the simulator crew. The console duplicated cockpit displays and provided "quick-look" feedback on crew performance. From the console, the test engineer controlled simulator operation and selected test parameters (test subject number, test conditions, mission number, malfunctions, etc.).

## Procedure

Aircrews (P, CP and Booms) were on site at the CSEF for a period of 1 week during which time they participated in system training and data collection flights. Approximately 2 weeks before their arrival, crews [illegible] instructed to review Dash 1 procedures to i[illegible]e their knowledge of the INS/DNS and radar systems. These readings included detailed descriptions of the Phase 1 systems including systems operating procedures and illustrations. On the first day, crews received a standardized brief covering the purpose of the study, safety procedures, training program, systems descriptions and the schedule for their remaining week of the study.

Crews were also briefed on the Subjective Workload Assessment Technique (SWAT) and Subjective Workload Dominance Technique (SWORD). In addition, each crew underwent training to ensure familiarity with the design and operating characteristics of the system. This included a 2 hour briefing on the systems, their use, individual cockpit displays and system modifications.

Each crew then received one-on-one training on the systems use in the simulator itself; CSEF personnel as well as a qualified instructor navigator were on hand to answer all questions and provide input when necessary. This session included detailed explanations of the checklists, real-time application of the systems and additional uses of the displays. Following this training, crews were given a variety of tasks to ensure minimum system knowledge necessary for study success.

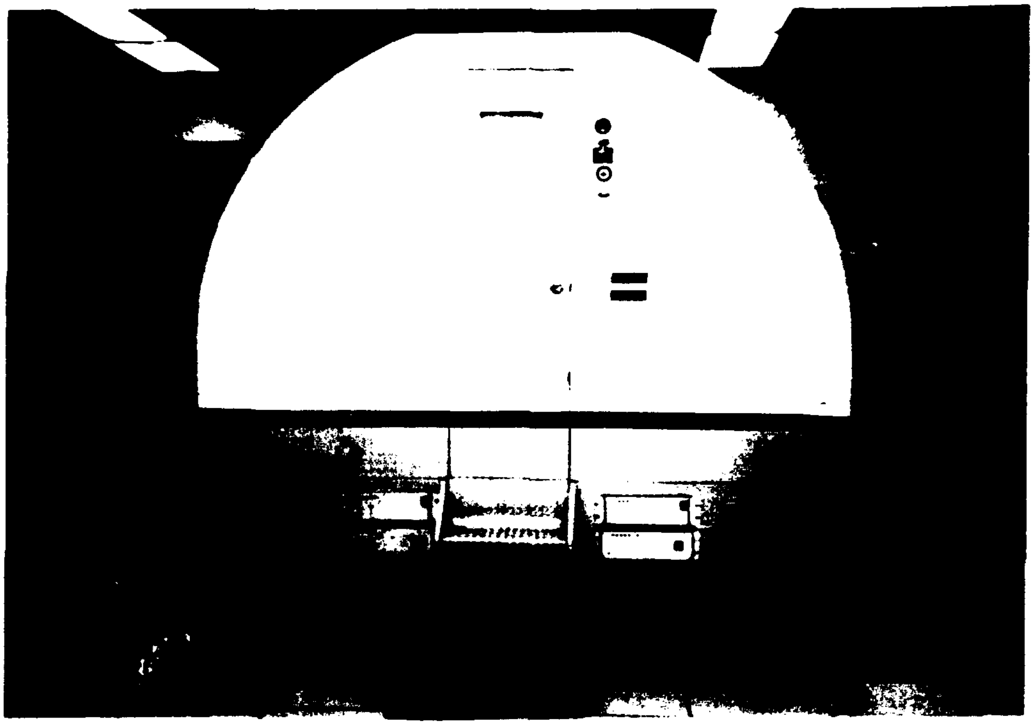

Figure 1. CSEF KC-135 Simulator (Exterior)

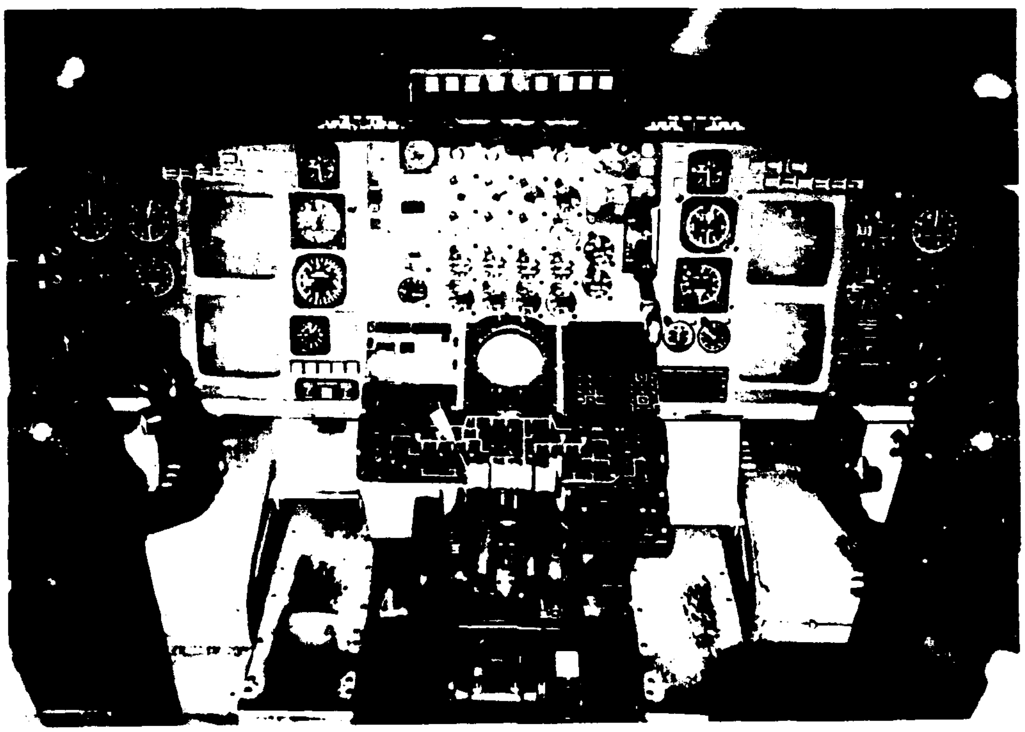

Figure 2. KC-135 Simulator (Interior)

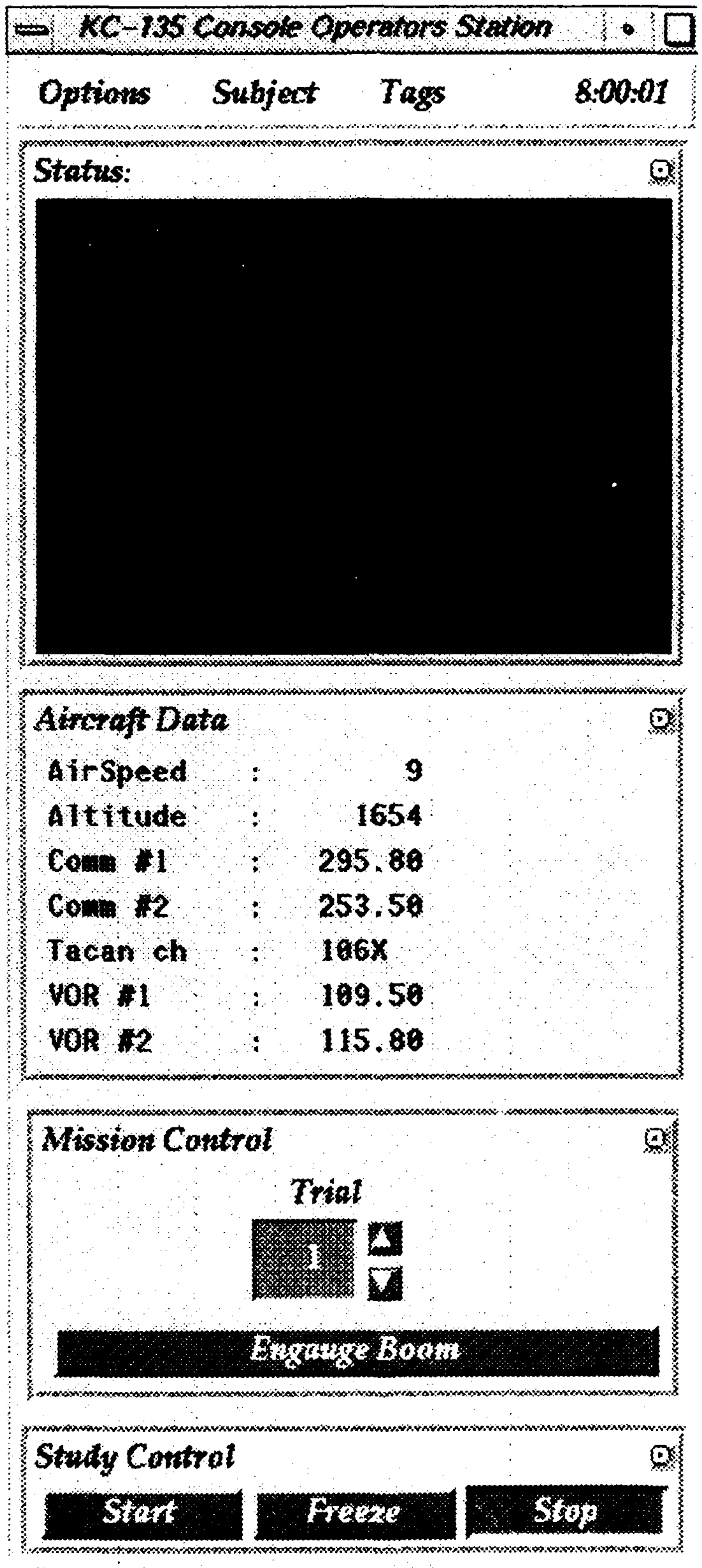


Figure 3. Mission Control Page

Upon completion of training, mission materials for the following days sortie were available for crew review and mission preparation. These materials included mission takeoff data, flight plan, communications and navigation frequencies and a chart covering their intended route of flight. Crews were required to conduct mission planning and prepare any additional paperwork specific to their crew.

Missions were not revealed until the day prior to the actual flight. The crew was expected to have completed all mission paperwork prior to arrival for the flight. The following 4 days were used to fly each of the three missions as a no-navigator crew.

## Mission Simulation

Each crew arrived at the CSEF according to normal mission timing and was briefed on the Notices to Airman (NOTAMS) and any changes to the schedule. The aircrews arrived with all flight equipment ordinarily brought on regular sorties with the exception of flight lunches and helmets. The crew was given a weather briefing (weather sheets were locally developed to further enhance mission realism), a cell briefing and a time hack. As soon as they were ready, the crews proceeded to the simulator to perform the necessary preflight inspections.

Figure 3 shows an example of the mission control page that the experimenter used to select the mission flown, the crew involved and the data collection status of the computers. A COS display also continuously displayed the real-time characteristics of the simulator as it flew each mission. The experimenters started the simulation via the COS setup page when the crew arrived at the cockpit. Experimenters continuously monitored the status of the aircraft via the COS display. The experimenter changed the NVS airport database through the use of the airport selection window. This allowed the console operator to change the visual scene without the knowledge of the pilots and without mission interference.

The crews flew three different missions. These missions were examples of missions flown at Minot AFB, ND, Castle AFB, CA and a mission resembling those flown on typical channel runs (cargo hauling missions) from McChord AFB, WA. The missions ranged from 2 hours to 3 1/2 hours in duration depending on crew reaction and decisions. In addition, mission difficulty was manipulated through the use of weather, maintenance problems and a variety of mission changes to evaluate performance across a variety of workload situations. The crews began their missions by completing the necessary preflight and interior inspection checklists and remained in the simulator until mission completion.

For each of the missions, experimenters used standardized mission scripts to ensure the proper sequencing of events as well as the correct use of terminology by air traffic control, other crew members (crew chiefs and boom operator), weather service personnel, operations personnel and other aircrews. These scripts and scenarios were developed by operational aircrew members to ensure their accuracy and realism.

The crews were required to make all radio calls and perform all activities as they would for actual flight. This included all start engines, taxi, takeoff and cell formation calls. In addition, any mission changes and subsequent routing changes had to be cleared by ARTCC. Experimenters were operational crewmembers who listened intently to all radio calls and responded as necessary.

Some of the missions required the failure of various systems on board the aircraft. These malfunctions were chosen through the use of a malfunction window on the mission control page. This allowed the experimenter to fail systems necessary to induce workload at a predetermined time, standardizing all mission profiles.

Upon completion of the mission, the crew gathered their equipment and was then led to a debriefing room. The crew then filled out their ratings onto the mission specific SWORD data collection worksheets, and then completed the mission specific questionnaire. Upon

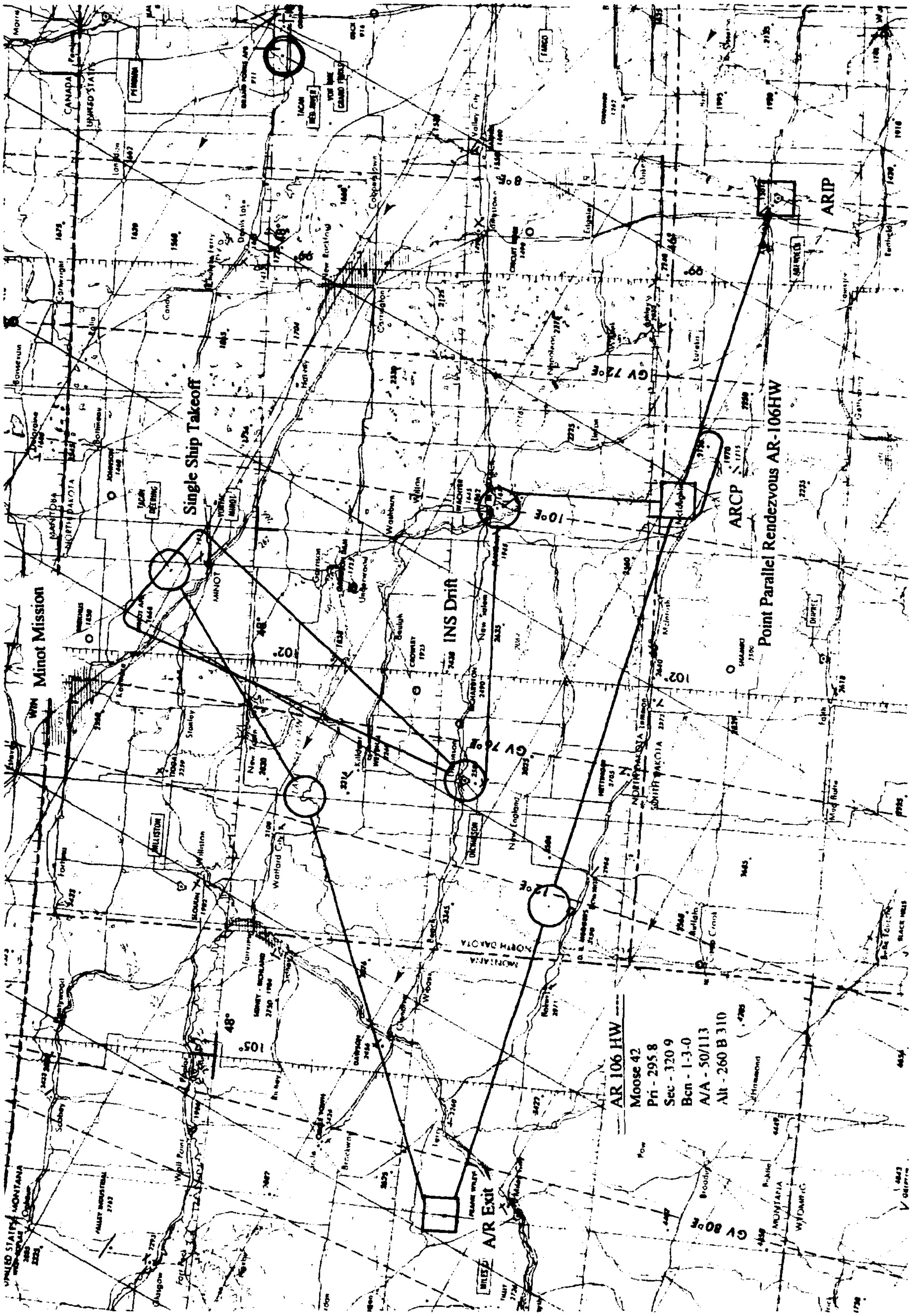


**Figure 4. Minot Mission**

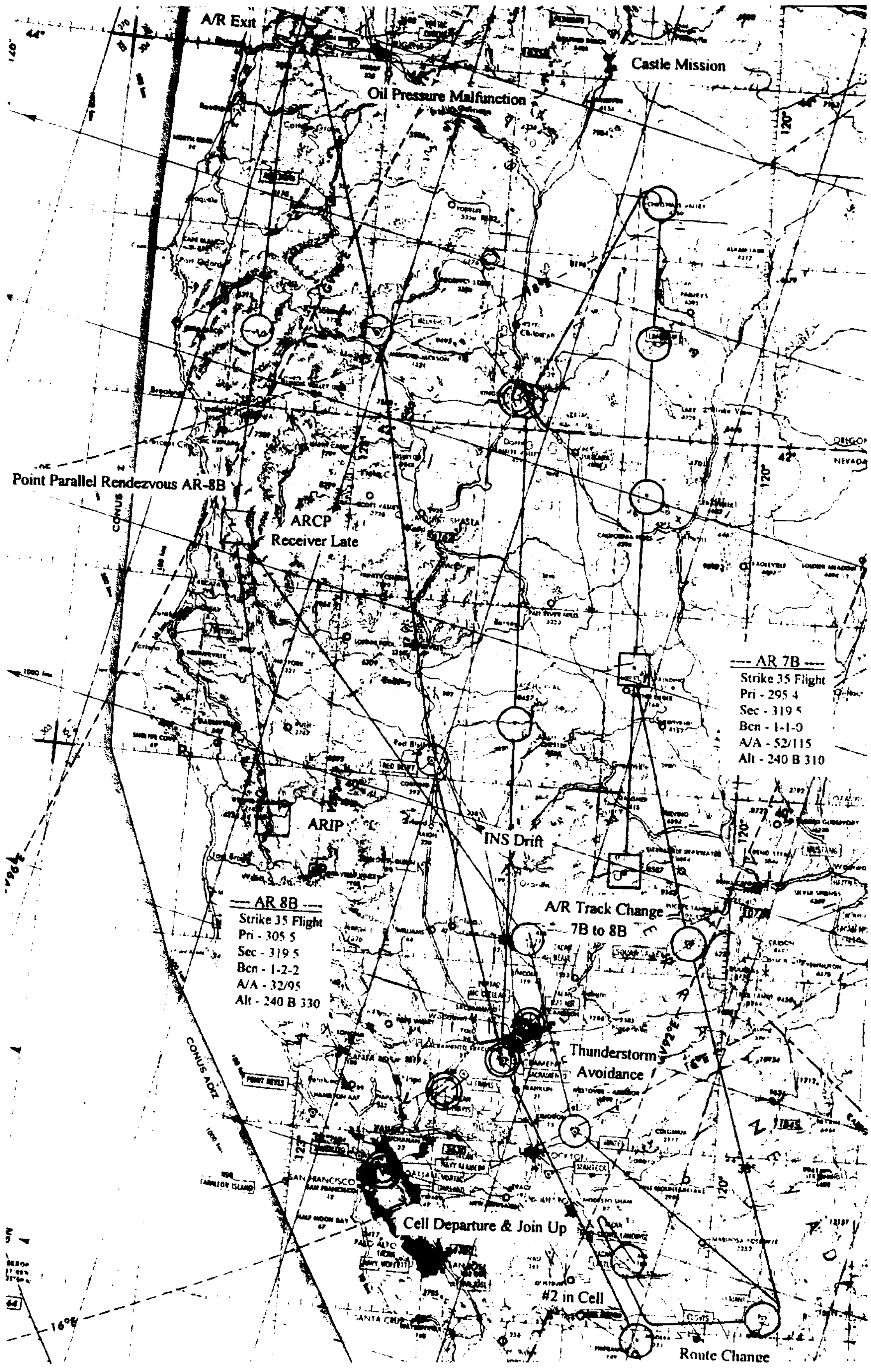


Figure 5. Castle Mission


**Figure 6. McChord Missions**

questionnaire completion, the crew was debriefed on the mission, answered any questions and the following days mission information was distributed. Upon completion of the final mission, the crews were given mission questionnaires and a final SWAT card sort was performed.

**Minot Mission** This mission (Figure 4) was classified as the "easy" mission. The flight was a single ship departure from Minot AFB. The receiver was a single B-52 scheduled for a point-parallel rendezvous at the ARIP for 106 HW. The originally scheduled offload was passed to the receiver. Following the completion of air refueling, the crew returned to Minot and landed. INS drift was 1 NM per hour.

**Castle Mission** This mission (Figure 5) was a difficult mission. The crew was number two in a two-ship cell. The mission started with an on time takeoff from Castle AFB along the Forrt-1 Standard Instrument Departure (SID). Immediately following takeoff, the crew was given a route change to force them to interface with the INS/DNS. Cell break-up was accomplished at the Friant TACAN. Enroute to the original Air Refueling Control Point (ARCP) at AR 6B, the crew encountered weather forcing inflight deviations. With the weather handled, the crew was given an air refueling track change from AR 6B to AR 7B which required mission timing and routing changes.

The scheduled receivers, a flight of four F-16s, experienced maintenance problems and showed up with two aircraft on time and two aircraft late. This forced the crew to coordinate with ARTCC as well as the receiver aircraft for additional orbits down track.

Following air refueling, the crew returned to Castle AFB. Enroute the crew experienced a loss of oil pressure forcing the shutdown of their number two engine. As a result of this malfunction, the crew was forced to coordinate with ARTCC and various command posts for landing. The crew requested landing weather and was given minimum weather required for a precision approach. The crew broke out and the mission was complete. Throughout this mission, the crew was required to deal with drifting INS's (approximately 3 NM per hour) which required numerous updates.

**McChord Mission** This mission (Figure 6) was a two part mission labeled as both the "hard" and "easy" mission. On the first mission, the crew took off as a single-ship departure. After flying radar vectors, the crew was cleared on its route of flight. Enroute to Castle AFB, the crew requested landing weather and was given the minimum required weather for landing. The crew was given radar vectors to final and as a result of weather, never broke out for a landing. After the missed approach, the crew was vectored for a second attempt at landing. The second landing was flown to minimums and the crew landed at Castle AFB.

The second mission was flown immediately after the first mission was completed. The crew took off from Castle and proceeded along the Forrt-1 Standard Instrument Departure (SID). Along the SID, the crew was given a routing change by ARTCC. The crew was forced to input this change as they flew the SID. Upon level-off, the crew experienced an autopilot failure which forced them to hand fly the remainder of the mission. The crew requested landing weather and attempted a landing at Edwards AFB, CA.

The weather at Edwards was below minimums and the crew was forced to divert to the Red Flag alternate of March AFB, CA. This divert forced the crew to coordinate with command post and various control agencies for routing changes. Along the route of flight, the crew was intentionally vectored toward a large mountain near their new landing base at March AFB. Once past the mountain, vectors were given to bring the crew onto the Instrument Landing System (ILS) approach. The ILS was out of service and the crew was forced to transition to the TACAN approach for landing.

Based on the initial direction received from the system program office and Air Mobility Command (AMC), several assumptions were made at the beginning of this four phase effort:

1. The missions were to be unclassified. Classified command and control procedures were purposely ignored.

2. All mode 1, 2 and 4 settings were assumed to be correct. Except for the Mode 3, no actual mode codes were set by the crew members.

3. Celestial navigation was not required.

4. Dual INS's were available and used.

5. Current Federal Aviation Administration (FAA)/Air Force/Air Mobility Command regulations and directives were followed.

6. Crews were familiar with the mission planning software used throughout this study.

## Experimental Design

The primary objectives of this study were to determine the feasibility of the experimental cockpit design proposed under the Phase 1 modification plan as well as take an initial look at training requirements of the crew and cockpit resource management (CRM) requirements involved with the new crew duties. In order to isolate the sources of workload and focus on specific areas of the cockpit design which may require further modification, additional comparisons across mission, mission segments, and segment tasks were also conducted. These analysis will be further detailed in the Results and Discussion section of this report. The order of the missions flown (Minot, Castle and McChord 1 and 2) and the time of day that each was flown (morning or afternoon session) was counterbalanced to remove both training and ordered effects.

## Data Collection

## Objective Measures

Objective performance of each of the crews was monitored from the Console Operator Station during each of the data collection missions. Experimenters monitored a selected set of performance parameters to ensure that the missions were being accomplished within acceptable limits. The parameters of concern and criteria were as follows.

1. Control Time/Time over Steerpoint Deviations: Timing performance was monitored to ensure that crew did not missed designated control times (e.g., ARCT, RZ CT, etc.) by more than +/- 3 min (Ref: AMCR 60-4, Vol IX)

2. Control Point or Steerpoint Deviations: Navigation deviations were monitored to ensure that crews did not miss designated control points (e.g., ARCP, RZ PT) by more than 10 NM (Ref: AMCR 60-4, Vol IX)

3. Airspeed Deviation: Since airspeed is the primary method used in timing control, airspeed deviation was evaluated during the air refueling portion of the mission. It is during this phase of flight that tanker pilots must maintain a set airspeed. 60-4 Vol. IV states that airspeed must be within +/- 10 knots during the rendezvous with the autopilot on and within +15/ -10 knots during contact. With the autopilot off an airspeed range of +15/-15 knots must be maintained during the rendezvous and +20/-15 while the receiver is in the contact position.

4. Altitude Deviation: AMCR 60-4, Vol IV requires that aircraft altitude be maintained within +/- 150 feet for autopilot on flight during cruise and +/-200 feet during air refueling. With the autopilot off, tolerances are loosened to +/- 225 and +/- 300 respectively. Since crewmembers can and often times did request other than originally planned altitudes, increased importance was placed on the experimenter and observer notes to derive altitude deviations.

5. Weather Deviation: AFR 60-16, AMC Sup 1 imposes a minimum distance criteria for severe weather and thunderstorm avoidance. It states that during the en route portion of their flights, crews should avoid thunderstorm activity by any means available by at least 20 NM at or above Flight Level (FL) 230 and by 10 NM below FL 230.

## Subjective Measures

The purpose of the present evaluation was twofold. First, determine whether the missions could be performed in a 2-man cockpit within acceptable workload limits. The second was to identify potentially high workload areas and features of the Phase 1 cockpit and its reallocated tasks which may require additional study. By using such an approach, CSEF personnel could validate system functional requirements by establishing a list of must have requirements without which workload would reach unacceptable levels.

To accomplish these two objectives, three separate techniques were used: the Subjective Workload Assessment Technique (SWAT), Subjective Workload Dominance (SWORD) metric and crew debrief questionnaires. The two workload metrics were used such that they complemented one another in isolating sources of high workload. Because SWAT provides an absolute measurement of subjective workload, it can be used to 1) determine whether workload levels exceeded acceptable limits, and 2) identify specific mission segments where workload exceeds these limits. SWORD, on the other hand, provides a comparative measure of workload, and while it does not establish absolute workload limits, is more sensitive to the differences in workload and pinpoints specific sources of crew workload (such as functions or tasks).

The mission specific questionnaires which were completed at the end of each mission and at the conclusion of the study were instrumental in further isolating sources of workload. In addition, the questionnaires were also used as a means of obtaining explanations from the crews as to why certain segments were higher in workload and what could be done to bring workload levels to within acceptable limits.

A detailed discussion of how each of these metrics was implemented for the current study is provided below:

**Subjective Workload Assessment Technique (SWAT).** SWAT (Reid, et al, 1989) provides a global measure of mental workload that is obtained subjectively. SWAT assumes that workload is composed of three dimensions:

(1) Time Stress - refers to the amount of time available to an operator to accomplish a task, and is rated on a 3-point scale from 1-Often have spare time to 3-Almost never have spare time.

(2) Mental Effort Load - refers to the amount of attention or concentration that is required to perform a task and is rated on a 3-point scale from 1-Very little conscious mental effort or concentration required to 3-Excessive mental effort and concentration required.

(3) Psychological Stress - refers to the presence of confusion, frustration or anxiety associated with task and is also rated on a 3-point scale from 1-Little confusion, risk, frustration, and/or anxiety exists and can easily be accommodated, to 3-High to very intense stress due to confusion, frustration or anxiety.

During the initial pilot training period, a set of 27 cards, representing all possible combinations of workload levels of all three dimensions (time, mental effort, and psychological stress) were sorted by each pilot from lowest to highest workload. The resulting rankings were then used during data analysis to develop a baseline workload scale for the group. When reporting workload throughout the mission, pilots provided three separate ratings, one for each workload dimension. For example a very low workload task would be reported as "1, 1, 1" for time load, mental effort and psychological stress, respectively.

**Subjective WORkload Dominance (SWORD).** SWORD (Vidulich, 1991) uses a series of relative judgments comparing the workload of different task and mission segments in reference to the aircraft flown. The subject was presented with a rating sheet that listed all the possible paired comparisons of the measured tasks. One task was presented on the left-hand side of the page and another on the right. Crewmembers were instructed to mark the equal space if both tasks caused identical workload. Likewise, if either task caused higher workload, they were instructed to mark the space closer to the dominant task. The greater the difference between the two tasks, the closer the mark was placed toward the more difficult task.

**Questionnaire Data.** Crewmembers were also given several questionnaires during the course of this study. Mission specific questionnaires were given to each subject immediately following each mission. This questionnaire was used to pinpoint high workload areas during each mission; subjects could explain specific difficulties encountered during the mission just flown. Several questions were repeated across the mission questionnaires to help identify common problem areas across missions and as a measure of workload manipulation. Following each question was a comments section which allowed the crewmember to fully explain or expand on his/her answers. These questionnaires were designed to identify specific function and information requirements that crewmembers felt necessary for mission accomplishment.

## RESULTS AND DISCUSSION

The results section is broken up into two sections. The first section covers the crew's performance, across a variety of performance parameters, during each mission. These results were gathered in order to ensure that crews were performing within the Federal Aviation Administration, Air Force and Air Mobility Command regulations and directives. The second section looks at the subjective workload measures used in this study, SWAT and SWORD, to determine the feasibility of the Phase 1 conceptual design and high workload areas which may require additional analysis.

Throughout these two sections, the reader will be presented multiple figures for both the pilot group (without the boom) and the overall crewmember group. SWAT and SWORD figures represent the pilot group rating unless labeled otherwise. The various groups being measured are noted in the legend of each figure. In all cases, the two-man crew (2-MAN) represents the conceptual cockpit flown with a pilot and copilot and the reference (REF) represents the current aircraft flown with a pilot, copilot and a navigator. The sample size for each group, unless stated otherwise is as follows: pilots (n=16) and boom operators (n=8). For purposes of this study, pilots and copilots were grouped together for analysis.

### Crew Performance

Most of the objective measures did not reveal any differences between cockpit configurations or missions flown. With one major exception, most performance deviations were corrected in a timely manner without experimenter intervention.

**Control Time Over Steerpoint Deviations.** The control time over steerpoint deviation was evaluated against the scheduled rendezvous (RZ) time and Air Refueling Control time (ARCT) for each mission. SACR 60-4, Vol I dictates that all timing control points be made within +/- 3 minutes. No control time difficulties were noted by the observer or experimenter.

**Control Point/Steerpoint Deviations.** Course deviations are not to exceed ten NM on either side of track in accordance with SACR 60-4 Vol IV. Course deviation was evaluated throughout the flight with increased emphasis placed on the periods from the beginning of Air Refueling (AR) through the end of Air Refueling. No deviations from the ten nautical mile corridor were noted.

**Airspeed Deviations.** A review of the data showed that there were no airspeed deviations that exceeded air refueling limitations during the study.

**Altitude Deviations.** One of the most startling discoveries developed during the McChord 2 mission. When deviating from Edwards AFB, CA to March AFB, CA crews were purposely vectored into a large mountain approximately 30 miles northwest of the field. This was done to determine crew situational awareness during unplanned mission changes usually characterized by high workload. Three of the eight crews flew into the mountain without realizing what had occurred, one crew missed the mountain without knowing it was out there, two crews barely hit the mountain after last minute discovery of their location in relation to the field and two crews actively avoided the mountain through planning and maintaining situational awareness. These "accidents" directly support additional situational awareness displays which would reduce workload and maintain the safety of the KC-135 and its crew as it exists today.

**Weather Deviation Distances.** Thunderstorm avoidance was measured during the entire flight. Throughout this study only one crew failed to avoid a thunderstorm by the prescribed distance. The deviation was noticed and immediately corrected.

## Crew Workload

## Mission Difficulty

The three missions used during this study (Minot, Castle and McChord 1 and 2) were planned with varying levels of difficulty based on the following factors: (1) takeoff time, (2) cell monitoring procedures, (3) inflight replanning, (4) weather avoidance and (5) various systems/equipment malfunctions.

The results of the analysis show that workload for the two-man crew was less than that for the reference crew, as evidenced by a significant main effect for Mission, $F(3,56)=15.96$, $p<0.0001$. The general trend of the data follows the expected pattern of results. Mission difficulty increased from the Minot mission to the Castle mission and from the McChord 1 to McChord 2 mission.

In summary, the increase in mission difficulty from the Minot mission to the Castle mission and from the McChord 1 to McChord 2 missions was as expected for the two-man crew and proved that the manipulation of mission difficulty was successful. Additionally, these missions spanned the range of mission difficulty (from easy to hard) and were representative of current operational missions.

**Mission/Segment Workload**

Presented in Figures 8, 9, and 10 are the SWAT ratings for the Minot, Castle, and McChord 1 and 2 missions, for their associated mission segments.

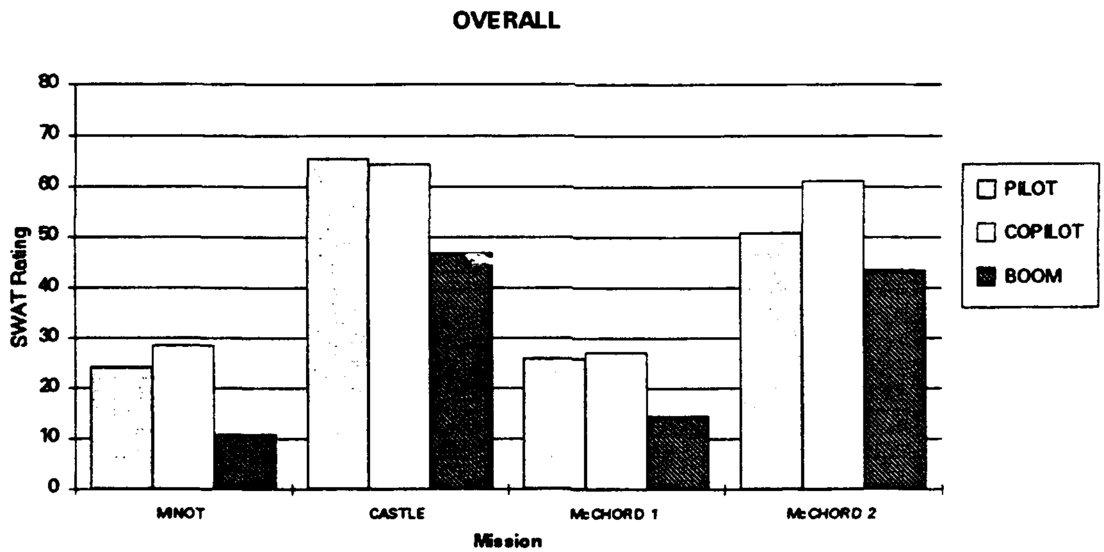


Figure 7. KC-135 Overall SWAT Workload Ratings

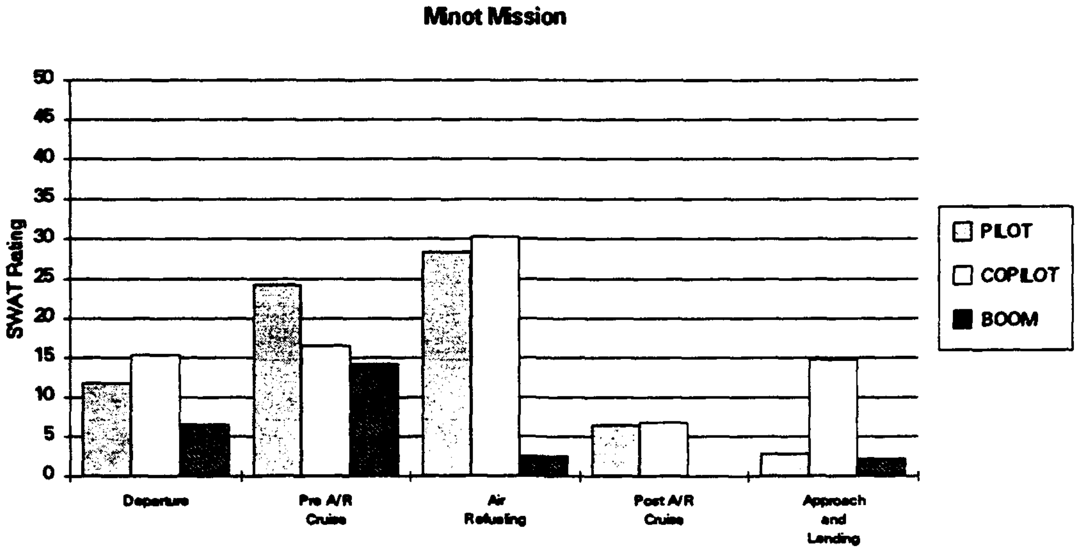


Figure 8. Minot Mission SWAT Ratings for various mission events

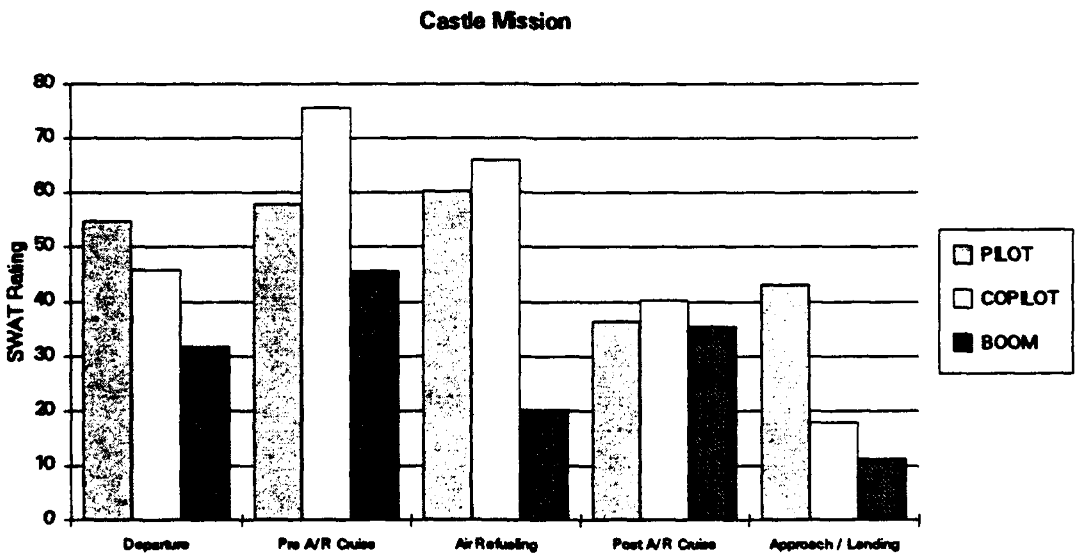


Figure 9. Castle Mission SWAT Ratings for various mission events

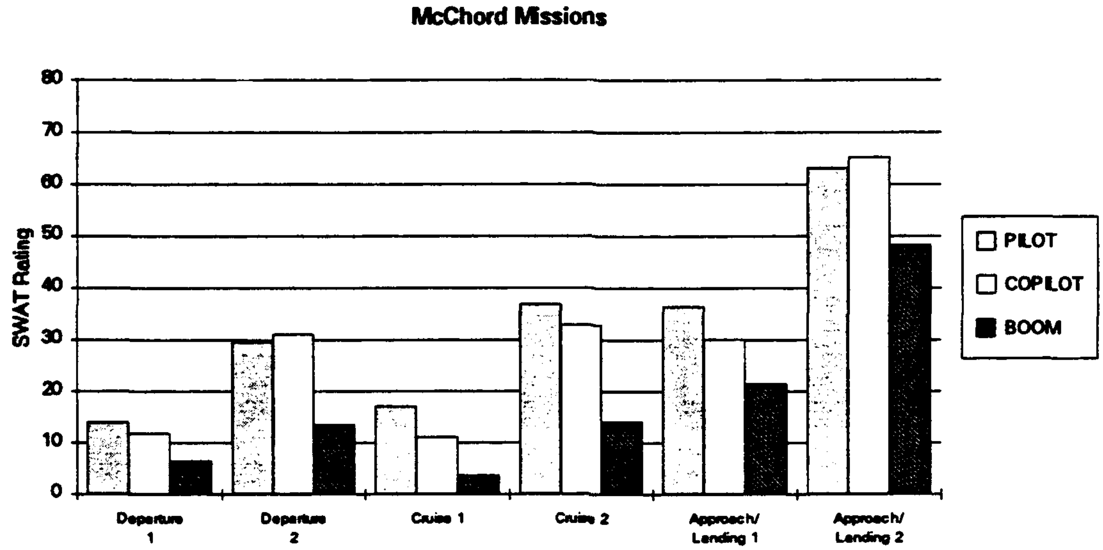


Figure 10. McChord Mission SWAT Ratings for various mission events

A review of Figure 8 reveals that none of the Minot mission events received a rating of over 40 in either the two-man configuration. This indicates that an "easy" mission such as this one would result in workloads that are manageable, given the Phase 1 conceptual cockpit design.

For the Castle mission, Figure 9 indicates that four of the five mission events are potential areas for concern. The departure, pre-air refueling cruise, air refueling, and approach and landing events all had ratings of over 40. This mission was designed to imitate missions currently flown in the operational arena and push mission workload to the level experienced by crews today (with a navigator). Thorough debriefings revealed that KC-135 pilots and copilots felt that additional training in navigation systems procedures and radar usage were a must prior to any cockpit modification. Additionally, continual updates of the INS were also a cause of increased workload and need to be investigated. One major concern was a lack of situational awareness caused by the air refueling track change and mission changes without a navigator.

Finally, analysis of the McChord 1 and McChord 2 missions indicates that three of five events flown were possible areas of concern (Figure 10). This mission was also designed to imitate sorties flown by crews in the field and drive mission workload to the level currently experienced by crews (with a navigator). Discussions with crewmembers revealed that, as previously noted, training was insufficient in both the navigation and radar usage areas to gain thorough proficiency in systems usage. In addition, INS recycle procedures occurred frequently and detracted from overall mission performance. One major concern was a lack of situational awareness caused by the weather divert without a navigator.

**Segment/Task Workload**

SWORD data were collected for three mission segments across the three different missions. The three mission segments for Minot, Castle and McChord 1 and McChord 2 were chosen prior to data collection, based on those segments which were thought to contain the highest workload. In addition, specific segment tasks were chosen for analysis based on the following criteria: (1) tasks believed to be performed most often and (2) anticipated level of difficulty associated with a given task as determined by Ward, et al. (1991).

Figure 11 provides the results for the cruise segment of the Minot Mission. During this segment of the mission the flying task, communications task and the navigation task were compared. The flying task included all things necessary to control heading, altitude and airspeed of the aircraft. For the communications task, all communications with Center, the selection of assigned radio frequencies and the control of both UHF and HF radios were measured. The navigation task included all activities necessary to ensure mission timing and course alignment were met. An analysis of variance indicated a significant main effect for cockpit configuration, $F(1,42)=40.18$, $p<.0001$. Post hoc analysis revealed that a significant difference existed between the two-man and reference configuration.

Figure 12 graphs the results of the Air Refueling segment for each of the missions. The planning task (PLAN) included all timing and route changes, coordinating with center and other aircraft and situational awareness necessary for mission accomplishment. The communications task (COMM) and the navigation task (NAV) were similar to those previously noted.

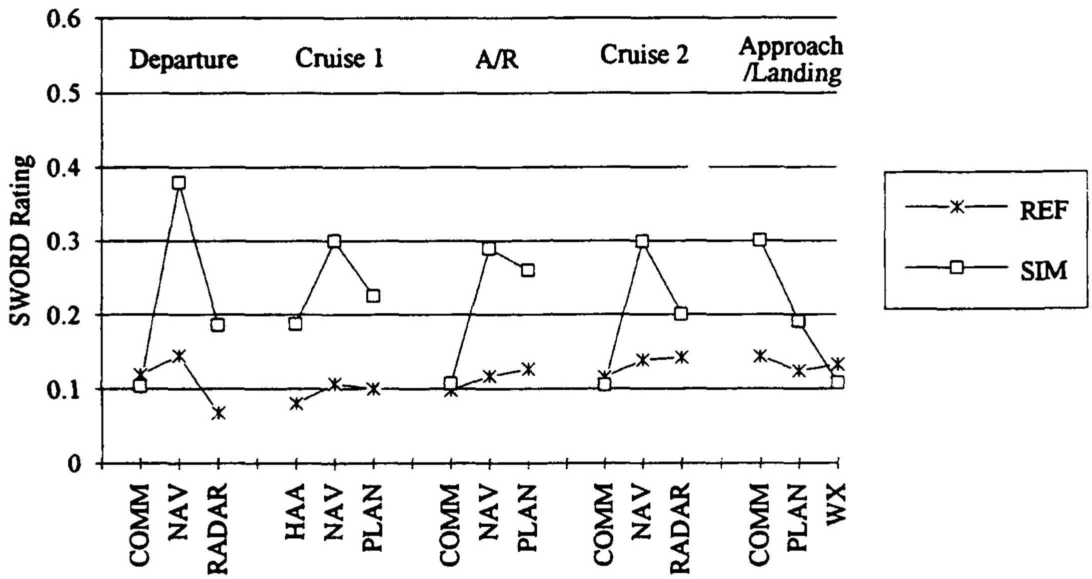


Figure 11. Minot Mission SWORD Ratings

As the graph indicates, the navigation portion of the air refueling segment was considered more difficult across all missions. Post hoc analysis found that the two-man conceptual cockpit yielded significantly higher workload ratings than the reference aircraft. Pilots attributed this to a lack of familiarity with the radar and system setup, the navigation tasks and procedures and the loss of situational awareness during mission changes caused by the removal of the navigator. No significant effects were found between the communications task and the fueling task for any of the missions.

The results of the departure segment of the missions are presented in Figure 13. The radar task (RADAR) included the tuning of the radar to include tilt, gain, range and mode selections and also radar scope interpretation. The COMM and NAV task were as previously explained.

While no significant differences were noted for the communication task for both missions, results indicated a significant main effect for configuration was found for both the radar (RADAR) and the navigation task (NAV). Post hoc analyses revealed that there was a significant main effect between the two-man and reference configurations. As previously mentioned, pilots felt these difficulties arose from a lack of familiarity with the radar system, the navigation tasks and procedures and the loss of situational awareness during mission changes caused by the removal of the navigator.

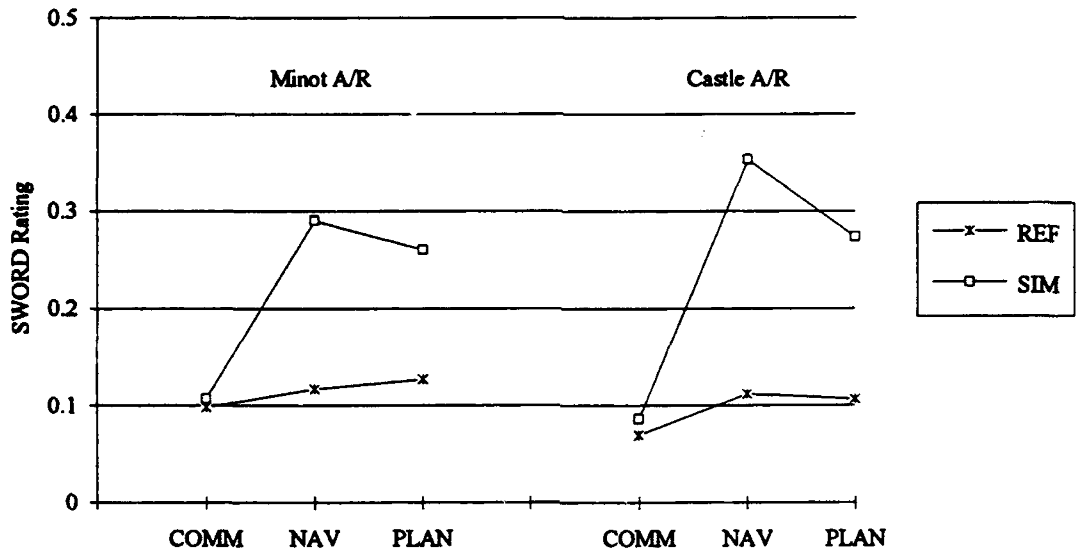


Figure 12. SWORD Ratings for the Air Refueling Segment

Figure 14 shows the workload ratings for the Castle and Minot missions during the cruise segment of the mission. Figure 15 shows the workload ratings for the McChord 1 and McChord 2 missions during the cruise segment of the mission. These segments included all tasks necessary to get from point A to point B, tasks required to determine the new route of flight, input the new route into the Inertial Navigation System (INS) and navigate the aircraft to its new route of flight.

The results indicated that while there was no significant difference in workload for the communications task (COMM), there were statistically significant differences for cockpit configuration for the navigation (NAV) and inflight planning (PLAN) tasks. Results showed that there was a statistically significant difference between the two-man and reference configurations indicating significantly higher levels of workload in the no-nav cockpit configuration. This even occurred during fairly simple missions such as the McChord 1 mission. When asked about the workload differences, pilots felt this was a direct result of the loss of situational awareness during mission changes caused by the removal of the navigator, lack of proper radar training and lack of system familiarity. Simply put by one pilot, "This system takes away a vital part of our crew and gives us no new equipment to help us overcome the loss. They have taken our navigator and given us nothing in return."

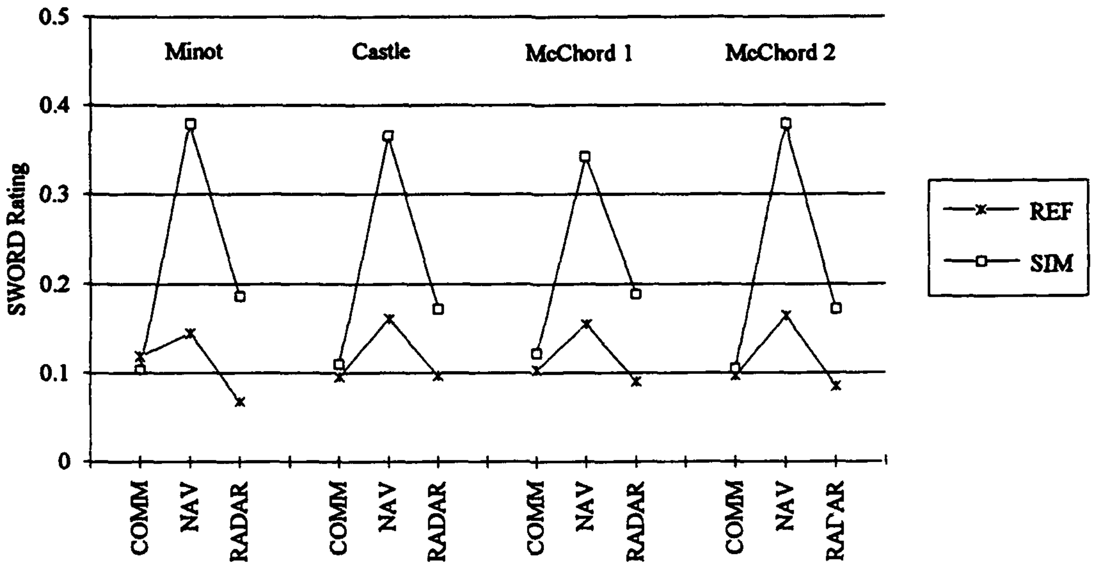


Figure 13. SWORD Ratings for the Cell Departure and Join-up Segment

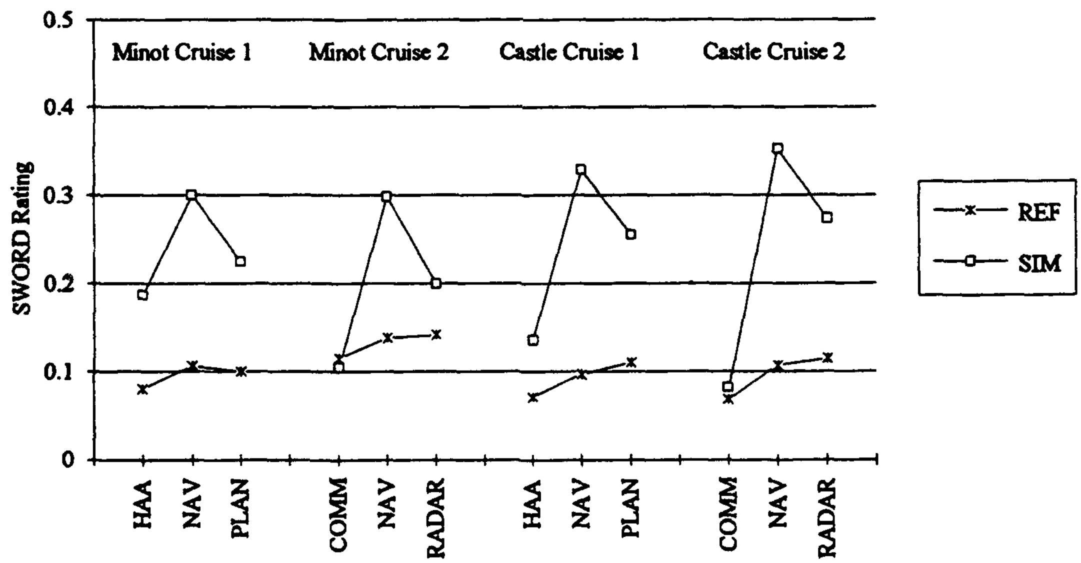


Figure 14. SWORD Ratings for the Cruise Segment

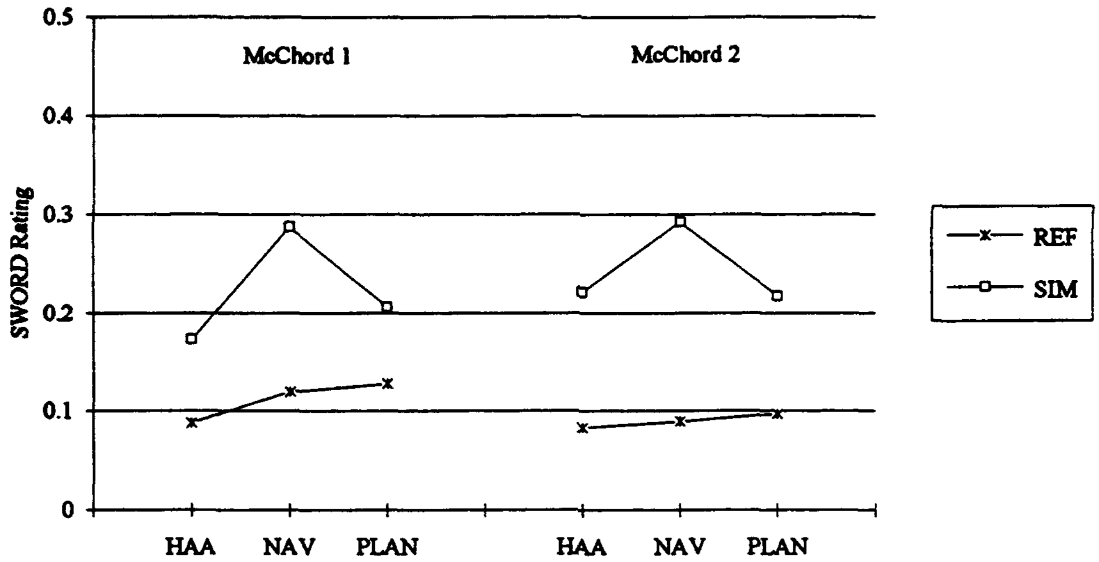


Figure 15. SWORD Ratings for the McChord Cruise Segments

Overall, SWORD results show that workload, when compared to the reference aircraft, was significantly higher for the Phase 1 conceptual cockpit. In fact, the reference configuration produced less workload during almost every task of the missions flown.

Pilots unanimously stated that the major cause of workload during these missions was the loss of situational awareness and safety back up caused by the removal of the navigator. This was largely due to the fact that, as one pilot put it, "When you add other factors such as mission changes, equipment changes, etc., the workload increases significantly on the non-flying pilot leaving no one to back up the pilot flying the airplane. Unless additional avionics equipment is added, I believe that the nav cannot be removed from the cockpit; the nav is essential to our primary mission of air refueling." When this loss of situational awareness was combined with the additional problems of receiver delays, emergencies and mission changes, workload was significantly increased.

The most significant finding of these SWORD results is that relative workloads in the Phase 1 conceptual cockpit were believed (as measured by crewmember responses) to be significantly higher than those encountered in the existing aircraft, due to the removal of the navigator from the crew.

**Questionnaire Results**

While workload and performance measures are extremely important to experimental analyses, crew comments are extremely important in developing the requirements that will guarantee program success. Workload across a variety of missions was well outside the desired range. Mission questionnaires (Appendices C-E) were collected at the end of each mission to help in determining what areas caused crews the greatest difficulty and, consequently, the highest workload. The results of these questionnaires are summarized below.

**Minot Mission**

Crewmembers found this mission the easier of the two air refueling missions. Yet due to the equipment available, over 50% of the pilots felt that the mission segments (departure, pre A/R cruise, air refueling, post A/R cruise and approach and landing) resulted in moderate increases in workload as compared to a normal mission with a navigator. It should be noted that in order to establish a workload baseline, this mission went as planned from takeoff to landing. Crews were also asked if they thought that an inexperienced crew could fly this mission without a navigator provided adequate training. While 67% of the crewmembers responded "yes", they also commented that this would only be the case "if there were no mission changes, weather, malfunctions, navigation problems and everything goes as planned"; this is a luxury that a tanker crew does not have. Crews were also given a chance to comment on any other concerns they had regarding this program. Without question, crews were worried about the removal of the navigator from the crew without any significant equipment upgrades. In addition, crews worried about the required systems training and CRM training necessary to make this program work in the time allotted. Stated on pilot, "It would be difficult for the crew to fly anything but the most basic missions - which rarely if ever happens."

**Castle Mission**

Crewmembers found this the more difficult of the air refueling missions. 67% of the crewmembers surveyed stated that this mission, which included mission changes, weather and an oil pressure malfunction, caused a substantial increase in workload (the highest rating on the scale) and 30% of the crewmembers stated that this mission caused a moderate increase in workload when compared to normal mission with a navigator. Here again, crews were asked if they thought that an inexperienced crew could fly this mission without a navigator provided adequate training. The response was almost unanimous, 97% of those surveyed stated that given this cockpit configuration and an inexperienced crew, this mission would have been impossible to accomplish. Stated one very experienced instructor pilot, "I believe a dangerous situation would have occurred here with violations and maybe much worse. Enormous amounts of training and much better equipment are needed to make this work."

**McChord 1 Mission**

Crewmembers found this mission the easier of the two cargo hauling missions. Yet due to the equipment available, over 55% of the pilots felt that the mission segments (departure, cruise, and approach and landing) resulted in moderate increases in workload as compared to a normal mission with a navigator. It should be noted that in order to establish a workload baseline, this mission went as planned from takeoff to landing. Crews were also asked if they thought that an inexperienced crew could fly this mission without a navigator provided adequate training. While 62% of the crewmembers responded "yes", they also commented that this would only be the case "if there were no mission changes, weather diverts and the mission went as planned; a new crew would be very overworked causing potential safety of flight concerns". Once again, system modification cannot be tied to missions going "as planned" - this rarely, if ever, occurs.

**McChord 2 Mission**

Crewmembers found this the more difficult of the cargo hauling missions. 55% of the crewmembers surveyed stated that this mission, which included route changes, weather divert and enhanced situational awareness to avoid ground collision, caused a substantial increase in workload (the highest rating on the scale) and 29% of the crewmembers stated that this mission caused a moderate increase in workload when compared to normal mission with a navigator. Here again, crews were asked if they thought that an inexperienced crew could fly this mission without a navigator provided adequate training. The response was almost unanimous, 88% of those surveyed stated that given this cockpit configuration and an inexperienced crew, this mission would have been extremely difficult to fly and very unsafe. Stated one very experienced instructor pilot, "We had an experienced pilot and co-pilot and we still had our hands full on this mission." Stated a very experienced boom operator, "This mission, more than any other, demonstrated the need for increased training as well as major equipment changes to prevent aircraft mishaps."

## Program Findings

Results of the Subjective Workload Assessment Technique (SWAT), the Subjective WORKload Dominance (SWORD) technique, the mission questionnaires, objective performance data and crew debriefings consistently support the following results:

1. The mission difficulty yielded expected results. The Minot mission was the easiest, followed by the Castle mission, and the McChord 2 mission was seen as more difficult than the McChord 1 mission.

2. Most crewmembers felt that a minimally qualified crew could not have successfully completed the three sample missions flown, given the Phase 1 system capabilities.

3. Increased workloads were encountered during the inflight replanning, random refueling, navigation and radar tasks. Since these workloads were so far outside the desired range, additional training and system familiarity alone cannot guarantee system success.

## Conclusion

The findings of this study do not support the two-person (No Nav) Phase 1 cockpit, given the planned equipment modifications. Of the missions flown, only the most basic missions (Minot and McChord 1 - which did not include any mission or timing changes, weather or receiver problems) were flown safely and with acceptable crew workload. Recommendations for system modification cannot be linked to the most basic missions, but rather, must be tied to a more realistic sampling of missions actually flown - which includes mission changes. These unforeseen changes are where the workload was the highest and, consequently, where the navigator is of the greatest use to the crew. Additionally, crew workload levels were significantly higher in the Phase 1 conceptual cockpit and safety of flight concerns existed that could have been avoided in the KC-135 cockpit as it is currently flown.

The conclusions listed above are based upon using the final design, identical in system capabilities, as proposed in the Phase 1 modification plan; any changes to this design must be analyzed in detail to accurately measure their effects on crew workload. The key to the success of this program lies in the utilization of previously identified modifications and the proper implementation of those modifications in future KC-135 cockpits.

## ISSUES TO CONSIDER

As in previous studies, several issues were identified as cornerstones to the success of the KC-135 Improved Cockpit Program. The importance of these issues warrants further attention in order to increase the efficiency and reliability of the tanker, its crew and the air refueling mission.

1. Reliable Autopilot. Without question a reliable autopilot was seen as necessary by every crewmember. In failing the autopilot, experimenters found that workload increased dramatically. While one pilot concentrated on flying the airplane, the other was forced to coordinate multiple radios, navigation information and rendezvous progress with limited back up. With the removal of the navigator, pilots felt the autopilot would allow the pilot flying the aircraft the opportunity to back up and even share the workload with the pilot not flying the aircraft.

2. Increased Training for Pilots and Boom Operators. As previously mentioned, much of the workload encountered by the crews in this study was caused by a lack of system familiarity or inadequate training in navigator specific tasks. More specifically, radar tuning and usage, INS updates and operations and rendezvous procedures training were identified as vital elements to any training pilots/booms received. System familiarity and proper training, in addition to enhanced navigation and situational awareness displays, were seen as crucial to the successful removal of the navigator from the KC-135.

3. Reliable Inertial Navigation System (INS). In the Phase 1 cockpit design, it was assumed that two INS's would replace the navigator. The drifting of both INS's caused a moderate increase in workload during the Minot mission and a significant workload increase during the Castle mission. This alone indicates the need for a reliable and accurate navigation system, above and beyond their current levels. Due to the fact that TACAN and VOR navigation are still available during routine missions, the loss of the INS's and GPS during cargo hauling runs within the CONUS is not nearly as critical as losing these systems during an air refueling mission or during a wartime mission where TACAN or VOR navigation is of little help or non-existent.

4. Electronic Horizontal Situation Indicator (EHSI). With the removal of the navigator, situational awareness is paramount to mission success and crew survivability. An EHSI capable of providing moving map displays, location of other aircraft and full weather radar display provides this situational awareness. It provides a central location for tactical and navigation information, will support future integration of threat warning systems and inter/intra-flight data link systems and can provide display area coverage in both the front and rear hemispheres. In order to remove the navigator, this equipment must be in place.

## SUMMARY

This study was part one of the Phase 1 effort to demonstrate the feasibility of a two person (no-navigator) conceptual cockpit proposed by Air Mobility Command Headquarters. Eight KC-135 crews participated in this study for one week each over a one month period. During the study a variety of information was collected to include both subjective (SWAT, SWORD and systems questionnaires) and objective measures (i.e. altitude and airspeed). In addition, several issues of concern were mentioned. Recommendations for system modification cannot be linked to the most basic missions, but rather, must be tied to a more realistic sampling of missions actually flown - which includes mission changes. As a result of this workload data, safety of flight concerns and crew interviews, the feasibility of the Phase 1 modification plan must be re-assessed prior to its installation into the KC-135 to ensure its success and the success of the KC-135 Improved Cockpit Program.

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APPENDIX A

# SWORD RATING FORMS

CREW # ____ CREW POSITION: ____

# MINOT MISSION
## Departure

| | Absolute | | Very Strong | | Strong | | Weak | | Equal | | Weak | | Strong | | Very Strong | | Absolute | |
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| Sim - Radar | | | | | | | | | | | | | | | | | | Sim - Comm |
| Sim - Radar | | | | | | | | | | | | | | | | | | Sim - Nav |
| Sim - Radar | | | | | | | | | | | | | | | | | | Ref - Radar |
| Sim - Radar | | | | | | | | | | | | | | | | | | Ref - Comm |
| Sim - Radar | | | | | | | | | | | | | | | | | | Ref - Nav |
| Sim - Comm | | | | | | | | | | | | | | | | | | Sim - Nav |
| Sim - Comm | | | | | | | | | | | | | | | | | | Ref - Radar |
| Sim - Comm | | | | | | | | | | | | | | | | | | Ref - Comm |
| Sim - Comm | | | | | | | | | | | | | | | | | | Ref - Nav |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Radar |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Comm |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Nav |
| Ref - Radar | | | | | | | | | | | | | | | | | | Ref - Comm |
| Ref - Radar | | | | | | | | | | | | | | | | | | Ref - Nav |
| Ref - Comm | | | | | | | | | | | | | | | | | | Ref - Nav |

AIRCRAFT: SIM - Phase 1 Simulator KC-135
REF - Actual KC-135

TASKS: Radar - Radar Operations
Comm - Communications Procedures
Nav - Navigation Procedures

CREW # ____ CREW POSITION: ____

# MINOT MISSION
## CRUISE # 1

| | Absolute | | Very Strong | | Strong | | Weak | | Equal | | Weak | | Strong | | Very Strong | | Absolute | |
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| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - Plan |
| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - HAA |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Nav |
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| Sim - Plan | | | | | | | | | | | | | | | | | | Sim - HAA |
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| Sim - HAA | | | | | | | | | | | | | | | | | | Ref - Nav |
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| Ref - Nav | | | | | | | | | | | | | | | | | | Ref - Plan |
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| Ref - Plan | | | | | | | | | | | | | | | | | | Ref - HAA |

AIRCRAFT: SIM - Phase 1 Simulator KC-135
REF - Actual KC-135

TASKS: Nav - Nav Operations
Plan - Inflight Planning Procedures
HAA - Heading, Altitude and Airspeed control

CREW # _____ CREW POSITION: _____

# MINOT MISSION
# AIR REFUELING

| | Absolute | | Very Strong | | Strong | | Weak | | Equal | | Weak | | Strong | | Very Strong | | Absolute | |
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| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - Comm |
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| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Plan |
| Sim - Comm | | | | | | | | | | | | | | | | | | Sim - Plan |
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| Sim - Plan | | | | | | | | | | | | | | | | | | Ref - Plan |
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| Ref - Nav | | | | | | | | | | | | | | | | | | Ref - Plan |
| Ref - Comm | | | | | | | | | | | | | | | | | | Ref - Plan |

AIRCRAFT: SIM - Phase 1 Simulator KC-135
REF - Actual KC-135

TASKS: Nav - Nav Operations
Comm - Communications Procedures
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CREW # _____ CREW POSITION: _____

# MINOT MISSION
# CRUISE # 2

| | Absolute | | Very Strong | | Strong | | Weak | | Equal | | Weak | | Strong | | Very Strong | | Absolute | |
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| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - Comm |
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| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Plan |

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| Ref - Comm | | | | | | | | | | | | | | | | | | Ref - Plan |

AIRCRAFT: SIM - Phase 1 Simulator KC-135
REF - Actual KC-135

TASKS: Nav - Nav Operations
Comm - Communications Procedures
Plan - Inflight Planning Operations

CREW # ____ CREW POSITION: ____

# MINOT MISSION
# APPROACH and LANDING

| | Absolute | | Very Strong | | Strong | | Weak | | Equal | | Weak | | Strong | | Very Strong | | Absolute | |
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| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - WX |
| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - Plan |
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| Sim - WX | | | | | | | | | | | | | | | | | | Ref - Nav |
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| Sim - Plan | | | | | | | | | | | | | | | | | | Ref - Plan |
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| Ref - Nav | | | | | | | | | | | | | | | | | | Ref - Plan |
| Ref - WX | | | | | | | | | | | | | | | | | | Ref - Plan |

AIRCRAFT: SIM - Phase 1 Simulator KC-135
REF - Actual KC-135

TASKS: Nav - Nav Operations
WX - Weather Effects on Approach Procedures
Plan - Inflight Planning Operations

CREW # ____ CREW POSITION: ____

# CASTLE MISSION

## Cell Departure and Join Up

| | Absolute | | Very Strong | | Strong | | Weak | | Equal | | Weak | | Strong | | Very Strong | | Absolute | |
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| Sim - Radar | | | | | | | | | | | | | | | | | | Sim - Comm |
| Sim - Radar | | | | | | | | | | | | | | | | | | Sim - Nav |
| Sim - Radar | | | | | | | | | | | | | | | | | | Ref - Radar |
| Sim - Radar | | | | | | | | | | | | | | | | | | Ref - Comm |
| Sim - Radar | | | | | | | | | | | | | | | | | | Ref - Nav |

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| Sim - Comm | | | | | | | | | | | | | | | | | | Sim - Nav |
| Sim - Comm | | | | | | | | | | | | | | | | | | Ref - Radar |
| Sim - Comm | | | | | | | | | | | | | | | | | | Ref - Comm |
| Sim - Comm | | | | | | | | | | | | | | | | | | Ref - Nav |

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| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Radar |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Comm |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Nav |

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| Ref - Radar | | | | | | | | | | | | | | | | | | Ref - Comm |
| Ref - Radar | | | | | | | | | | | | | | | | | | Ref - Nav |

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| Ref - Comm | | | | | | | | | | | | | | | | | | Ref - Nav |

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# CASTLE MISSION
# CRUISE # 1

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| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - Plan |
| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - HAA |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Nav |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Plan |
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| Sim - HAA | | | | | | | | | | | | | | | | | | Ref - Nav |
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| Ref - Nav | | | | | | | | | | | | | | | | | | Ref - Plan |
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# CASTLE MISSION
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| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - Comm |
| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - Plan |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Nav |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Comm |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Plan |
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| Sim - Plan | | | | | | | | | | | | | | | | | | Ref - Comm |
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| Ref - Nav | | | | | | | | | | | | | | | | | | Ref - Comm |
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CREW # ____ CREW POSITION: ____

# CASTLE MISSION
# CRUISE # 2

| | Absolute | | Very Strong | | Strong | | Weak | | Equal | | Weak | | Strong | | Very Strong | | Absolute | |
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| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - Comm |
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| Ref - Nav | | | | | | | | | | | | | | | | | | Ref - Plan |
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AIRCRAFT: SIM - Phase 1 Simulator KC-135
REF - Actual KC-135

TASKS: Nav - Nav Operations
Comm - Communications Procedures
Plan - Inflight Planning Operations

CREW # _____ CREW POSITION: _____

# CASTLE MISSION
## APPROACH and LANDING

| | Absolute | | Very Strong | | Strong | | Weak | | Equal | | Weak | | Strong | | Very Strong | | Absolute | |
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| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - WX |
| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - Plan |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Nav |
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| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Plan |
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| Sim - WX | | | | | | | | | | | | | | | | | | Ref - Nav |
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| Sim - WX | | | | | | | | | | | | | | | | | | Ref - Plan |
| Sim - Plan | | | | | | | | | | | | | | | | | | Ref - Nav |
| Sim - Plan | | | | | | | | | | | | | | | | | | Ref - WX |
| Sim - Plan | | | | | | | | | | | | | | | | | | Ref - Plan |
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AIRCRAFT: SIM - Phase 1 Simulator KC-135
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TASKS: Nav - Nav Operations
WX - Weather Effects on Approach Procedures
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CREW # ____ CREW POSITION: ____

# Mc CHORD # 1 MISSION

## Departure

| | Absolute | | Very Strong | | Strong | | Weak | | Equal | | Weak | | Strong | | Very Strong | | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sim - Radar | | | | | | | | | | | | | | | | | | Sim - Comm |
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| Sim - Radar | | | | | | | | | | | | | | | | | | Ref - Radar |
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| Ref - Radar | | | | | | | | | | | | | | | | | | Ref - Nav |
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TASKS: Radar - Radar Operations
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CREW # ____ CREW POSITION: ____

# Mc CHORD # 1 MISSION
## CRUISE

| | Absolute | | Very Strong | | Strong | | Weak | | Equal | | Weak | | Strong | | Very Strong | | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - Plan |
| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - HAA |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Nav |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Plan |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - HAA |
| Sim - Plan | | | | | | | | | | | | | | | | | | Sim - HAA |
| Sim - Plan | | | | | | | | | | | | | | | | | | Ref - Nav |
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| Sim - HAA | | | | | | | | | | | | | | | | | | Ref - Nav |
| Sim - HAA | | | | | | | | | | | | | | | | | | Ref - Plan |
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| Ref - Nav | | | | | | | | | | | | | | | | | | Ref - Plan |
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AIRCRAFT: SIM - Phase 1 Simulator KC-135
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TASKS: Nav - Nav Operations
Plan - Inflight Planning Procedures
HAA - Heading, Altitude and Airspeed control

CREW # _____ CREW POSITION: _____

# Mc CHORD # 1 MISSION
# APPROACH and LANDING

| | Absolute | | Very Strong | | Strong | | Weak | | Equal | | Weak | | Strong | | Very Strong | | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - WX |
| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - Plan |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Nav |
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| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Plan |
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AIRCRAFT: SIM - Phase 1 Simulator KC-135
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TASKS: Nav - Nav Operations
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CREW # ____

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# Mc CHORD # 2 MISSION
## Departure

| | Absolute | | Very Strong | | Strong | | Weak | | Equal | Weak | | Strong | | Very Strong | | Absolute | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sim - Radar | | | | | | | | | | | | | | | | | | Sim - Comm |
| Sim - Radar | | | | | | | | | | | | | | | | | | Sim - Nav |
| Sim - Radar | | | | | | | | | | | | | | | | | | Ref - Radar |
| Sim - Radar | | | | | | | | | | | | | | | | | | Ref - Comm |
| Sim - Radar | | | | | | | | | | | | | | | | | | Ref - Nav |
| Sim - Comm | | | | | | | | | | | | | | | | | | Sim - Nav |
| Sim - Comm | | | | | | | | | | | | | | | | | | Ref - Radar |
| Sim - Comm | | | | | | | | | | | | | | | | | | Ref - Comm |
| Sim - Comm | | | | | | | | | | | | | | | | | | Ref - Nav |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Radar |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Comm |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Nav |
| Ref - Radar | | | | | | | | | | | | | | | | | | Ref - Comm |
| Ref - Radar | | | | | | | | | | | | | | | | | | Ref - Nav |
| Ref - Comm | | | | | | | | | | | | | | | | | | Ref - Nav |

AIRCRAFT: SIM - Phase 1 Simulator KC-135
REF - Actual KC-135

TASKS: Radar - Radar Operations
Comm - Communications Procedures
Nav - Navigation Procedures

CREW # ____ CREW POSITION: ____

# Mc CHORD # 2 MISSION
## CRUISE

| | Absolute | | Very Strong | | Strong | | Weak | | Equal | | Weak | | Strong | | Very Strong | | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - Plan |
| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - HAA |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Nav |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Plan |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - HAA |
| Sim - Plan | | | | | | | | | | | | | | | | | | Sim - HAA |
| Sim - Plan | | | | | | | | | | | | | | | | | | Ref - Nav |
| Sim - Plan | | | | | | | | | | | | | | | | | | Ref - Plan |
| Sim - Plan | | | | | | | | | | | | | | | | | | Ref - HAA |
| Sim - HAA | | | | | | | | | | | | | | | | | | Ref - Nav |
| Sim - HAA | | | | | | | | | | | | | | | | | | Ref - Plan |
| Sim - HAA | | | | | | | | | | | | | | | | | | Ref - HAA |
| Ref - Nav | | | | | | | | | | | | | | | | | | Ref - Plan |
| Ref - Nav | | | | | | | | | | | | | | | | | | Ref - HAA |
| Ref - Plan | | | | | | | | | | | | | | | | | | Ref - HAA |

AIRCRAFT: SIM - Phase 1 Simulator KC-135
REF - Actual KC-135

TASKS: Nav - Nav Operations
Plan - Inflight Planning Procedures
HAA - Heading, Altitude and Airspeed control

CREW # ____

CREW POSITION: ____

# Mc CHORD # 2 MISSION
## APPROACH and LANDING

| | Absolute | | Very Strong | | Strong | | Weak | | Equal | | Weak | | Strong | | Very Strong | | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - WX |
| Sim - Nav | | | | | | | | | | | | | | | | | | Sim - Plan |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Nav |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - WX |
| Sim - Nav | | | | | | | | | | | | | | | | | | Ref - Plan |
| Sim - WX | | | | | | | | | | | | | | | | | | Sim - Plan |
| Sim - WX | | | | | | | | | | | | | | | | | | Ref - Nav |
| Sim - WX | | | | | | | | | | | | | | | | | | Ref - WX |
| Sim - WX | | | | | | | | | | | | | | | | | | Ref - Plan |
| Sim - Plan | | | | | | | | | | | | | | | | | | Ref - Nav |
| Sim - Plan | | | | | | | | | | | | | | | | | | Ref - WX |
| Sim - Plan | | | | | | | | | | | | | | | | | | Ref - Plan |
| Ref - Nav | | | | | | | | | | | | | | | | | | Ref - WX |
| Ref - Nav | | | | | | | | | | | | | | | | | | Ref - Plan |
| Ref - WX | | | | | | | | | | | | | | | | | | Ref - Plan |

AIRCRAFT: SIM - Phase 1 Simulator KC-135
REF - Actual KC-135

TASKS: Nav - Nav Operations
WX - Weather Effects on Approach Procedures
Plan - Inflight Planning Operations

# APPENDIX B

# PERSONAL DATA QUESTIONNAIRE

PERSONAL DATA QUESTIONNAIRE

Crew # ____
Crew Position ____

Name (Optional): ____________________________

Rank: __________

Age: ___________

Crew Position: ____________________ (IP, P, CP, IBO, BO)

Aeronautical Ratings Held: ____________________ (Prior Nav, etc.)

Organization: ____________________

Duty Station: ____________________

Phone Number (DSN): ____________________

Total Flying Time: __________ Hours

Total KC-135 Flying Time: __________ Hours

Total Hours Current Position: __________ Hours

Time Since Last Flight: __________ Days

KC-135 Version Flown: __________ (A, E, R, Q)

Other Aircraft Flown: ____________________

# APPENDIX C

# MINOT MISSION QUESTIONNAIRE

# AND CREW RESPONSES

**CREW #____**

**CREW POSITION____**

**Minot Mission**

**Questionnaire**

This questionnaire is a mission specific questionnaire concerning the various events encountered during the last mission. You should answer the questionnaire from your own perspective by circling the appropriate answer. If you feel that any question needs further explanation, please feel free to ask one of the experimenters for clarification. If you feel no one answer is adequate, please use the comments section after each question to elaborate on it. A comments section has been provided after each question to allow you to actively express all concerns you might have about a given question, mission, or instrument. You are encouraged to use the comments section whenever possible. For those questions requiring more space than that provided, simply turn the page over and write on the back. Additional comment space is also provided on the last page of the questionnaire.

**1. The late takeoff caused (a) _______ increase in mission difficulty/aircrew workload.**

a. No   b. Slight   c. Moderate   d. Substantial

Pilot 1: No, due to given orbit time, no problems were noted due to late takeoff.
Copilot 1: Slight, due to renumbering of waypoints.
Boom 1: No.
Pilot 2: No.
Copilot 2: No.
Boom 2: No.
Pilot 3: No.
Copilot 3: No.
Boom 3: No.
Pilot 4: Slight.
Copilot 4: No.
Boom 4: No.
Pilot 5: No.
Copilot 5: No.
Boom 5: No.
Pilot 6: No.
Copilot 6: No.
Boom 6: No.
Pilot 7: No.
Copilot 7: No.
Boom 7: No.
Pilot 8: No.
Copilot 8: No.
Boom 8: No.

**2. Prior to Air Refueling, did you detect your INS's were drifting? Radar Pressurization fluctuations? (Please explain when and how you detected your INS's were drifting in the Comments section).**

a. Yes   b. No

Pilot 1: Yes, I thought the INS was drifting more than it was due to how we have to figure out which box is more accurate.
Copilot 1: Yes, INS did not match the radio navaids as well as the DNS. We relied on the DNS for offset but also used the radar. We did not detect the radar problem.
Boom 1: No.
Pilot 2: No, did not realize it drifted.
Copilot 2: No.
Boom 2: No.
Pilot 3: No.
Copilot 3: No.
Boom 3: No.
Pilot 4: No.
Copilot 4: No.

Boom 4: No.
Pilot 5: No.
Copilot 5: Yes. TACAN mixing was accomplished.
Boom 5: No.
Pilot 6: Yes. Did not see radar press fluctuations.
Copilot 6: No. No comment
Boom 6: No. No comment
Pilot 7: Yes. Compared INS #1 & INS #2 then verified with a TACAN fix that #1 had drifted.
Copilot 7: Yes. INS -- Yes, RADAR -- No.
Boom 7: No. No comment.
Pilot 8: No. No comment.
Copilot 8: No. No comment.
Boom 8: No. No comment.

**3. The drifting of the INS system/radar fluctuations caused (a) _______ increase in mission difficulty/aircrew workload.**

| | | | | |
|---|---|---|---|---|
| INS | a. No | b. Slight | c. Moderate | d. Substantial |
| Radar | a. No | b. Slight | c. Moderate | d. Substantial |

Pilot 1: Moderate/ No. Increased difficulty due to finding out which box to use for the RZ. The radar might have been more of a problem, but I didn't know there was a problem w/ radar.
Copilot 1: Moderate/No. Between the INS, DNS, TACAN and radar beacon, we were able to run an acceptable RZ.
Boom 1: *Moderate/No. INS takes the attention away from other flying duties in the cockpit area:* altitudes, headings radio calls.
Pilot 2: No/No. Did not realize it drifted.
Copilot 2: No/No.
Boom 2: No/No. Didn't check for drift.
Pilot 3: No/No.
Copilot 3: No/No.
Boom 3: No/No.
Pilot 4: Slight/No.
Copilot 4: No/No. Did not notice the drift.
Boom 4: No/No. I need more training.
Pilot 5: No/No.
Copilot 5: Slight/Slight. Once the TACAN mixing was in, it was hard to tell which box was right.
Boom 5: No/No. I didn't think they drifted.
Pilot 6: Slight/No. No comment
Copilot 6: No/No. No comment
Boom 6: No/No. No comment
Pilot 7: Slight/No. No comment.
Copilot 7: No. No comment.
Boom 7: No/No. No comment.
Pilot 8: Moderate/Moderate. No comment.
Copilot 8: No/No. No comment.
Boom 8: No/No. No comment.

**4. Were you able to identify your receiver on radar prior to your rendezvous turn inbound toward the ARCP?**

a. Yes b. No

Pilot 1: Yes, but I need more radar interpretation training to get something more useful out of the radar.
Copilot 1: Yes, his beacon was easy to find. I have a sense that it wouldn't be so easy to find his beacon with the repeater scope in the airplane
Boom 1: Yes.
Pilot 2: No, we didn't use the radar (used A/A)
Copilot 2: No, we didn't use the radar (used A/A)
Boom 2: No, we didn't use the radar (used A/A)
Pilot 3: No, sim problems
Copilot 3: No, sim problems
Boom 3: No, sim problems
Pilot 4: No, we didn't use the radar (used A/A)
Copilot 4: No, we didn't use the radar (used A/A)
Boom 4: No, we didn't use the radar (used A/A)
Pilot 5: Yes, we identified his beacon
Copilot 5: Yes, we identified his beacon
Boom 5: Yes, we identified his beacon
Pilot 6: No, we didn't use the radar (used A/A)
Copilot 6: No, we didn't use the radar (used A/A)
Boom 6: No, we didn't use the radar (used A/A)
Pilot 7: Yes
Copilot 7: Yes
Boom 7: Yes
Pilot 8: Yes
Copilot 8: Yes
Boom 8: Yes

**5. The receiver's early arrival at the ARIP caused (a) _______ increase in mission difficulty/aircrew workload.**

a. No b. Slightc. Moderate d. Substantial

Pilot 1: No.
Copilot 1: Slight.
Boom 1: No.
Pilot 2: No.
Copilot 2: Slight.
Boom 2: No.
Pilot 3: Slight.
Copilot 3: No.
Boom 3: Slight.
Pilot 4: No.
Copilot 4: Moderate.
Boom 4: No. I was in the boom pod doing my normal duties.
Pilot 5: No.
Copilot 5: No.

Boom 5: No.
Pilot 6: No. Receiver was late. That caused a slight increase.
Copilot 6: No. No comment.
Boom 6: No. No comment.
Pilot 7: No. No comment.
Copilot 7: No. No comment.
Boom 7: No. No comment.
Pilot 8: N/A.
Copilot 8: No. No comment.
Boom 8: No. No comment.

**6. The communication difficulties encountered at EAR caused (a) _______ increase in mission difficulty/aircrew workload.**

a. No b. Slight c. Moderate d. Substantial

Pilot 1: No.
Copilot 1: No.
Boom 1: No.
Pilot 2: No.
Copilot 2: Slight.
Boom 2: No.
Pilot 3: No.
Copilot 3: No.
Boom 3: No.
Pilot 4: No.
Copilot 4: No.
Boom 4: Slight. EAR was a little tense for communications and the big picture.
Pilot 5: No.
Copilot 5: No.
Boom 5: No.
Pilot 6: No. No difficulties.
Copilot 6: No. No comment.
Boom 6: No. No comment.
Pilot 7: No. No comment.
Copilot 7: No. No comment.
Boom 7: No. No comment.
Pilot 8: N/A.
Copilot 8: No. None.
Boom 8: Slight. No comment.

**7. What type of work-around procedures were used to overcome the difficulties encountered during this mission?**

Pilot 1: Dividing up duties such as the radios among other crew members.
Copilot 1: Boom operator monitored fuel panel much more closely. Both pilots worked nav computers.
Boom 1: We took various tasks and split them up among the crewmembers.
Pilot 2: Boom did a lot of nav duties; A/C did the other nav duties. Copilot did the fuel panel, all backed each other up.
Copilot 2: No Comment.

Boom 2: No difficulties.
Pilot 3: Team work and load sharing.
Copilot 3: Copilot and the boom operator took most of the navs old duties and the pilot took the Comm 1 radio during A/R.
Boom 3: No comment.
Pilot 4: Extra mission planning.
Copilot 4: Turned circles at the CP rather than figure out necessary mission timing.
Boom 4: Better crew coordination helped. Familiarity with the nav's procedures and jumping in to take them over was hard.
Pilot 5: None were needed.
Copilot 5: Used TACANs to navigate around for the most part.
Boom 5: No.
Pilot 6: No comment
Copilot 6: Divide crew duties.
Boom 6: No difficulties encountered.
Pilot 7: This mission wasn't difficult, still used the boom to back up mission progress.
Copilot 7: N/A.
Boom 7: CRM.
Pilot 8: No comment.
Copilot 8: Used normal procedures.
Boom 8: Used the pilots TACAN to keep an idea of our approximate location.

**8. Did you encounter any other problem areas during this mission?**
**(Please explain in comments section)**

a. Yes b. No

Pilot 1: Yes, confusion due to new crew coordination during all phases of flight. Overloading of the copilot and the boom operator.
Copilot 1: Yes, there was much more to do in the right seat as the pilot not flying. We can alleviate this with good CRM.
Boom 1: Yes, clearer objectives on tasks to be divided up among crewmembers, practiced, briefed and applied. Use the boom any way possible to alleviate the pilots' workload.
Pilot 2: No.
Copilot 2: No.
Boom 2: Yes. If the INS head was at the nav station, it would have helped CRM. Put the control head at the nav station and the select switch up front. The pilots can still use both systems and the boom can reduce pilot workload.
Pilot 3: No.
Copilot 3: Yes, had problems tuning the radar.
Boom 3: Yes, uncertain on the tuning of the radar during different modes of flight.
Pilot 4: Yes. Failed to notice the INS/DNS drift in a timely manner.
Copilot 4: No.
Boom 4: Yes. Taking over and trying to do the nav's normal duties was "interesting". I need more training. Move the HF radio to the nav's station and let the boom take over that radio.
Pilot 5: No.
Copilot 5: No.
Boom 5: Yes. A CDU at the nav's station would be a big help if I'm to back up the crew.
Pilot 6: No. No comment.
Copilot 6: No. No comment.
Boom 6: No. No comment.

Pilot 7: No. No comment.
Copilot 7: No. No comment.
Boom 7: No. No comment.
Pilot 8: No. No comment.
Copilot 8: No. No comment.
Boom 8: No. No comment.

**9. Which pieces of equipment were extremely hard to use and, consequently, caused high workload? (Please explain in comments section)**

Pilot 1: Radar due to very little experience using the equipment.
Copilot 1: The radar was hard to work. The only time we knew what we were seeing was in the beacon mode.
Boom 1: No equipment was extremely hard to use, it was extremely hard to guess how to use. Educate me on the basics of what the task is, give me a checklist and it will be handled The equipment at the nav station can be monitored and used by the boom operator. Most booms have a good handle on nav duties like radar use, HF, beacon use, radio calls, prep for contact check. The boom can wait until after the 15 minute prior call before he/she goes to the pod for A/R.
Pilot 2: Radar was not used much due to (lack of meaningful info).
Copilot 2: In the airplane, the distance the copilot might have to reach for the additional CDU could cause problems. Quick dons and headset cords may not reach.
Boom 2: No difficulties.
Pilot 3: Radar was hard to use. No real increase in workload.
Copilot 3: The radar was hard to use. We need more training on it.
Boom 3: No comment.
Pilot 4: No comment.
Copilot 4: The CDU head was hard to use.
Boom 4: Need to have an overall list of all nav's duties and maybe an IRC course for the booms??
Pilot 5: INS/DNS and the radar.
Copilot 5: None.
Boom 5: None, I didn't have any nav equipment to use - get a CDU at the nav's station.
Pilot 6: No comment
Copilot 6: No comment
Boom 6: No comment
Pilot 7: N/A. With available time and lower workload there was adequate time to figure out the CDU, timing, etc.
Copilot 7: Again, adequate training on CDU heads, procedures, and trouble shooting techniques are needed.
Boom 7: Radar lack of proper training.
Pilot 8: Need to change control head to match the FSAS control head.
Copilot 8: None.
Boom 8: Getting nav from the pilots positions

**10. Please recommend any improvements to the aircrew training program that you feel would improve aircrew efficiency and reduce aircrew workload?**

Pilot 1: Stress more items during mission planning geared to problems with timing and navigation.
Copilot 1: Even out workload between pilots. booms need training in TERPS, radar, navigation, and approach altitude calls.
Boom 1: Use the least busy crewmember at times to back up the crew on (all additional duties possible). Use and train the boom as a scaled down FE.

Pilot 2: Put another CDU at the navigator's station for the boom operator.
Copilot 2: No Comment.
Boom 2: Give the boom more training in INS and radar operations.
Pilot 3: Pilot training on radar usage.
Copilot 3: All crewmembers need to become more familiar with the nav's checklists and systems (radar, INS/DNS, etc.)
Boom 3: No comment.
Pilot 4: Keep the navigator on the crew or upgrade the avionics systems. Put all nav system switches where pilots can reach them.
Copilot 4: Install a moving map/GPS receiver/communications database and automate as much of the cockpit as possible. As a tanker we do not fly from point A to point B. We must be able to change A/R tracks or timing at a moments notice to accommodate our receivers. This cockpit cannot do the job.
Boom 4: Boom needs nav training for all phases of flight.
Pilot 5: Pilot need more training in the INS/DNS and radar operations.
Copilot 5: Training on keeping the boxes tight with the CDU.
Boom 5: Training the boom on radar.
Pilot 6: No comment
Copilot 6: Keep the nav's onboard.
Boom 6: See prior critique.
Pilot 7: No comment.
Copilot 7: See 9 above. CDU at boom/nav table would be a definite plus(if not necessity). BO's will require ground training as will pilot team. Also the BO we had was prior gunner on a B-52. His "air sense" and prior training enabled us to do and adequate job. A brand new BO would have been hard pressed to stay in the loop.
Boom 7: Boom ground school to include basic nav.
Pilot 8: Must be a very in depth program to train the boom operator and copilot to prepare them for the hectic pace and inevitable mission changes in essence train them to be a navigator.
Copilot 8: No comment.
Boom 8: If the boom will be backing up the crew they need the equipment and training to be able to do it. The KC-135 booms are already over tasked with additional pax/cargo duties to expect them to also perform navigation/coordination is folly.

**11. What adjective best describes the overall difficulty of this mission?**

a. Easy b. Medium c. Hard

Pilot 1: Medium.
Copilot 1: Medium.
Boom 1: Medium due to lack of training.
Pilot 2: Easy.
Copilot 2: Easy.
Boom 2: Easy.
Pilot 3: Medium.
Copilot 3: Medium.
Boom 3: Easy.
Pilot 4: Medium.
Copilot 4: Easy.
Boom 4: Easy.
Pilot 5: Easy.
Copilot 5: Easy.

Boom 5: Easy.
Pilot 6: Easy.
Copilot 6: Easy.
Boom 6: Easy.
Pilot 7: Easy.
Copilot 7: Easy.
Boom 7: Easy.
Pilot 8: Easy.
Copilot 8: Easy.
Boom 8: Easy.

**12. For the previous mission, rate your workload as compared to what you think it would have been with the present KC-135 system and a navigator. With the system that I just flew my workload was ________.**

a. Substantially decreased
b. Moderately decreased
c. Slightly decreased
d. Not changed
e. Slightly increased
f. Moderately increased
g. Substantially increased

Pilot 1: Moderately Increased. This would have been a simple mission with a navigator on board. With a new copilot and boom it would have been extremely difficult.
Copilot 1: Moderately Increased.
Boom 1: Substantially Increased. An experienced boom has gained enough knowledge without being taught to be able to help the pilots workload considerably without a nav. Simple introductory training on equipment, -1 procedures and nav checklist steps would allow less experienced booms to back up pilots well.
Pilot 2: Moderately Increased. Being a sim, the comm was excellent, in the aircraft, stress level would increase and the crew coordination would suffer.
Copilot 2: Moderately Increased. The boom operator was (very helpful as navigator).
Boom 2: Moderately Increased. Workload was increased, but not unreasonable.
Pilot 3: Slightly Increased.
Copilot 3: Moderately Increased.
Boom 3: Slightly Increased. A list of required duties based upon what the nav does right now would be very helpful for missions.
Pilot 4: Substantially Increased. Too much time spent looking down at the displays trying to get info.
Copilot 4: Substantially Increased.
Boom 4: Slightly Increased. The mission was a simple one with few distractions. Even with a nav it would have been easy. The boom can do more to back up the pilots just give him a checklist and a CDU and the training to do it and it will get done.
Pilot 5: Slightly Increased. Primarily due to a lack of radar, INS/DNS training.
Copilot 5: Slightly Increased.
Boom 5: Not changed. My pilot team took up the extra nav's duties. I just made some radio calls and backed up their flying - I do that all the time.
Pilot 6: Moderately increased. No comment
Copilot 6: Slightly increased. No comment
Boom 6: Not changed. No comment
Pilot 7: Slightly increased. No comment.

Copilot 7: Slightly decreased. No comment.
Boom 7: Not changed. No comment.
Pilot 8: Slightly increased. No comment.
Copilot 8: Slightly increased. No comment.
Boom 8: Moderately increased. No comment.

**13. Provided adequate training, could a minimally experienced pilot with a minimally experienced copilot successfully fly this mission?**

a. Yes b. No

Pilot 1: Yes, but I think it is going to take a lot more training to be able to get a low time crew to the point that they wouldn't get lost if something (out of the ordinary occurs).
Copilot 1: Yes, adequate training is the key.
Boom 1: No. What's the boom going to do watch two pilots (get task saturated) or contribute to the success of this mission??
Pilot 2: Yes, it's possible, mission better have no changes, weather, navigation malfunctions or EP's.
Copilot 2: No Comment.
Boom 2: Yes, provided no weather, mission changes, nav malfunctions or EP's.
Pilot 3: No.
Copilot 3: No.
Boom 3: No.
Pilot 4: Yes, only if there are no mission changes, no bad weather, and everything remains as planned.
Copilot 4: Yes, if nothing changes like in this mission.
Boom 4: Yes, very simple mission. Better make sure that nothing changes on the mission.
Pilot 5: Yes, provided nothing changes like on this mission.
Copilot 5: Yes, if everything stays the same as it did today.
Boom 5: Yes, nothing out of the ordinary came up. The boxes barely drifted and the TACAN worked so there were no problems.
Pilot 6: Yes. No comment
Copilot 6: No answer. No comment
Boom 6: No answer. No comment
Pilot 7: Yes. No comment.
Copilot 7: Yes. No comment.
Boom 7: Yes. No comment.
Pilot 8: Yes. With no changes and no WX this mission would be OK but there is no guarantee that will be the case in real life and a crew could quickly become task saturated.
Copilot 8: Yes. No comment.
Boom 8: No. No comment.

**14. The following space is provided for you to elaborate on questions 1-13 or for you to identify any other concerns that you might have.**

Pilot 1: My concerns start at mission planning. There needs to be training and division of the navigators normal duties, chart, 200, restricted areas, etc. More radar training is needed and how to back up the INS/DNS to see which is more accurate. The boom can be a big help but again training is needed in all areas he is not used to, including the radar and 200.
Copilot 1: My biggest concern is that we need to come up with some CRM concepts for splitting up nav duties and some good training. Also, I don't think that a non-experienced crew could have handled this mission.

| | |
|---|---|
| Boom 1: | Crew duties will have to be re-addressed. Mission planning duties for the boom will be increased both in the planning and the briefings. Have checklist incorporate how to use equipment; a boom need not know how all nav equipment works, but how to work it. |
| Pilot 2: | No Comment. |
| Copilot 2: | No Comment. |
| Boom 2: | No Comment. |
| Pilot 3: | Without a moderately experienced pilot and copilot and extensive upgrades, it would be difficult for the crew to fly anything but the most basic mission. |
| Copilot 3: | In an emergency situation with the boom in the back, the added tasking between the pilot and copilot with no one watching to ensure pilots don't get too focused on one task (looking at light bulbs) could lead to a dangerous situation. Put a CDU at the nav's station for the boom. |
| Boom 3: | No comment. |
| Pilot 4: | The new configuration creates too much heads down display during flight. The complexity of the mission we fly requires a full time navigator to prevent a dangerous or unsafe situation from developing. The aircraft was designed for four qualified crewmembers to accomplish the mission. Even the airlines didn't remove the flight engineer *until a fully automated* cockpit was available. There is absolutely no reason this new concept needs to be implemented with the speed that it is going. |
| Copilot 4: | The CDU and FSAS are now a heads down display. This cockpit is totally unsatisfactory. The airlines fly canned routes from point A to point B with two very, very experienced pilots, plus a flight engineer and they have automated cockpits. We have complicated mission that changes at a moments notice. We do not have a full time flight engineer because the boom has many other duties and cannot stay in the cockpit. Finally, we have no moving maps or automated systems which will allow us to fly with only two pilots. This design is dangerous. |
| Boom 4: | A major concern of mine is how much time the pilots spend in the cockpit. During critical phases of *flight, this could be a big problem. The boom needs to be given more* responsibility to lighten the pilots load. In this cockpit it is too easy to miss a critical item during critical phases of flight especially during EP's or abnormal ops. Also, who will pull CB's during A/R?? |
| Pilot 5: | No comment. |
| Copilot 5: | If this program is geared toward reducing the crew size, get cargo loading experts on the ground at various locations and make the nav a refueling specialist. Don't get rid of the nav without updating the airplane's systems. |
| Boom 5: | A CDU at the nav's station would be great. Give the boom proper training for basic nav skills. Radar use, INS and DNS training are a must. |
| *Pilot 6:* | *No comment.* |
| Copilot 6: | No comment. |
| Boom 6: | No comment. |
| Pilot 7: | No comment. |
| Copilot 7: | With out added stresses (WX, EP's, mission delta's, equipment problems) a 3 person team could accomplish a generic "local" mission. With the added stresses and without substantial automation/upgrade of instrumentation mission accomplishment and safety will be compromised. |
| Boom 7: | No comment. |
| Pilot 8: | No comment. |
| Copilot 8: | Although mission could be successfully flown without NAVs I think the quality and the safety of the missions will suffer. Under normal conditions there would be no problem but when you add other factors such as mission changes, equipment problems, etc. the workload increases significantly on the non flying pilot which leaves no one to back up the flying pilot. I feel the nav is essential to our primary mission of air refueling regardless of where or when. |
| Boom 8: | No comment. |

# APPENDIX D

# CASTLE MISSION QUESTIONNAIRE

# AND CREW RESPONSES

**CREW #____**

**CREW POSITION____**

**Castle Mission**

**Questionnaire**

**This questionnaire is a mission specific questionnaire concerning the various events encountered during the last mission. You should answer the questionnaire from your own perspective by circling the appropriate answer. If you feel that any question needs further explanation, please feel free to ask one of the experimenters for clarification. If you feel no one answer is adequate, please use the comments section after each question to elaborate on it. A comments section has been provided after each question to allow you to actively express all concerns you might have about a given question, mission, or instrument. You are encouraged to use the comments section whenever possible. For those questions requiring more space than that provided, simply turn the page over and write on the back. Additional comment space is also provided on the last page of the questionnaire.**

**1. The cell departure/join-up requirement caused (a) ______ increase in mission difficulty/aircrew workload.**

a. No b. Slight c. Moderate d. Substantial

| | |
|---|---|
| Pilot 1: | Moderate. The increase in workload came in dividing up the nav's duties in station keeping during the takeoff. |
| Copilot 1: | Moderate. Had to use differential DME on the SID. This won't work well on radar vectors. |
| Boom 1: | Slight. |
| Pilot 2: | Moderate. |
| Copilot 2: | Moderate. |
| Boom 2: | Slight. |
| Pilot 3: | Moderate. |
| Copilot 3: | Slight. The boom had the lead tanker on radar backup by the TACAN. This increased the pilots' workload because we had to cross tune. With or without a nav, the workload would have been the same. |
| Boom 3: | Moderate. |
| Pilot 4: | Slight. |
| Copilot 4: | Moderate. |
| Boom 4: | No comment |
| Pilot 5: | Moderate. Majority increase due to "sim-ism". |
| Copilot 5: | Moderate. No comment |
| Boom 5: | Moderate. Radar with no training. A/A TACAN was in instead of normal TACAN and no CDU at the nav station. |
| Pilot 6: | Slight. It was slight because lead magically got some 40 NM ahead of us by the first turn, so we ignore any attempt at cell join-up and flew the SID. |
| Copilot 6: | Substantial. No comment |
| Boom 6: | Slight. With proper training the Boom would be more involved in the join-up ?? radar. |
| Pilot 7: | Moderate. It's difficult to monitor lead without visual conditions. |
| Copilot 7: | Moderate. No comment |
| Boom 7: | Slight. Boom operators should receive additional training on radar operation. |
| Pilot 8: | Substantial. Confusion over who was to operate the radar during flight caused us to establish the boom as the radar operator by default because the copilot is too busy backing up the pilot during a cell departure especially in the weather. |
| Copilot 8: | Slight. No particular problem as far as systems operation. |
| Boom 8: | No comment |

**2. The routing change during the departure caused (a) ______ increase in mission difficulty/aircrew workload.**

a. No b. Slight c. Moderate d. Substantial

| | |
|---|---|
| Pilot 1: | Moderate. More attention was given to loading new points into the INS/DNS than to backing up the flying of the aircraft |
| Copilot 1: | Moderate. This would have been worse in a faster climbing aircraft like the R-Model because the climb would have occurred more quickly. |
| Boom 1: | Moderate. |
| Pilot 2: | Moderate. |
| Copilot 2: | Moderate. |
| Boom 2: | Slight. |

Pilot 3: Moderate. One pilot was busy flying and the other pilot was responsible for the route change.
Copilot 3: Slight. No comment
Boom 3: Moderate.
Pilot 4: Moderate.
Copilot 4: Substantial. Need more training on the nav duties.
Boom 4: No comment
Pilot 5: Slight. No comment
Copilot 5: Substantial. Very difficult to change points, lookup and enter data into computer all one leg.
Boom 5: Slight. Following the course was difficult due to lack of equipment.
Pilot 6: Moderate. No comment
Copilot 6: Substantial. No comment
Boom 6: No. No comment load off of pilots.
Pilot 7: Moderate. No comment
Copilot 7: Substantial. No comment
Boom 7: Slight. CDU for INS should also be located at nav (Boom) station to take workload off of pilots.
Pilot 8: Moderate. No comment
Copilot 8: Slight. No comment
Boom 8: No comment

3. **The air refueling area change caused (a) ______ increase in mission difficulty/aircrew workload.**

a. No b. Slight c. Moderate d. Substantial

Pilot 1: Substantial. We were able to recover quickly due to paper brains we had for all A/R tracks in the Castle area. We had no time to check if the INS/DNS was drifting. If we fly without a navigator, we need more reliable equipment than the INS/DNS we have now.
Copilot 1: Substantial. We had paper brains from Castle and were experienced on this track. Without a depiction of the track, we would've had to draw one on the chart.
Boom 1: Substantial. Other crew coordination items suffered due to looking things up. A less experienced crewmember would've been unable to find track info and also would've had a problem getting the correct info to the pilots. Training of the IFR supplement and AP 1/B needs to be given to the boom.
Pilot 2: Moderate.
Copilot 2: Substantial.
Boom 2: Substantial.
Pilot 3: Moderate. Confusion on where the track was located caused us to have less than 15 minutes of orbit time.
Copilot 3: Moderate. The boom tried to help with the routing as much as possible; however, since he didn't have a CDU he had to write all the info down or talk over the intercom to get the info forward. This resulted in an unusually long time to get everything squared away. Also since the CO had to look up a lot of air info it kept his head in the cockpit instead of looking outside for traffic.
Boom 3: Substantial.
Pilot 4: Substantial. I was heads down from the initial route change until the A/R - not good.
Copilot 4: Substantial. Between plotting, charting and trying to help each other out, it reminded me of S-3 at Castle. People who know what to do but can't quite do it without some type of help.
Boom 4: No comment
Pilot 5: Slight. No comment

Copilot 5: Substantial. Same.
Boom 5: No. My duties didn't change.
Pilot 6: Moderate. No comment
Copilot 6: Moderate. No comment
Boom 6: Moderate. No comment
Pilot 7: Slight. An unfamiliar area would be more difficult.
Copilot 7: Substantial. No comment
Boom 7: Moderate. See comments for 2.
Pilot 8: Moderate. Could happen in real life but rare. Again pilot can turn to general direction but it will take time if flying a long distance to get the waypoints punched in and the navigation fine tuned to hit the target on the mark.
Copilot 8: Substantial. It's just a little more difficult handling changes of that degree where the physical confines of the right seat make it hard to get in the books & plot charts, etc.
Boom 8: No comment

**4. Thunderstorm avoidance caused (a) _______ increase in mission difficulty/crew workload.**

a. No b. Slight c. Moderate d. Substantial

Pilot 1: Moderate. We need to train the pilots and the boom how to use the radar. I would gladly trade a ground mapping radar... for a full color weather radar.
Copilot 1: Moderate. We were able to find the WX by luck. The real radar would've been more difficult than the one in the sim.
Boom 1: Slight. Radar use training and beacon use needs to be given to all booms and pilots as well or get newer equipment that is easier to interpret.
Pilot 2: Moderate.
Copilot 2: Moderate.
Boom 2: Slight.
Pilot 3: Moderate. The sim painted WX better than the airplane. Increased training for the pilots and booms is needed.
Copilot 3: Slight. No comment
Boom 3: Moderate.
Pilot 4: Moderate.
Copilot 4: Slight. No big problem because the boom can help but what about during A/R? Might be hard for the pilots to try and find a T-Storm let alone see on their radar with the glare it sometimes gets.
Boom 4: No comment
Pilot 5: Slight. No comment
Copilot 5: Moderate. No comment
Boom 5: Moderate. Lack of radar training and poor WX radar!
Pilot 6: Slight. No comment
Copilot 6: Moderate. No comment
Boom 6: Substantial. Yes, with the training needed for radar operation Boom will be able to interpret and give better information.
Pilot 7: Substantial. Better training in radar ops would help quite a bit.
Copilot 7: Substantial. No comment
Boom 7: Slight. See comment on question 1.
Pilot 8: Substantial. Cause great increase by trying to monitor exact position. Anyone can avoid a thunderstorm on radar but to know the position of a restricted area would be very difficult.
Copilot 8: Moderate. WX avoidance caused the most stress on crew interaction.
Boom 8: No comment

**5. Prior to Air Refueling, did you detect your INS's were drifting? Radar Pressurization fluctuations? (Please explain when and how you detected your INS's were drifting in the Comments section).**

a. Yes b. No

| | |
|---|---|
| Pilot 1: | No, with mission changes we did not have time to check the boxes and just used the INS. Again, without a nav, we need better navigation equipment. |
| Copilot 1: | No. There was not enough spare time for us to cross track the boxes to see which was more accurate. Also, we were unable to accomplish TAC Mixing with all the mission changes, loading new TACANs would have been impossible anyway. |
| Boom 1: | No. |
| Pilot 2: | Yes, the drift between the INS/DNS were opposite. |
| Copilot 2: | Yes. |
| Boom 2: | Yes. The drift between the INS/DNS was different. We had to TAC mix to determine which box was accurate. |
| Pilot 3: | Yes. We expected the boxes to drift so we tried to keep them tight with TAC mixing. |
| Copilot 3: | No. The INS and DNS were TAC mixing most of the time. |
| Boom 3: | Yes. Noticed that the XTK on the INS and DNS were different going toward 8B. |
| Pilot 4: | Yes. The INS and DNS were not the same. |
| Copilot 4: | Yes. The pilots found it, the boom can't do much without a CDU - put a CDU in at the nav's station! |
| Boom 4: | No comment |
| Pilot 5: | No. No comment |
| Copilot 5: | No. No comment |
| Boom 5: | No. No comment |
| Pilot 6: | No. No comment |
| Copilot 6: | Yes. TAC mixed the CP INS and found about a 2 mile difference in CP's and AC's INS. |
| Boom 6: | No. Didn't detect. |
| Pilot 7: | Yes. Track error increased in the pilots HSI, in addition to CDI drifting from anticipated heading corrected for drift. Comparing with the Copilots confirmed. |
| Copilot 7: | No answer. INS-yes Pressurization-no. On CP's CDU couldn't get it to do WP delta, then noticed distances and HSI displays were off. |
| Boom 7: | No. Boom cannot see INS. |
| Pilot 8: | No. No comment |
| Copilot 8: | No. No comment |
| Boom 8: | No comment |

**6. The drifting of the INS system/radar fluctuations caused (a) _______ increase in mission difficulty/aircrew workload.**

| | | | | |
|---|---|---|---|---|
| INS | a. No | b. Slight | c. Moderate | d. Substantial |
| Radar | a. No | b. Slight | c. Moderate | d. Substantial |

| | |
|---|---|
| Pilot 1: | No/No. We didn't know it drifted. |
| Copilot 1: | Slight/No. |
| Boom 1: | No/No. Need more training on the systems and their use. |
| Pilot 2: | Moderate/Slight. |
| Copilot 2: | Substantial/No. |
| Boom 2: | Moderate/No. |

| | |
|---|---|
| Pilot 3: | Slight/No. The boom should have a CDU at the nav's station so he could TAC mix and remove this work from the pilots. |
| Copilot 3: | Slight/No. No comment |
| Boom 3: | Moderate/No. |
| Pilot 4: | Moderate/No. Trying to TAC mix the boxes caused more heads down time. |
| Copilot 4: | Slight/Slight. Boom could help out more here if there was a CDU at the nav's station. |
| Boom 4: | No comment |
| Pilot 5: | No/No. No comment |
| Copilot 5: | No/No. Didn't notice TACAN mixing. |
| Boom 5: | No/No. I don't have the ability to check the INS without a CDU, and without bothering the pilot team too much. RADAR just push a button to decrease pressurization. |
| Pilot 6: | No/No. Didn't detect either. |
| Copilot 6: | Slight/No. No comment |
| Boom 6: | No/No. I was unaware of either due to the lack of knowledge of both systems. |
| Pilot 7: | Moderate/No. When the INS drifted with the increased workload I went to TACAN fixes & disregarded INS data since I deemed it not reliable. Never noticed any ??? problems. |
| Copilot 7: | Moderate/No. No comment |
| Boom 7: | Slight/No. See 5. |
| Pilot 8: | Moderate/(No answer). It would take valuable time from the copilot to update the navigation system as opposed to monitoring the rendezvous. |
| Copilot 8: | No/No. No comment |
| Boom 8: | No comment |

**7. Were you able to identify your receiver on radar prior to your rendezvous turn inbound toward the ARCP?**

a. Yes b. No

| | |
|---|---|
| Pilot 1: | No, again training on the radar. |
| Copilot 1: | No. We were too busy running the first offload to use the radar for the second RZ. We used TACAN and INS backed up by timing. |
| Boom 1: | No. Again, we to be trained more on this system. |
| Pilot 2: | No, used for WX, had receiver do a fighter turn on. |
| Copilot 2: | No. |
| Boom 2: | No. |
| Pilot 3: | Yes. Need additional training. The sim radar is a lot better at painting things than the radar in the airplane. |
| Copilot 3: | Yes. No comment |
| Boom 3: | No. |
| Pilot 4: | No. |
| Copilot 4: | N/A. I was in the pod. |
| Boom 4: | No comment |
| Pilot 5: | No. No comment |
| Copilot 5: | No. No comment |
| Boom 5: | No. Radar sucks! the simulator radar poor except the WX radar mode is nice. Receivers didn't have a beacon. |
| Pilot 6: | No. No comment |
| Copilot 6: | No. No comment |
| Boom 6: | No. No comment |
| Pilot 7: | No. Used A/A only. |

Copilot 7: Yes. After BO had done the timing etc. & called out the RCVR on the scope. Otherwise I wouldn't have attempted to find the RCVR due to my trying to effect the RZ.

Boom 7: Yes. No comment

Pilot 8: Yes. Need to be more communication between operators. booms aren't as skilled to using it and the pilots can work with it better than the booms.

Copilot 8: Yes. Second set - don't have the first set.

Boom 8: No comment

**8. The receiver's late arrival caused (a) _______ increase in mission difficulty/aircrew workload.**

a. No b. Slightc. Moderate d. Substantial

Pilot 1: Moderate. Considerations over different RZ and everyone working different tasks left no one for back up.

Copilot 1: Substantial. The second RZ was conducted solely by the pilot. CO and boom were handling the receivers. Switch for the radar needs to be up front as boom left with control aft.

Boom 1: Slight. Having to come up with options for RZ without a nav limited our choices.

Pilot 2: Moderate.

Copilot 2: Slight.

Boom 2: No.

Pilot 3: Slight. Once established on the A/R track, picking up the second receiver was not hard.

Copilot 3: Slight. Trying to figure out a new turn range + offset again kept to CO's head inside while the first receivers were on the wing.

Boom 3: Moderate.

Pilot 4: Moderate.

Copilot 4: Slight.

Boom 4: No comment

Pilot 5: Slight. No comment

Copilot 5: Moderate. No comment

Boom 5: No. Happens all the time.

Pilot 6: Slight. No comment

Copilot 6: Slight. No comment

Boom 6: No. Pilots already worked the problem.

Pilot 7: Slight. No comment

Copilot 7: Slight. No comment

Boom 7: Slight. No comment

Pilot 8: Moderate. No comment

Copilot 8: Moderate. The pilots didn't see the same solution to the problem which caused some delay where as a nav would have been more directive and accepted as a solution.

Boom 8: No comment

**9. The oil pressure malfunction (EP) caused (a) _____ increase in aircrew workload.**

a. No b. Slight c. Moderate d. Substantial

Pilot 1: Slight. The EP would have caused the same workload with or without a navigator. The only workload increases were caused by having to deviate around weather and navigate. Train boom on navs duties during EPs.

Copilot 1: Substantial. We were so busy that we weren't paying attention to aircraft systems and missed the malfunction for about six minutes. Wasn't too hard to handle after we found it.

Boom 1: No. Just another EP easily handled by good crew coordination and -1 procedures.

**Pilot 2:** Slight.
**Copilot 2:** Slight.
**Boom 2:** Slight.
**Pilot 3:** Substantial. Rather than having two pilots to work the problem, one was busy navigating the airplane.
Copilot 3: Moderate. Any malfunction is going to increase the crews workload.
Boom 3: Substantial.
Pilot 4: Moderate.
Copilot 4: Substantial. Workload was increased but well distributed. It got very busy and pilots tended to get heads down in the cockpit.
Boom 4: No comment.
Pilot 5: Slight. No comment
Copilot 5: Moderate. No comment
Boom 5: Slight. Went through the normal EP'S and had to make addition radio calls. But wasn't very hard.
Pilot 6: Slight. No comment
Copilot 6: Moderate. No comment
Boom 6: Slight. Got into the book.
Pilot 7: Moderate. The Boom can be used for command post/pubs research, however a gear or flap problem would have increased the workload.
Copilot 7: Substantial. No comment
Boom 7: Slight. No comment
Pilot 8: Substantial. No one to monitor position. Boom could pick out thunderstorms but not exact position which is what you need.
Copilot 8: Slight. No comment
Boom 8: *Moderate.*

**10. The low ceiling and visibility during the approach caused (a) _____ increase in aircrew workload.**

a. No b. Slight c. Moderate d. Substantial

Pilot 1: Slight. Need to train the boom on what the nav does during an approach; maybe a course like NIRC would be helpful.
Copilot 1: Slight. No big deal for pilots. booms need more training on TERPS/Instruments for the approaches. Our boom was a big help, but newer booms wouldn't be so helpful.
Boom 1: Moderate. Thinking of options, working radios and getting weather would have been bigger problems on less experienced crews.
Pilot 2: Slight.
Copilot 2: Slight.
Boom 2: No.
Pilot 3: Slight.
Copilot 3: Slight. No comment
Boom 3: Slight.
Pilot 4: Substantial.
Copilot 4: Slight.
Boom 4: Moderate.
Pilot 5: Slight. No comment
Copilot 5: Slight. No comment
Boom 5: No. No comment
Pilot 6: Slight. No comment

| | |
|---|---|
| Copilot 6: | No. No comment |
| Boom 6: | No answer. No comment |
| Pilot 7: | Slight. No comment |
| Copilot 7: | Moderate. No comment |
| Boom 7: | Slight. No comment |
| Pilot 8: | Moderate. No comment |
| Copilot 8: | Slight. No comment |
| Boom 8: | Moderate. |

**11. What type of work-around procedures were used to overcome the *difficulties* encountered during this mission?**

| | |
|---|---|
| Pilot 1: | A lot of tasks were delegated and due to the experience level of the crew were accomplished. With newer crewmembers, a lot more directing would be needed and a dangerous situation could occur. |
| Copilot 1: | Used ATC for weather avoidance. |
| Boom 1: | Delegation of duties - very good crew back-up and coordination. We were an experienced crew; other crews may have had more distracters and stress/task saturation. |
| Pilot 2: | Had receiver do a fighter turn on for the point parallel. |
| Copilot 2: | Used TACAN for navigation as much as possible. |
| Boom 2: | Had to reach up front to get info when pilots were busy. |
| Pilot 3: | With Phase 1, the nav hasn't been removed from the airplane, one of the pilots has been turned into the nav leaving only one pilot to fly the airplane without backup. |
| Copilot 3: | The Boom and CO took on a lot more workload. This resulted in one pilot flying and talking on the radios while the other was just trying to navigate. |
| Boom 3: | Divided work among crew and prioritized, dropping off what we couldn't get done. |
| Pilot 4: | Used the TACAN for navigation due to drifting boxes. |
| Copilot 4: | Boom had the books and the pilots handled the EP and radios. Experience showed here. |
| Boom 4: | No comment |
| Pilot 5: | CRM properties (prioritization, delegation.) |
| Copilot 5: | Divided up workload. |
| Boom 5: | Prioritized tasks and transferred duties throughout crew. |
| Pilot 6: | No comment |
| Copilot 6: | Giving the radios to the AC while I worked navigation. Used the boom with the radar and weather avoidance. |
| Boom 6: | Due to the lack of training and knowledge my inputs were few. The pilots accomplished the extra workload. |
| Pilot 7: | Made due with what we had. Delegated more work to the boom, used TACAN fixes & dropped out the INS when it messed up prioritized tasks. |
| Copilot 7: | CRM, increased reliance on the BO. |
| Boom 7: | Crew coordination and CRM. |
| Pilot 8: | No comment |
| Copilot 8: | Communications and clarification. BO good backup. Used radar to avoid thunderstorms. Pilot took over some tasks to relieve workloads on CP & BO. |
| Boom 8: | No comment |

**12. Did you encounter any other problem areas during this mission?**
(Please explain in comments section)

a. Yes b. No

Pilot 1: Yes, training in the navigation areas. We as a tanker force can get the mission done, but need better equipment and training in the areas in which we are not accustomed.

Copilot 1: Yes. Egress, take off radio calls and what about inflight logs?? Who pulls CB's during AR??

Boom 1: Yes. Being able to stay ahead of the aircraft as I usually can was more difficult. With the increase in workload, lack of training would have distracted from my situational awareness.

Pilot 2: No.

Copilot 2: No.

Boom 2: No.

Pilot 3: No. The boom was very helpful but would be even more helpful if he had a CDU at his new station and more training on its operation.

Copilot 3: Yes. Because of some confusion between the pilots, we ended up heading to the IP instead of the CP after center notified us the problem was corrected. More training to the Boom in becoming familiar with the AP-1B could help current problem.

Boom 3: Yes. Inexperienced crewmembers needed instruction on new equipment and were a distraction.

Pilot 4: No.

Copilot 4: Yes. Any EP that needs more than one person to accomplish the corrections will leave only one pilot up front. That's a very uncomfortable position to be in.

Boom 4: No comment

Pilot 5: No. No comment

Copilot 5: Yes. Circuit breakers needed to be pulled while Boom was aft.

Boom 5: Yes. Poor equipment, poor equipment lack of training with radar and charts.

Pilot 6: Yes. The simulator is so difficult to hand fly (pitch and roll changes occur constantly without pilot input) that the pilot flying can offer no assistance to the pilot not flying nor will he notice minor problems or hear all radio calls. This increases the workload on the non-flying pilot.

Copilot 6: No. No comment

Boom 6: No. No comment

Pilot 7: Yes. The simulator handling characteristics detracted from mission effectiveness.

Copilot 7: Yes. 1) Sim-isms decreased some efficiencies due to wasted habit pattern movements. This is the 1 and only time I'll write this up. 2) Limited space in CP/AC area leads to charts & pubs strewn all over the cockpit, especially when several mission changes occur. (How about a fold down table at CP station HA

Boom 7: No. No comment

Pilot 8: No answer. A lack of effective CRM. Pilot was doing everything because copilot was busy figuring out our position and boom wasn't familiar with the navigators equipment.

Copilot 8: Yes. Stress got a little high when I was trying to bring WX avoidance to pilots attention. Pilot wasn't comfortable with not having an experienced nav to interpret WX on radar for avoidance actions.

Boom 8: No comment

**13. Please recommend any improvements to the training program that you feel would improve aircrew efficiency and reduce aircrew workload?**

Pilot 1: Having better equipment (INS and color WX radar)

Copilot 1: All specialties - radar, beacon, INS/DNS ops. booms - approach altitude calls, NIRC and chart prep. Have boom attend sim training with the pilots.

Boom 1: More time for crews to review the mission and brief new duties. This would allow time for delegation of duties in the airplane.

Pilot 2: Leave the nav on the aircraft. The CDU up front is a safety of flight issue.

Copilot 2: Look at crew coordination and the amount of cross cockpit interference to get info/back up pilots.

Boom 2: Move the INS back to the nav station and the INS/DNS select switch up front.

Pilot 3: Need a lot more training at CCTS for new crewmembers and the procedures defining the division of the pilot's and boom operator.

Copilot 3: Current booms should be sent to a navigation school to become more familiar with navigation. This course could then be incorporated into initial boom training. Also the pilots would need more training in this area and more time spent with getting familiar with the equipment.

Boom 3: Have crewmembers draw all tracks to the areas in which they are flying.

Pilot 4: Automate the cockpit or keep the navigator.

Copilot 4: More nav type training and a CDU in the back.

Boom 4: No comment

Pilot 5: No comment

Copilot 5: No comment

Boom 5: Set the simulators up like the plane is actually going to be. Less pretending makes a more believable Sim.

Pilot 6: Leave the navigator in the cockpit!!!

Copilot 6: Keep the nav onboard until we get a full glass cockpit with a good color radar for weather avoidance.

Boom 6: No comment

Pilot 7: Make the simulator fly realistic.

Copilot 7: Without a nav, the 3 remaining crew members will require nav academics (as a minimum) on the radar, WX avoidance, and technical procedures for making changes in mission profiles while airborne.

Boom 7: *INS CDU at Boom's (nav's) station to reduce workload on pilots.*

Pilot 8: Have an electronic display which is overlaid with aircraft's position and heading as related by navaids (like the airlines) otherwise keep the navigator.

Copilot 8: BO could be better trained on looking up information (where & what, etc.).

Boom 8: No comment

**14. What adjective best describes the overall difficulty of this mission?**

a. Easy  b. Medium  c. Hard

Pilot 1: Hard.
Copilot 1: Hard.
Boom 1: Medium.
Pilot 2: Hard.
Copilot 2: Hard.
Boom 2: Medium.
Pilot 3: Medium.
Copilot 3: Hard.
Boom 3: Hard.
Pilot 4: Hard.
Copilot 4: Hard.
Boom 4: Hard.
Pilot 5: Easy.
Copilot 5: Hard.
Boom 5: Medium.
Pilot 6: Easy.

**Copilot 6:** **Medium.**
**Boom 6:** **Easy.**
**Pilot 7:** **Medium.**
**Copilot 7:** **Hard.**
**Boom 7:** **Medium.**
**Pilot 8:** **Hard.**
**Copilot 8:** **Hard.**
**Boom 8:** **Hard.**

**15. For the previous mission, rate your workload as compared to what you think it would have been with the present KC-135 system and a navigator. With the system that I just flew my workload was ________.**

a. Substantially decreased
b. Moderately decreased
c. Slightly decreased
d. Not changed
e. Slightly increased
f. Moderately increased
g. Substantially increased

Pilot 1: Substantially Increased. Since this mission dealt with navigation changes including A/R changes while airborne, a nav would have made this mission a lot easier.
Copilot 1: Substantially Increased. Castle paper brains helped a lot because they had all the information on them. AP 1/B would be more useful if it had the info like in our paper brains. As it stands now, crews should go out on their missions with several AR tracks drawn.
Boom 1: Substantially Increased. I need more training. If I had more training, I would have been more situationally aware and had clearer options. Training is needed with new tasks spread out on the crew.
Pilot 2: Substantially Increased.
Copilot 2: Substantially Increased. This mission proves the foolhardiness of removing the navigator from the crew. Make the staff fly this one and see what they think then.
Boom 2: Moderately Increased.
Pilot 3: Substantially Increased. Instead of having two pilots responsible for flying you only had one because the other pilot was too busy directing all his time and effort to navigating.
Copilot 3: Substantially increased. The navigation changes on this mission took up a lot of my time and kept me from paying more attention to my other duties.
Boom 3: Substantially Increased.
Pilot 4: Substantially Increased.
Copilot 4: Substantially Increased.
Boom 4: No comment
Pilot 5: Moderately decreased. No comment
Copilot 5: Substantially Increased. Doing radios, plotting changes, entering data into computers all seem to happen at the same time. Also both pilots are required to have heads down much of the time also reaching forward, leaning over, etc. Leans could be a big player. Radar could also require a lot of tweaking and fumbling. All distracting in a more crowded airspace.
Boom 5: Slightly increased. A CDU at the nav's would have increased my workload to a moderate level. But not impossible by any means. More Radar and navigation training would be mandatory.
Pilot 6: Moderately increased. No comment
Copilot 6: Substantially increased. No comment

Boom 6: Moderately increased. With the proper training regarding the navigation equipment and associated systems the boom operators will increase the workload substantially.

Pilot 7: Substantially increased. More training in RDR & INS procedures will help.

Copilot 7: Moderately increased. With a nav onboard, I could have concentrated more on the EP. with the engine and backing up the pilot a lot more than I was able to do while trying to do the navigation as well.

Boom 7: Moderately increased. No comment

Pilot 8: Substantially increased. Don't need navigator for dead head missions but must be present for air refueling and wartime missions. This wouldn't work at all in any wartime scenario. Think of keeping the tanker navigator.

Copilot 8: Substantially increased. During A/R, having to manage systems, comms, and A/C control plus primary navigation (with or without changes) greatly increases workload/stress.

Boom 8:

**16. Provided adequate training, could a minimally experienced pilot with a minimally experienced copilot successfully fly this mission?**

a. Yes b. No

Pilot 1: No. I believe a dangerous situation would have occurred with violations or worse. Training and better equipment are needed.

Copilot 1: Yes. This would require substantial training and more thorough mission planning for greater inflight flexibility.

Boom 1: No. This is not a two-man aircraft. Years of observation in this plane have allowed booms to increase a crews effectiveness and flexibility. Include booms in all training or this concept will not work.

Pilot 2: No.

Copilot 2: No. It would be an accident waiting to happen.

Boom 2: No.

Pilot 3: No. Maybe if there were no systems degrades; without an autopilot, this mission could not be done.

Copilot 3: No. No comment

Boom 3: No.

Pilot 4: No.

Copilot 4: No.

Boom 4: No.

Pilot 5: Yes. With 80% probability.

Copilot 5: No. This cockpit wasn't designed to be run by a 3-man crew. Standard mission workload is very much higher. I would hate flying through Europe, Saudi with full charts, radar req'ts, etc.

Boom 5: Yes, but the training has to be for real. No pushing or helping along, either pass or fail.

Pilot 6: No. But of course that depends on what "provided adequate training" is.

Copilot 6: No. No comment

Boom 6: No. Workloads would be too large and an inexperienced or some experienced booms are going to be of little help due to the lack of knowledge of overall navigation.

Pilot 7: No. The equipment is inadequate for this configuration. Performance would be marginal for a minimum experience crew & eventually some airplanes will be crashed.

Copilot 7: Yes. With a decrease in safety.

Boom 7: Yes. No comment

Pilot 8: No. I wouldn't try it.

Copilot 8: Yes. Successfully-yes, with the same degree of accuracy and safety-no.

Boom 8: No.

17. The following space is provided for you to elaborate on questions 1-16 or for you to identify any other concerns that you might have.

Pilot 1: We need better equipment and training. Break up navs duties during all phases of flight and train crew on new duties. Look at egress, A/R CB's, HF radio and radar during A/R - who will do these??

Copilot 1: The modified CDU was no easier or harder to use than the one in the aircraft. Let's try to get some equipment that already has the NAVAID database in it. The biggest heads-down, time-consuming, frustrating, "SA eating" time is inserting all the TAC Mix info. The INS/DNS must warn the pilots when they drift and there needs to be a better method to determine which box is right than just radio NAVAIDS. What does the F-15 guy do when his INS is inaccurate??

Boom 1: Each crew position needs to decide what they should be responsible for, how much training will be needed to perform that task at a given level of proficiency, what type of training is needed (sim/flight) and then use the experience levels of the crews wisely. Much can be gained by using booms who have watched every task for years but performed only their own. Use this knowledge and expand on it. You could get a crewmember with good systems knowledge, CRM, and with a little nav training and systems monitoring get a very well rounded and useful crewmember. If the plan is to remove the nav and not update or replace the current systems, then more training on equipment use will be needed in all crew positions. Assignment of responsibilities for all phases of flight need to be looked at and checklist changes made. Training does not have to be costly or lengthy if all that is needed is systems operators/monitors. The smart thing to do would be to use the boom to his/her maximum potential. The -135 mission is important and CRM needs to be very high, especially during mission changes. If this is to be a two-man (no boom) concept then make it so, if not then use the boom effectively and wisely and refer to it as a three man crew. Make booms a part of the solution.

Pilot 2: No Comment.

Copilot 2: No Comment.

Boom 2: No Comment.

Pilot 3: A CDU at the boom station is a must. Training programs for the new crewmember as well as in-house training for experienced crewmembers will be required for the crews to do anything other than the most generic mission. Hard crews may help crews in dealing with these mission changes without a nav on board.

Copilot 3: Since who is going to do the navigators tasks is really not defined, recommend going back to hard crews so the crew members know is going to do what. The dash-1 and checklists need to be changed to reflect who will do the navigators duties. Although it says the AC will insure it gets done when the nav isn't on board. A CDU must be at the nav station. You cannot compare this change with a KC-10, C-141 or C-5 because they all have FE's onboard as well as a boom operator or load specialist.

Boom 3: With the changes that took place today, I don't feel this sortie could have been flown in the real world safely. This program may succeed but not if it is done too hastily. Equipment upgrades must be a part of the program and comments from experienced crewmembers should be taken seriously and not dismissed because the decision has been made that this change is going to happen.

Pilot 4: Despite the cockpit layout, the CO was heads down for most of the flight. We must automate this cockpit or keep the nav. Even for a relatively simple mission, like this, complete plans for all tracks should be taken on board.

Copilot 4: Try to move as many instruments as possible onto the left hand side of the nav's station to aid in monitoring systems and backing up of the pilots.

Boom 4: No comment

Pilot 5: No comment

Copilot 5: Definitely need another INS/GPS & new radar.

Boom 5: This system could work with a minimum of an extra INS. With a carousel 4 at the nav's station for the boom operator. Addition training must be involved with the radar or a WX radar must be implemented. The boom operator should learn basic navigational skills. Many already have them, myself included, but there's no accreditation without format training. But if the Boom couldn't keep up with the training they cannot be allowed to fly with the new system! The cockpit is not a place for carrying someone or making up for a weak link. There's already too many boom operators and so many eager people to enter the Air Force as a Boom. Perhaps mandatory nav-training and more strict requirements for basic trainee booms and perhaps warrant officer status.

Pilot 6: LEAVE THE NAV IN THE AIRCRAFT!!!

Copilot 6: No comment

Boom 6: LEAVE THE NAV IN THE AIRCRAFT.

Pilot 7: To be effective the 135 will need a 1.) good radar much much better than the current equipment. 2.) give the Boom a CDU and training. 3.) install an A/A TACAN with bearing and range information.

Copilot 7: No comment

Boom 7: In order to distribute pilots' and Boom workload a INS CDU must be at the Boom's station and in addition for the new crew to work Boom operator's must receive adequate ground school flights to fully understand navigation and to allow smooth flight ops. The way it is designed now the pilot's workload is increased and the boom can do little to help but with proper training the boom could share in the workload.

Pilot 8: No comment

Copilot 8: My big concern is that our primary mission of air refueling will not be accomplished with the same degree of safety as it is with a navigator.

Boom 8: No Comment

# APPENDIX E

# McCHORD MISSION QUESTIONNAIRE

# AND CREW RESPONSES

**CREW #____**

**CREW POSITION____**

**Mc Chord Mission**

**Questionnaire**

**This questionnaire is a mission specific questionnaire concerning the various events encountered during the last mission. You should answer the questionnaire from your own perspective by circling the appropriate answer. If you feel that any question needs further explanation, please feel free to ask one of the experimenters for clarification. If you feel no one answer is adequate, please use the comments section after each question to elaborate on it. A comments section has been provided after each question to allow you to actively express all concerns you might have about a given question, mission, or instrument. You are encouraged to use the comments section whenever possible. For those questions requiring more space than that provided, simply turn the page over and write on the back. Additional comment space is also provided on the last page of the questionnaire.**

## MISSION # 1

1. **The increased communications with Center during departure caused (a) _______ increase in mission difficulty/aircrew workload.**

a. No b. Slight c. Moderate d. Substantial

Pilot 1: No.
Copilot 1: No.
Boom 1: No.
Pilot 2: Slight.
Copilot 2: Moderate.
Boom 2: No.
Pilot 3: No. No increase noted.
Copilot 3: No. No comment
Boom 3: No. No comment
Pilot 4: Slight. No comment
Copilot 4: Slight. No comment
Boom 4: Slight. Some difficulty was noted, but is also normal.
Pilot 5: No. No comment
Copilot 5: Slight. No comment
Boom 5: No. Pilots took care of it.
Pilot 6: No. No comment.
Copilot 6: Slight. No comment.
Boom 6: No. No comment.
Pilot 7: Slight. No comment.
Copilot 7: Slight. No comment.
Boom 7: Slight. No comment.
Pilot 8: Slight. No comment.
Copilot 8: No. No comment.
Boom 8: Slight. Transition to SID - not hard - had already looked at it.

2. **Thunderstorm avoidance caused (a) _______ increase in mission difficulty/crew workload.**

a. No b. Slight c. Moderate d. Substantial

Pilot 1: No.
Copilot 1: Slight.
Boom 1: No.
Pilot 2: Slight.
Copilot 2: Moderate.
Boom 2: No.
Pilot 3: Moderate. Better training is required for pilots/booms on thunderstorm ID on the radio.
Copilot 3: Slight. The boom did a good job of picking up the WX on radar and made good calls while deviating.
Boom 3: Moderate. No comment
Pilot 4: Slight. No comment
Copilot 4: Slight. No comment
Boom 4: No. T-storms weren't a real factor.
Pilot 5: No. No comment
Copilot 5: Slight. No comment

Boom 5: No. Pilots took care of it.
Pilot 6: No. No comment.
Copilot 6: Slight. No comment.
Boom 6: Slight. The WX was seen early enough that coordination was accomplished well in advance.
Pilot 7: Slight. No comment.
Copilot 7: Moderate. No comment.
Boom 7: No. No comment.
Pilot 8: Moderate. Having to deviate for weather is a everyday occurrence. Having to do it and know exactly were you are is very challenging.
Copilot 8: Slight. No comment.
Boom 8: Comm out.

**3. Prior to descent, did you detect your INS's were drifting? Radar Pressurization fluctuations? (Please explain when and how you detected your INS's were drifting in the comments section).**

a. Yes b. No

Pilot 1: Yes, we had plenty of time enroute to TAC Mix both the INS/DNS
Copilot 1: No.
Boom 1: No.
Pilot 2: No.
Copilot 2: No.
Boom 2: No.
Pilot 3: Yes. Pilot's INS was drifting when we passed a known TACAN fix - tried to TAC mix. Did not notice any other problems.
Copilot 3: Yes. After plotting our position noticed that the DNS and INS were slightly off (indicate drift in different directions) TAC mixed the DNS, tried to TAC mix the INS.
Boom 3: No. No comment
Pilot 4: No. No comment
Copilot 4: No answer. No comment
Boom 4: No. Radar pressurization fluctuation was not noted.
Pilot 5: No. No comment
Copilot 5: No. TAC mixing.
Boom 5: No. No comment
Pilot 6: No. Both INS's were TAC mixed all the way & were with .1 NM of each other & TACAN throughout.
Copilot 6: No. No comment.
Boom 6: No. No comment.
Pilot 7: Yes. Copilots INS showed excessive drift compared with a TACAN station & the other INS.
Copilot 7: INS Yes RADAR No. Problems with input to WP's initially wouldn't accept WP deltas and Dis & time readouts locked (operator error?).
Boom 7: No. No comment.
Pilot 8: No. No comment.
Copilot 8: No. No comment.
Boom 8: Comm out.

**4. The drifting of the INS system/radar fluctuations caused (a) _______ increase in mission difficulty/aircrew workload.**

**INS** a. No b. Slight c. Moderate d. Substantial

**Radar** a. No b. Slight c. Moderate d. Substantial

Pilot 1: No/No.
Copilot 1: No/No.
Boom 1: No/No.
Pilot 2: Slight/No.
Copilot 2: Moderate/No.
Boom 2: Slight/No. Caused a little confusion over drift.
Pilot 3: Moderate/No. No comment
Copilot 3: Moderate/No. The nav would make sure the boxes weren't drifting/if there was a (CDU) box for the boom he could help take some of the workload off the pilots so they could spend more time with their eyes outside the cockpit.
Boom 3: (No answer)/(No answer). No comment
Pilot 4: No/No. Did not notice INS drifting.
Copilot 4: (No answer)/(No answer). No comment
Boom 4: (No answer)/(No answer). The crew didn't note any drifting radar fluctuation.
Pilot 5: No/No. No comment
Copilot 5: No/No. Used TACAN mostly.
Boom 5: No/No. Didn't know that they were drifting.
Pilot 6: No/No. No comment.
Copilot 6: No/No. No comment.
Boom 6: No/No answer. INS were tight all mission.
Pilot 7: Moderate/No. No comment.
Copilot 7: Moderate/No. No comment.
Boom 7: No answer/No. No comment.
Pilot 8: No answer/Moderate. Noticed no INS malfunctions.
Copilot 8: No/No. No comment.
Boom 8: Comm out.

**5. The missed approach caused (a) _____ increase in aircrew workload.**

a. No b. Slight c. Moderate d. Substantial

Pilot 1: No.
Copilot 1: Slight.
Boom 1: Slight. Just more workload causing stress and testing SA.
Pilot 2: Moderate.
Copilot 2: Substantial.
Boom 2: Moderate.
Pilot 3: Substantial. Without a nav to help in the climbout - next approach, the workload was noticeably increased.
Copilot 3: Slight. Although the pilots would be familiar with the M/A procedures, the nav would back up the pilots or the procedures The booms need to become more familiar with approach plates and need to back up the pilots with altitude calls heading when up front.
Boom 3: Slight. No comment
Pilot 4: Substantial. No comment

| | |
|---|---|
| Copilot 4: | No answer. No comment |
| Boom 4: | Moderate. Every go around missed approach I've experienced causes increased crew workload concern. |
| Pilot 5: | Slight. No comment |
| Copilot 5: | Moderate. No comment |
| Boom 5: | No. We just went around pickle power, speed brakes, flaps. |
| Pilot 6: | Slight. No comment. |
| Copilot 6: | Slight. No comment. |
| Boom 6: | Slight. No comment. |
| Pilot 7: | Slight. No comment. |
| Copilot 7: | Moderate. No comment. |
| Boom 7: | Slight. No comment. |
| Pilot 8: | Moderate. Having to navigate and also keep up with the flying was a very difficult area when accustomed to the navigator maintaining exact position awareness. |
| Copilot 8: | Moderate. No comment. |
| Boom 8: | Comm out. |

**6. What type of work-around procedures were used to overcome the difficulties encountered during this mission?**

| | |
|---|---|
| Pilot 1: | No problems with this mission. One of the easiest I've flown. |
| Copilot 1: | No comment. |
| Boom 1: | Helping relieve workload from pilots on fuel panel, radios, etc. |
| Pilot 2: | AC gave each position specific duties for crunch points - back up was everyone's job. |
| Copilot 2: | Relied on VOR's and TACAN's. |
| Boom 2: | *Boom reached up front to reprogram the* INS. |
| Pilot 3: | Crew coordination between pilots. Better training/ job specification required for booms to relieve some tasks from the pilots. |
| Copilot 3: | The boom took care of the radar i.e. WX while the pilots took care of the navigation and boxes. |
| Boom 3: | I (as the boom) picked up some tasks that the nav would have done, but the pilots picked up much more. |
| Pilot 4: | Prior planning. |
| Copilot 4: | No comment |
| Boom 4: | Standard procedure now used. Call for appropriate checklists & backup copilots. |
| Pilot 5: | Prioritization |
| Copilot 5: | Had the boom look up some of the IFR sup stuff. |
| Boom 5: | It was a straight forward flight. |
| Pilot 6: | No comment. |
| Copilot 6: | Divided up the crew duties. |
| Boom 6: | Tasks were handed out to each crewmember. However some of these duties i.e. High terrain, coordinating WX may be more difficult for an inexperienced boom operator. More training in the area of approach plates and requirements is going to be necessary. |
| Pilot 7: | Utilizing the boom and task prioritization. |
| Copilot 7: | Utilization of B.O. to talk in Radios, operate radar, etc. |
| Boom 7: | CRM distribution of crew duties. |
| Pilot 8: | Try to get everyone involved in helping to maintain position awareness did not work very good because boom operator not familiar enough with the controls or functions previously held by the navigator. |
| Copilot 8: | Crew coordination. Requested deviation for thunderstorm avoidance. |
| Boom 8: | Comm out. |

**7. Did you encounter any other problem areas during this mission?**
(Please explain in comments section)

a. Yes b. No

| | |
|---|---|
| Pilot 1: | No. |
| Copilot 1: | No. |
| Boom 1: | No. |
| Pilot 2: | No. |
| Copilot 2: | Yes, trying to add waypoints into the INS. |
| Boom 2: | No. |
| Pilot 3: | No. No comment |
| Copilot 3: | No answer. Pilots became a little tasked saturated resulting in a less than optimum enroute descent. |
| Boom 3: | Yes. booms need training (extensively on navigation and approaches. |
| Pilot 4: | Yes. No comment |
| Copilot 4: | No answer. No comment |
| Boom 4: | Yes. Knowing exactly when we were in flight. The boom has no gauge instruments to use directly that can tell him at any time the aircraft's exact location. |
| Pilot 5: | No. No comment |
| Copilot 5: | Yes. Navigation over high terrain is very edgy without a nav. |
| Boom 5: | No. No comment. |
| Pilot 6: | No. No comment. |
| Copilot 6: | No. No comment. |
| Boom 6: | No. No comment. |
| Pilot 7: | Yes. The simulator is difficult to handle at times making workloads a little higher. |
| Copilot 7: | No. No comment. |
| Boom 7: | Yes. Boom need advanced ground school in navigation. |
| Pilot 8: | Yes. Situational awareness, the precise situational awareness which is normally handled by the navigator the upgrading of the radar, INS and installing of the GCAS system would be much needed more so than removing the navigator. |
| Copilot 8: | No. No comment. |
| Boom 8: | Comm out. |

**8. Which pieces of equipment were extremely hard to use and, consequently, caused high workload?**
(Please explain in comments section)

| | |
|---|---|
| Pilot 1: | No problems. |
| Copilot 1: | None. |
| Boom 1: | None. Just need more training on this equipment. |
| Pilot 2: | Re-programming the INS while the CO was running checklists, communicating and working the DNS. |
| Copilot 2: | INS CDU. |
| Boom 2: | INS due to its location. |
| Pilot 3: | Radar - more training required. |
| Copilot 3: | No comment |
| Boom 3: | Radar - difficulty in tuning and interpreting |
| Pilot 4: | No comment |
| Copilot 4: | No comment |
| Boom 4: | Radar was fairly easy. Knowing exactly where we were wasn't very easy. |

| | |
|---|---|
| Pilot 5: | None. |
| Copilot 5: | None. CDU/DNS & radios switch should be up front. |
| Boom 5: | None. |
| Pilot 6: | No Comment. |
| Copilot 6: | None, we had plenty of time on the cruise to Castle AFB. |
| Boom 6: | Procedures in some navigation is necessary so that the Boomigator will be able to plot along if necessary on the chart. |
| Pilot 7: | HAA - ACFT control during hands on flying. The CDU is still awkward to work with lack of experience. |
| Copilot 7: | INS & DNS CDU's attempting to TAC mix, stop TAC mixing, etc. more training and experience on procedures & trouble shooting problems with them is required. |
| Boom 7: | Radar lack of system knowledge caused more stress. |
| Pilot 8: | The old INS control head which wasn't very user friendly. It would help if it was similar to the FSAS control head. |
| Copilot 8: | 8) Radar - because of unfamiliarity with operating procedure. |
| Boom 8: | Comm out. |

**9. Please recommend any improvements to the aircrew training program that you feel would improve aircrew efficiency and reduce aircrew workload?**

| | |
|---|---|
| Pilot 1: | Nothing needed for this mission other than crew to passenger ratio. |
| Copilot 1: | No comment. |
| Boom 1: | Train people on the equipment expected to use. |
| Pilot 2: | Leave the CDU at the Nav's station or better yet, put two CDU's into the airplane. |
| Copilot 2: | No comment. |
| Boom 2: | Move the INS to the nav station or add another CDU. |
| Pilot 3: | Better training for booms to relieve pilots workload |
| Copilot 3: | More CRM/FE training for booms including basic navigation. Add another boom if you want to cut a nav out. |
| Boom 3: | Boom navigation training. Communication training without nav. |
| Pilot 4: | Radar operation, interpretation training. |
| Copilot 4: | No comment |
| Boom 4: | An INS a DNS location readout at the nav/boom station. |
| Pilot 5: | No. |
| Copilot 5: | No comment |
| Boom 5: | Better upgraded equipment. Proper training. |
| Pilot 6: | Increased training for pilots and boom operators on use of the radar. |
| Copilot 6: | Keep the navigator as part of the crew or give the crew a full line flight engineer. |
| Boom 6: | Leaving a CDU at NAVs station would be beneficial. This would allow the pilots to be free of loading waypoints if need be. |
| Pilot 7: | Make the sim fly better. Training in CDU ops, a quick reference guide for CDU & RADAR. |
| Copilot 7: | See 8 above. |
| Boom 7: | booms & pilots going to ?? upgrade training course. |
| Pilot 8: | Retain the navigator. Even with skilled boom operators the learning curve would be slow until they've been fully trained but are lives lost and aircraft destroyed worth getting rid of the navigator for the sake of a few dollars. |
| Copilot 8: | Radar familiarization. |
| Boom 8: | Picking out weather is not as easy as it was in the sim. In a real system we would not have picked up on the weather. |

**10. What adjective best describes the overall difficulty of this mission?**

a. Easy b. Medium c. Hard

Pilot 1: Easy.
Copilot 1: Easy.
Boom 1: Easy.
Pilot 2: Easy.
Copilot 2: Easy.
Boom 2: Medium.
Pilot 3: Medium.
Copilot 3: Medium.
Boom 3: Medium.
Pilot 4: Medium.
Copilot 4: No answer
Boom 4: Medium.
Pilot 5: Easy.
Copilot 5: Hard.
Boom 5: Easy.
Pilot 6: Easy.
Copilot 6: Easy.
Boom 6: Medium.
Pilot 7: Medium.
Copilot 7: Medium.
Boom 7: Easy.
Pilot 8: Medium.
Copilot 8: Medium.
Boom 8: Easy.

**11. For the previous mission, rate your workload as compared to what you think it would have been with the present KC-135 system and a navigator. With the system that I just flew my workload was _______.**

a. Substantially decreased
b. Moderately decreased
c. Slightly decreased
d. Not changed
e. Slightly increased
f. Moderately increased
g. Substantially increased

Pilot 1: Not changed.
Copilot 1: Slightly Increased.
Boom 1: Not Changed. Experience helped here.
Pilot 2: Moderately Increased.
Copilot 2: Slightly Increased.
Boom 2: Moderately Increased.
Pilot 3: Moderately increased
Copilot 3: Moderately increased
Boom 3: Moderately increased
Pilot 4: Substantially increased

Copilot 4: Substantially increased. Without significant aircraft upgrades to all systems, this airplane cannot be successfully deployed and used, even in a peacetime environment.

Boom 4: Substantially increased. The boom is going to be extremely busy with the added workload. On descent & before landing when the boom checks off to check the APU compartment & boom latched & stowed. No one is available to back up the pilots & the boom will be behind the power curve once he is back in the seat up front.

Pilot 5: Slightly increased. No comment

Copilot 5: Moderately increased. Terrain avoidance with mission changes -- ouch

Boom 5: Slightly increased. The pilots have picked up most of the navigator's duties. I did have some additional duties that mad my time be a little more tied up.

Pilot 6: Moderately increased. No comment.

Copilot 6: Moderately increased. The KC-135 was designed to have a navigator and a proficient navigator was worth his weight in gold during critical situation, or EP and especially during a war when flying through tight air corridors and in small anchor areas is a critical and common occurrence.

Boom 6: Moderately increased. The work load would be substantially increased in the actual aircraft. This would be so because of the actual threat of life and compounded with actually flying an A/C which cannot be duplicated in a simulator.

Pilot 7: Moderately increased. No comment.

Copilot 7: Slightly increased. No comment.

Boom 7: Not Changed.

Pilot 8: Moderately increased. No comment.

Copilot 8: Moderately increased. For the specific mission a nav would have a greatly improved position awareness in regards to high terrain. For the present system flying without a nav is definitely not as safe. (improving radar, moving map, etc.)

Boom 8: Moderately increased. No comment.

**12. Provided adequate training, could a minimally experienced pilot with a minimally experienced copilot successfully fly this mission?**

a. Yes b. No

Pilot 1: Yes.

Copilot 1: Yes.

Boom 1: Yes.

Pilot 2: Yes, but if there were mission changes, weather diverts or Navaids not working, a new crew would be overworked causing potential loss of aircraft, crew and pax.

Copilot 2: Yes.

Boom 2: No. Too many route changes and mission changes.

Pilot 3: Yes. No comment

Copilot 3: Yes. If there were not too many changes.

Boom 3: No. No comment

Pilot 4: Yes. No comment

Copilot 4: Yes. No, if everything worked -> no engine failures, hydraulic problems etc. and with the help of professional radar controllers it is possible to safely complete the mission. However, without significant automation added to the jet many class A mishaps will occur.

Boom 4: Yes. A highly experienced boom would definitely help in some of the situations. In a wartime environment, things would get hectic. Still all pilots are trained in going from point A to B, VFR especially. IFR conditions, emergencies, A/R, weather diversions, or anything else out of the ordinary is going to cause tremendous task saturation for the pilots, let alone the boom.

Pilot 5: Yes. With 80% probability.
Copilot 5: Yes. Crash & burn which is much more expensive than a nav.
Boom 5: Yes. As long as the training was for real and that the comments made in these critiques are listened to.
Pilot 6: No. There is a good possibility that a minimally experienced crew (without a navigator) would have run into a mountain during the divert from Edwards AFB to March AFB. (This refers to mission #2. A minimally qualified crew would have flown mission #1.
Copilot 6: No. The aircraft is designed to have 4 crew members and with our current equipment we need the navigator.
Boom 6: No. I believe that an experienced navigator or just an inexperienced nav would greatly enhance the situation. Having the third person always backing up navigation, altitude, attitude, heading, that is knowledgeable is imperative. The boom is not that person due to the duties that remove him from the cockpit.
Pilot 7: Yes. It could be done however effectiveness would be decreased.
Copilot 7: Yes. with an involved B.O.
Boom 7: Yes. Again booms and pilots need additional ground training.
Pilot 8: No. There is to much going on for to low experienced crews to fly either mission.
Copilot 8: Yes. No comment.
Boom 8: No. Not with any degree of safety.

**13. The following space is provided for you to elaborate on questions 1-11 or for you to identify any other concerns that you might have.**

Pilot 1: No comments.
Copilot 1: No comments.
Boom 1: *Easy mission, experience made it even easier.*
Pilot 2: No comments.
Copilot 2: No comments.
Boom 2: No comments.
Pilot 3: No comment
Copilot 3: No comment
Boom 3: Pilots had a heavy workload, boom could not really help. CDU in back for boom allows pilots to have their eyes outside more.
Pilot 4: No comment
Copilot 4: No comment
Boom 4: The boom will definitely need more training to go without a nav (Consideration should be given to bringing back the rank of warrant officer if the booms training is going to incorporate so much of nav's responsibility.)
Pilot 5: No comment
Copilot 5: No comment
Boom 5: The boom operators would need extra nav training, RADAR/INS training.
Pilot 6: No comment.
Copilot 6: No comment.
Boom 6: No comment.
Pilot 7: No comment.
Copilot 7: No comment.
Boom 7: No comment.
Pilot 8: No comment.
Copilot 8: Procedures would need to be develop to backup the pilots where the nav usually would have EX. Have pilots brief high terrain with the initial enroute descent.
Boom 8: I was Comm out throughout the first mission.

## MISSION # 2

**1. The routing change during departure caused (a) ______ increase in mission difficulty/aircrew workload.**

a. No b. Slight c. Moderate d. Substantial

| | |
|---|---|
| Pilot 1: | Moderate. Increased workload due to loading INS/DNS. We could have just used TACAN fix-to-fix. |
| Copilot 1: | Moderate. |
| Boom 1: | Slight. I had other checklists that added to my workload and took me out of the cockpit when I would have rather stayed in the cockpit and backed up the crew. |
| Pilot 2: | Moderate. |
| Copilot 2: | Substantial. |
| Boom 2: | Slight. |
| Pilot 3: | Substantial. Without a nav to find the new points/ enter coordinates/ backup the pilots, the workload increase substantially for the pilots "flying the airplane". |
| Copilot 3: | Substantial. Locating new points and loading them in the boxes is usually done by the NAVs. The boom couldn't help load because there is not a CDU. |
| Boom 3: | Slight. No comment |
| Pilot 4: | Moderate. No comment |
| Copilot 4: | Moderate. No comment |
| Boom 4: | Slight. No comment |
| Pilot 5: | Slight. No comment |
| Copilot 5: | Slight. No comment |
| Boom 5: | Slight. Had to look up the new TACAN's in IFR supplement. Pretty easily accomplished. |
| Pilot 6: | Slight. We had previously discussed the route change as being a more appropriate route and were therefore ready for a route change. |
| Copilot 6: | Moderate. No comment. |
| Boom 6: | No. No comment. |
| Pilot 7: | Slight. No comment. |
| Copilot 7: | Moderate. No comment. |
| Boom 7: | Slight. No comment. |
| Pilot 8: | Moderate. No comment. |
| Copilot 8: | Slight. Transition to SID - not hard - had already looked at it. |
| Boom 8: | Slight. No comment. |

**2. The autopilot failure during cruise caused (a) _______ increase in mission difficulty/crew workload.**

a. No b. Slight c. Moderate d. Substantial

| | |
|---|---|
| Pilot 1: | Moderate. Basically took the pilot flying the airplane out of any planning or back up. |
| Copilot 1: | Moderate. |
| Boom 1: | Slight. Pain to hand fly with other stresses. |
| Pilot 2: | Moderate. |
| Copilot 2: | Moderate. |
| Boom 2: | Slight. |
| Pilot 3: | Moderate. The failure effectively took out one pilot from the task of helping to navigate. |

Copilot 3: Slight. Monitoring HAA takes a lot more time and effort with autopilot off. This also means the person flying can't concentrate as much on new mission changes.
Boom 3: Slight. No comment
Pilot 4: Substantial. No comment
Copilot 4: Substantial. Partially due to significant concentration required in basic acft control of the sim would not be as difficult in the jet.
Boom 4: Slight. No comment
Pilot 5: Slight. No comment
Copilot 5: Slight. No comment
Boom 5: No. I wasn't flying.
Pilot 6: Slight. This is due to the shortness of the mission. On a longer mission it would have moderately of even substantially increased mission difficulty. 3) No. No comment.
Copilot 6: Substantial. No comment.
Boom 6: No. No comment.
Pilot 7: Moderate. Only because the sim is harder to fly.
Copilot 7: Moderate. No comment.
Boom 7: Moderate. No comment.
Pilot 8: Substantial. No comment.
Copilot 8: Moderate. The flying CM had to devote all attention to flying the AC thus making him unable to help with planning.
Boom 8: Moderate. No comment.

**3. Prior to descent into Edwards, did you detect your INS's were drifting? Radar Pressurization fluctuations?**

*(Please explain when and how you detected your INS's were drifting in the Comments section).*

a. Yes b. No

Pilot 1: No. No time to check and not enough training. INS was not really needed.
Copilot 1: No.
Boom 1: No.
Pilot 2: No.
Copilot 2: No.
Boom 2: No.
Pilot 3: No. With the route changes, we didn't have time to come up with new coordinates and enter them into the boxes. Therefore we flew point to point using 51-37 techniques in the T-38.
Copilot 3: No. No comment
Boom 3: No. No comment
Pilot 4: No. No comment
Copilot 4: No answer. No comment
Boom 4: No. No comment
Pilot 5: No. Didn't use INS/DNS for short TACAN-to-TACAN hops.
Copilot 5: No. Weren't using them.
Boom 5: No. No comment.
Pilot 6: No. No comment.
Copilot 6: No. No comment.
Boom 6: No. No comment.
Pilot 7: No. No comment.
Copilot 7: No. No comment.
Boom 7: No. No comment.

Pilot 8: No. No comment.
Copilot 8: No. No comment.
Boom 8: No. I had no INS/means of monitoring position.

**4. The drifting of the INS system/radar fluctuations caused (a) _______ increase in mission difficulty/aircrew workload.**

**INS** a. No b. Slight c. Moderate d. Substantial

**Radar** a. No b. Slight c. Moderate d. Substantial

Pilot 1: No/No. No time to check them.
Copilot 1: No/No. Undetected.
Boom 1: No/No.
Pilot 2: Slight/No.
Copilot 2: Moderate/Moderate.
Boom 2: No/No.
Pilot 3: No/No. We did not have time to determine if the INS was drifting therefore we did not use the INS or DNS.
Copilot 3: No/No. No comment
Boom 3: (No answer)/(No answer). No comment
Pilot 4: No/No. Did not detect problems.
Copilot 4: (No answer)/No. Didn't see it drift.
Boom 4: (No answer)/(No answer). No comment
Pilot 5: No/No. No comment
*Copilot 5: No/No. No comment*
Boom 5: No/No. Didn't detect.
Pilot 6: No/No. Did not notice either especially on a short mission via jet routes or airways, a drifting INS would not likely be noticed and would cause no appreciable work load increase. If flying off of jet routes if could cause a considerable increase.
Copilot 6: No/No. No comment.
Boom 6: No/No. No comment.
Pilot 7: No/No. No comment.
Copilot 7: No/No. No comment.
Boom 7: No/No. No comment.
Pilot 8: No answer/Slight. No comment.
Copilot 8: No/No. No comment.
Boom 8: Moderate/No answer. What radar? The radar doesn't appear to operate like the APN-69.

**5. The missed approach and weather divert caused (a) ______ increase in aircrew workload.**

a. No b. *Slight* c. *Moderate* d. *Substantial*

Pilot 1: Substantial. Looking up frequencies, getting clearances and SA really suffered due to not having a trained person looking at a chart of the area.
Copilot 1: Substantial. Unfamiliarity with the terrain surrounding March AFB was not addressed during the divert. Luckily, our experienced boom caught the descent before we hit the terrain.
Boom 1: Moderate. Keeping SA was harder and backing up the crew also became harder.
Pilot 2: Moderate.
Copilot 2: Substantial.
Boom 2: Slight.

| | |
|---|---|
| Pilot 3: | Substantial. No comment |
| Copilot 3: | Moderate. Planning and coordination with proper authorities takes a lot more effort without a nav or a properly trained boom. (i.e. coordinating with command post and plotting new route. |
| Boom 3: | Substantial. No comment |
| Pilot 4: | Substantial. No comment |
| Copilot 4: | Substantial. No comment |
| Boom 4: | Moderate. The workload started to increase here. Not having proper training & equipment for exact aircraft location & terrain avoidance caused immense stress for me. |
| Pilot 5: | Slight. No comment |
| Copilot 5: | Substantial. High terrain with mission changes afterward were tasking. |
| Boom 5: | Slight. More difficult following along and avoiding mountains. |
| Pilot 6: | Moderate. No comment. |
| Copilot 6: | Substantial. No comment. |
| Boom 6: | Substantial. Due to terrain. |
| Pilot 7: | Moderate. No comment. |
| Copilot 7: | Substantial. No comment. |
| Boom 7: | Moderate. Boom's lack of radar knowledge nearly caused a aircraft crash. booms need and upgrade program. |
| Pilot 8: | Substantial. No comment. |
| Copilot 8: | Moderate. No comment. |
| Boom 8: | Moderate. No comment. |

**6. What type of work-around procedures were used to overcome the difficulties encountered during this mission?**

| | |
|---|---|
| Pilot 1: | Boom was used to back up all phases of flight. |
| Copilot 1: | No comment. |
| Boom 1: | Delegation was the key and also taking control/responsibilities. |
| Pilot 2: | Each position must work individually, without back-up. |
| Copilot 2: | Reliance on VOR's and TACAN's. |
| Boom 2: | Had to reach up front to program the INS. |
| Pilot 3: | Pilots used their experience to struggle through the problem. Shifting some of the work to the booms would help greatly. |
| Copilot 3: | Higher workloads for both pilots trying to come up with a game plan and navigate. However no one was monitoring terrain avoidance closely. |
| Boom 3: | The pilot and CO did all the work. If the boom had a CDU, he/she could enter the coordinates (it's not that hard!) |
| Pilot 4: | Prior planning. |
| Copilot 4: | Reliance on TACAN to TACAN navigation |
| Boom 4: | I was trying to remember everything nav's do during a flight & do them without a checklist. Backing up the pilots & doing safety checks was difficult & a little awkward. Time training & experience will overcome that. |
| Pilot 5: | Prioritization. |
| Copilot 5: | Copilot flew, P&B looked at charts & coordinated WX & app. |
| Boom 5: | The controller gave us an update to the flight plan so we did it. |
| Pilot 6: | No comment. |
| Copilot 6: | Divided the work load. The only reason we did not have more problems was that the two pilots were IP's and we had an IBO that had experience with charts and terrain avoidance. |
| Boom 6: | Duties were handed out i.e. weather, high terrain. |
| Pilot 7: | Using the boom effectively. |

Copilot 7: Involved B.O. in process.
Boom 7: CRM, crew duty sharing falling back on past radar knowledge.
Pilot 8: Retain the navigator to maintain precise situational awareness because one crew or airplane lost due to lack of it is unacceptable.
Copilot 8: Used proper procedures and alternate plans.
Boom 8: No quick way to get a lat long on lobo.

**7. Did you encounter any other problem areas during this mission?**
**(Please explain in comments section)**

a. Yes b. No

Pilot 1: Yes. No one backing up descents until we almost ran into a mountain. Boom (who was very experienced) discovered it. I don't think a less experienced boom would have caught this without significant training.
Copilot 1: No.
Boom 1: No.
Pilot 2: No.
Copilot 2: No.
Boom 2: No.
Pilot 3: Yes. Booms/ pilots unfamiliarity with the radar and radar terrain printing techniques caused impact with a mountain.
Copilot 3: Yes. Descended below MSA and did not catch it in time.
Boom 3: Yes. Training is needed for navigation and approach procedures.
Pilot 4: No answer. No comment
*Copilot 4: No answer. Crashed into a mountain.*
Boom 4: Yes. Terrain avoidance & A/C location. If a dual INS is used on the aircraft, give the boom operator a head to use in determining A/C location & backing the pilots. This would be especially helpful in crunched situation where terrain avoidance is necessary.
Pilot 5: No. No comment.
Copilot 5: No. No comment.
Boom 5: No. No comment.
Pilot 6: No. No comment.
Copilot 6: Yes. No comment.
Boom 6: No. No comment.
Pilot 7: No. No comment.
Copilot 7: Yes. Short span of mission combined with the WX and changes caused the pilot team to spend too much time inside looking at charts and navigating vs. flying the A/C. Combined with the auto pilot problem, we drifted off heading and altitude a lot. Not very safe!
Boom 7: No. No comment.
Pilot 8: No answer. With a reduced crew load and major or minor systems failures flying the aircraft and maintaining situational awareness without the navigator is an extremely challenging undertaking.
Copilot 8: Yes. ILS out at March AFB, accomplished TACAN.
Boom 8: Yes. No way to monitor position.

**8. Please recommend any improvements to the training program that you feel would improve aircrew efficiency and reduce aircrew workload?**

Pilot 1: Boom training on the instruments like an NIRC.

Copilot 1: Stress the fact that the boxes should be a lower priority on Jet/Victor routes or on vectors. Stress terrain awareness and divert procedures.
Boom 1: Train to use the equipment, get new checklist and fly sims/flights.
Pilot 2: No comment.
Copilot 2: Planning ahead for waypoint insertion.
Boom 2: Leave CDU at nav's station or add another CDU.
Pilot 3: Train the booms to take care of some of the nav workload.
Copilot 3: booms and pilots need proper radar training to try and locate weather, terrain and so on.
Boom 3: Same as mission #1.
Pilot 4: No comment
Copilot 4: Instruct pilots and booms in radar operation and use. Without significant equipment upgrades the only alternative would be genetic manipulation of the gnome to produce pilots with two heads and four hands.
Boom 4: Give the boom the instrument, tools & training to figure out the location of the A/C & for backing the pilots up!! Training on proper radar procedures would be beneficial as well!!
Pilot 5: None.
Copilot 5: No comment.
Boom 5: Upgraded equipment. Proper training.
Pilot 6: See #9 for mission #1.
Copilot 6: Keep the navigator on board. The plane and equipment were designed for a 4 person crew including a navigator.
Boom 6: If this program is to succeed it is imperative that the boom get extensive training in navigation training, approach procedures, and radar interpretation.
Pilot 7: Training to interpret radar.
Copilot 7: CRM to emphasize someone flies the plane at all times.
Boom 7: See question #12 mission #1.
Pilot 8: Retain a skilled and professionally trained navigator.
Copilot 8: No comment.
Boom 8: INS readout (CDU) at the nav station. Add a nav at the nav station. They got rid of training flight and now they're trying to figure out how to get it back.

**9. What adjective best describes the overall difficulty of this mission?**

a. Easy b. Medium c. Hard

Pilot 1: Hard.
Copilot 1: Hard.
Boom 1: Medium.
Pilot 2: Hard.
Copilot 2: Hard.
Boom 2: Medium.
Pilot 3: Hard.
Copilot 3: Hard.
Boom 3: Medium.
Pilot 4: Medium.
Copilot 4: Hard.
Boom 4: Medium.
Pilot 5: Easy.
Copilot 5: Hard.
Boom 5: Easy.
Pilot 6: Medium.

Copilot 6: Hard.
Boom 6: Medium.
Pilot 7: Medium.
Copilot 7: Hard.
Boom 7: Medium.
Pilot 8: Hard.
Copilot 8: Medium.
Boom 8: Medium.

**10. Provided adequate training, could a minimally experienced pilot with a minimally experienced copilot successfully fly this mission?**

a. Yes b. No

Pilot 1: No. I think that if they didn't get lost, they would have run into the mountain.
Copilot 1: No. I don't think most boom operators would have detected our impending demise.
Boom 1: No.
Pilot 2: No.
Copilot 2: No.
Boom 2: No. Too many changes and decisions in a short amount of time.
Pilot 3: No. We had an experienced pilot & experienced CO and we still had our hands full on this mission.
Copilot 3: No. Too many mission changes combined with the WX would leave the copilot useless and put even a greater workload on the others causing potential fatal results.
Boom 3: No. No comment
Pilot 4: Yes. Probably but a substantial amount of training would be required.
Copilot 4: No. Not without significant equipment upgrades.
Boom 4: No. Maybe yes. This mission more so than any other demonstrated the need for increased training as well a different instrument setup for the boom operator(s?) & pilots.
Pilot 5: Yes. With 50% probability.
Copilot 5: No. Crash & burn.
Boom 5: Yes. As long as the comments mentioned in these critiques are minded.
Pilot 6: No. See #12 for mission #1.
Copilot 6: No. Without a proficient navigator the potential for a FAA violation and even worse, and airplane crash, greatly increases.
Boom 6: No. The
Pilot 7: Yes. Effectiveness is decreased but it can still be done. The boom needs nav type training for radar ops.
Copilot 7: No. If our B.O. hadn't picked up the terrain on radar, the pilot team never caught the high terrain on the chart or the fact that we were vectored below it. If the B.O. hadn't said something, we would have impacted the ground.
Boom 7: Yes. No comment.
Pilot 8: No answer. In this situation the workload would be very high for all crewmembers involved.
Copilot 8: Yes. procedures & S.A. emphasized.
Boom 8: No. Even we hit the hill.

**11. For the previous mission, rate your workload as compared to what you think it would have been with the present KC-135 system and a navigator. With the system that I just flew my workload was _______.**

a. Substantially decreased
b. Moderately decreased
c. Slightly decreased
d. Not changed
e. Slightly increased
f. Moderately increased
g. Substantially increased

Pilot 1: Substantially Increased. Just navigating the aircraft on this mission was hard but not having a trained person with a chart for SA could have been deadly.
Copilot 1: Substantially Increased.
Boom 1: Moderately Increased. Just another person trained in navigation and having a chart, etc.
Pilot 2: Substantially Increased.
Copilot 2: Substantially Increased.
Boom 2: Moderately Increased.
Pilot 3: Moderately increased. No comment
Copilot 3: Substantially increased. No comment
Boom 3: Slightly increased. No comment
Pilot 4: Substantially increased. No comment
Copilot 4: Substantially increased. No comment.
Boom 4: Substantially increased. I was trying to back up the pilots. I had not the checklists or training to do it from the nav's position.
Pilot 5: Slightly increased. No comment.
Copilot 5: Substantially increased. No comment.
Boom 5: Slightly increased. The pilots have picked up most of the nav's jobs. The duties that I've picked up are pretty simple. Proper radar training would be beneficial.
Pilot 6: Moderately increased. No comment.
Copilot 6: Substantially increased. A navigator would have greatly reduced my work load.
Boom 6: Substantially increased. No comment.
Pilot 7: Moderately increased. No comment.
Copilot 7: Moderately increased. No comment.
Boom 7: Slightly increased. No comment.
Pilot 8: Substantially increased.
Copilot 8: Moderately increased. No comment.
Boom 8: Substantially increased. In real life the boom would have been required to remain in the cargo comp. with the pax the entire mission.

**12. The following space is provided for you to elaborate on questions 1-11 or for you to identify any other concerns that you might have.**

Pilot 1: Training on nav's duties for strange field procedures would have helped. A moving map display would have made a big difference.
Copilot 1: A moving map display would have been a life-saver on this sortie.
Boom 1: Very good missions. Our experience allowed us to work better as a crew. (More SA and knowledge of what's going on.) Aggressive booms will be a must and should be trained if they will be expected to do well in this program.
Pilot 2: No comment.
Copilot 2: No comment.

Boom 2: No comment.

Pilot 3: If the booms had a CDU at the nav station in which they could enter points/ check status/ TAC mix to keep the boxes tight. This would lower the work/stress on the pilots. Increased training for both pilots and booms on radar ops will also make that piece of equipment more useful.

Copilot 3: First put a CDU back at nav station. The pilot workload needs to be reduced by a) training the boom to be similar to an FE. b) add another body up front i.e. an extra boom

Boom 3: No comment

Pilot 4: Without significant equipment upgrades to reduce pilot workload this is an extremely difficult task at best when variables such as weather, terrain, unfamiliar airfields, environments (i.e. foreign country) exit. When emergencies arise workload could overload crew to dangerous degree.

Copilot 4: No comment.

Boom 4: The 1st mission with the lack of training was as difficult as trying to swim without lessons. The second sortie brought up situations that also proved this point. Pilots & booms need radar training. All booms will need to learn how to plot coordinates & be able to know where the plane is at any time. Removing the nav is safely possible but make sure the workload is distributed equally among the 3 remaining positions. Remember pax cannot be carried with just a 3 person crew. A problem to be considered with these 2 sorties.

Pilot 5: No comment.

Copilot 5: This is a bad idea to change the crew configuration without a substantial increase in instrumentation capabilities. We fly more in different & more crowded environments in a 4 man A/C; pulling 1 man with no upgrade B dangerous. What about extended anchor A/R (Saudi) where the boomigator would have to stay in back?

Boom 5: This would work with another INS, a carousel 4 at the nav's station and proper training for the boom on the INS/RADAR, and basic nav skills.

Pilot 6: No comment.

Copilot 6: No comment.

Boom 6: In order for this program to succeed it is imperative that the boom operators be trained in the areas of: basic navigation, radar interpretation, and approach plate interpretation. If this is not accomplished a level of security will be lost and under pressure the mission will fail. This change must be conducted and people must be allowed to build their confidence in the new way of flying.

Pilot 7: No comment.

Copilot 7: No comment.

Boom 7: Booms needed to attended an in depth flight school away from the home unit to be able to correctly learn to use equipment and to learn new responsibility and the boom running the radar the majority of the time pilots need to adapt to listening to an enlisted crew member. With new cockpit arrangement comm 3 radio must be installed at boom's refueling station

Pilot 8: No comment.

Copilot 8: With the proper information the BO could still be utilized in flight safety and situational awareness. For example -- INS head at nav station.

Boom 8: No comment.