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# KC-135 COCKPIT MODERNIZATION STUDY AND CREW REDUCTION FEASIBILITY DEMONSTRATION

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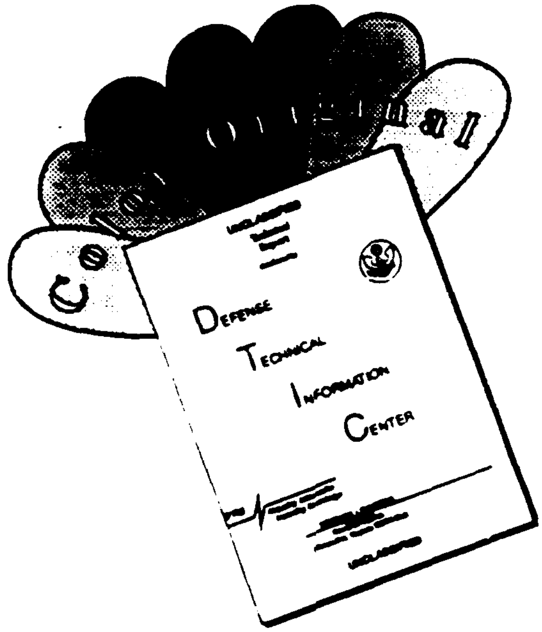


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Future KC-135 missions will require significant increases in aircraft flexibility to respond to the Air Force vision of "Global Reach, Global Power." Such flexibility typically translates into advanced avionics systems and system capabilities; however, 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 phase of this program and for the first time directly compares the two-man and three-man cockpit configurations. The validation of the reduced crew consisted of a comparison of crew performance across three distinct missions - Minot, Castle and Desert. Results supported the two-person (No Nav) cockpit, given certain modifiactions. Based on these results, the CSEF recommended follow-on flight test of the KC-135. Recommendations are based upon using the final design, identical in system capabilities, as developed at the Crew Station Evaluation Facility. The key to the success of this program lies in the utilization of the modifications discussed in this report and the proper implementation of those modifiactions in future KC-135 cockpits.

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# 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 Cockpit Modernization 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.

Due to the lessons learned during the Persian Gulf War, HQ AMC had renewed 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 navigator 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 during operational missions. Drawing upon information gathered during earlier 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.

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 in the Persian Gulf during Operations Desert Shield and Desert Storm. 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 not significantly different for the two-man conceptual cockpit and that the three-man configuration produced less workload during all mission tasks. The most significant of these results was that workload in the conceptual cockpit was not believed (as measured by crewmember responses) to be significantly higher than those encountered in the existing aircraft, despite 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, systems 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 Desert mission was seen as the most difficult.
2. Most crewmembers felt that a minimally qualified two-man crew could have successfully completed the three sample missions flown, given the CSEF system capabilities.
3. Increased workloads for the two-man crew were encountered during the inflight replanning, random refueling, navigation and radar tasks. While some of these workloads were outside the desired range, system familiarity, simple modifications to the CDU and Electronic Horizontal Situation Indicator (EHSI) and training should reduce workload to desired levels.

The findings of this study support the two-person (No Nav) cockpit, given the necessary modifications; workload levels for the two-man crew were not significantly higher in the CSEF conceptual cockpit when compared to the version of the KC-135 currently flown, even after the removal of the navigator. The conclusions listed above are based upon using the final design, identical in system capabilities, as developed at the Crew Station Evaluation Facility. The key to the success of this program lies in the utilization of modifications discussed in this report 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 Cockpit Modernization 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 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. 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 Offices (SPOs) use 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. 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 flight 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 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 design such that workload was kept at manageable level to ensure successful mission accomplishment. (Rueb, et al., 1992)

# CURRENT CSEF TASKING

Due to the lessons learned during the Persian Gulf War, HQ AMC had renewed 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 navigator 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 order to introduce the navigator to the modernized cockpit, CSEF personnel 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 at the navigator station. Control and display design modifications were based upon inputs from KC-135 crewmembers who were shown several design configurations and asked to provide modification recommendations. With the exception of tasks that were automated, tasks that were allocated to the pilot and copilot were then reallocated back to the navigator.

In the end, a navigator station was developed which support all navigator activities. At the same time, no function 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.

This volume describes the method and results of the test and evaluation phase of this effort. Additional 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 10 KC-135 crews (Pilots, Copilots, and navigators) were used in this study. They were operational crews from various air bases (Active Duty and Guard Units) 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 (A,E,R,Q), one crew was qualified in both the A and R versions, three crews were qualified in the KC-135E and five crews were qualified in the KC-135R. Overall KC-135 hours ranged from 150 to 4300 and averaged 1659.7 Total flying time ranged from 400 to 9950 and averaged 2762.6. The average time since the last KC-135 flight was 10.1 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 flown during the simulated mission is shown in Figures 1, 2 and 3. The simulator 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 described in Barnaba et al. (1992). Modifications based upon performance data and subjective inputs received during Study 1 (Rueb et al., 1992) 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 variables 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

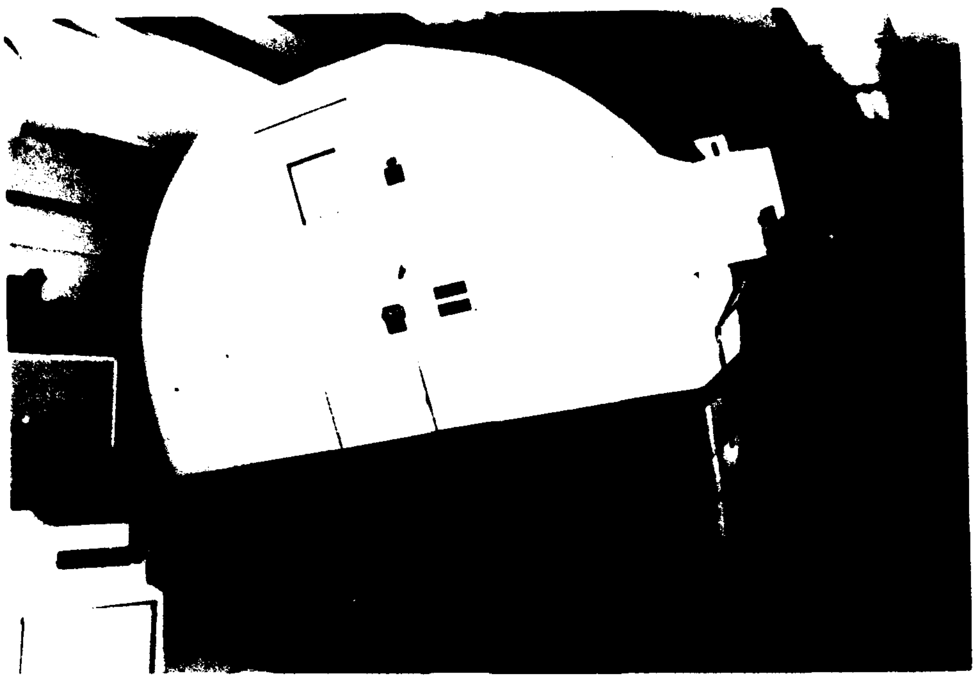

Figure 1. CSEF KC-135 Simulator (Exterior)

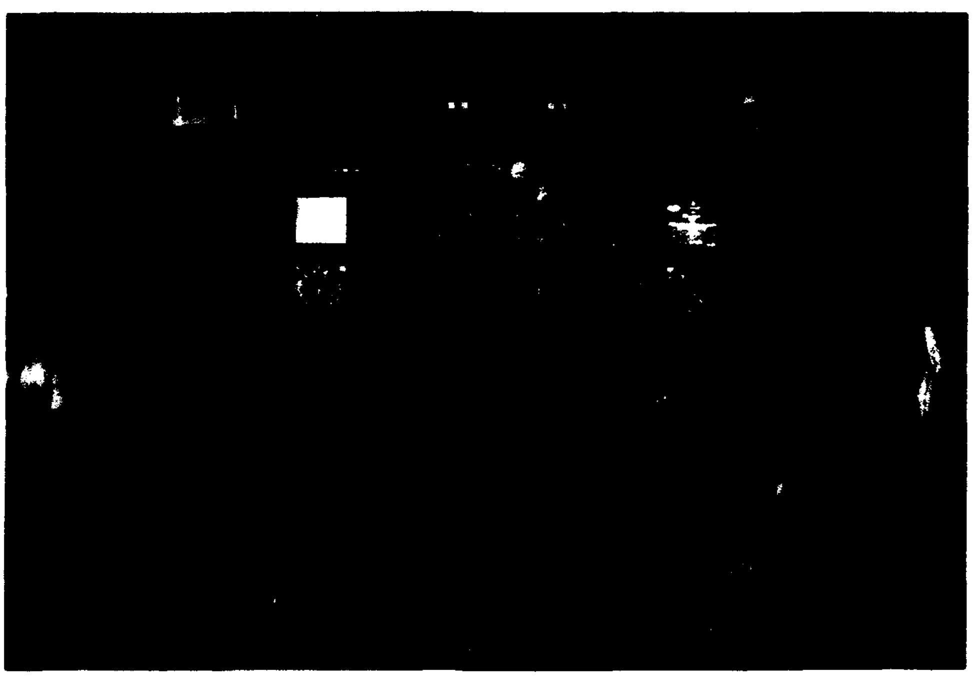

Figure 2. KC-135 Simulator (Interior)

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 aircraft EHSI.

**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 EADI/EHSI instrument displays and the experimenter's console displays.

## Experimenter's Console

The experimenter's console shown in Figure 4, 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, etc.).

## Procedure

Aircrews (P, CP and Nav) were on site at the CSEF for a period of 2 weeks during which time they participated in system training and data collection flights. Approximately 2 weeks before the arrival of the crews, training materials were forwarded to the aircrews for study. These materials included detailed descriptions of the systems including systems operating procedures and illustrations. On the first day, crews received a standardized brief covering the purpose of the study, training program, safety procedures, systems descriptions and the schedule for their remaining 2 weeks 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 and their use, individual displays and standard system symbology.

Each crew then received one-on-one training on the systems use in the simulator itself; CSEF personnel 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. On day two, each crew flew a training mission to re-emphasize the system during real time, full mission simulation. The goal of this training session was to ensure system familiarity and also to ensure exposure to the capabilities of the new system. Emphasis was placed on the use of the various subsystems, radar control panel and CDU page integration.

The training mission was a three-ship cell departure and join up from Castle AFB, CA as number two in the formation. At takeoff (TO) + 20 minutes, a cell lead change was accomplished and the crew became cell lead. The flight performed an enroute rendezvous with a flight of F-16s at the Air Refueling Initial Point (ARIP) for AR Route 6B. The flight of F-16s requested an additional 5,000 pounds of gas (5K) over the scheduled amount. The northern end of the AR track contained thunderstorms requiring crew deviation for mission success.

Following air refueling, the crew was then diverted by Command Post to McChord AFB, WA to await further instructions. Immediately following this diversion, the subsequent cell break-up and alter heading to McChord, the crew experienced a generator failure and the loss of both the GPS and INS navigation equipment. The crew was required to recycle the failed equipment, navigate to McChord and land.

Upon completion of training, crews were given mission materials for the following days sortie. These materials included mission takeoff data, flight plan, communications and

Figure 3. Navigator's Station

Figure 4. Experimenter' Console

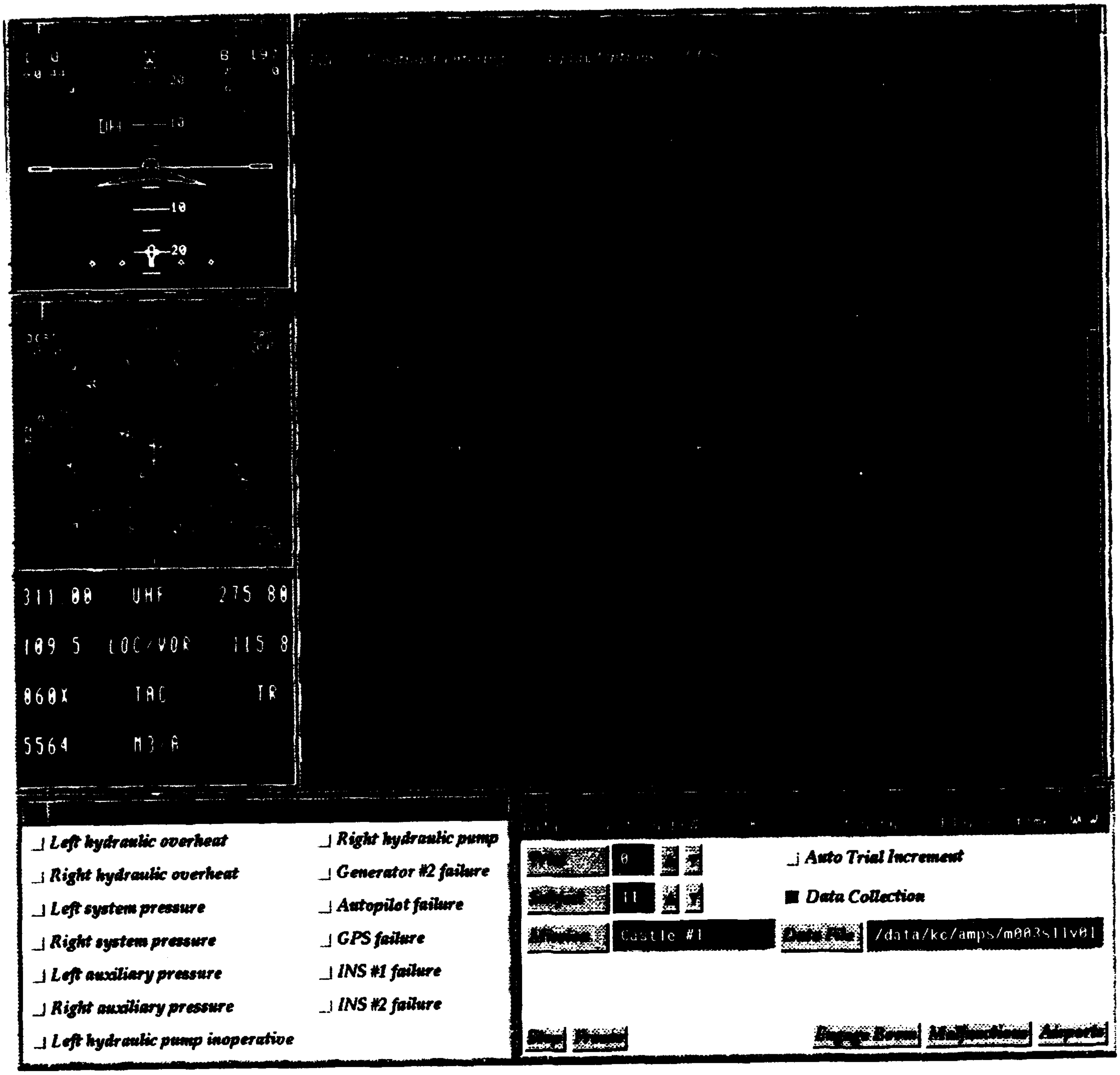


Figure 5. Mission Control Page

navigation frequencies and a chart covering their intended route of flight. They 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 8 days were used to fly each of the three missions- as both three-man and two-man crews.

**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 5 shows an example of the mission control page that the experimenter used to select the mission flown, the particular version of that mission, 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 in the Persian Gulf during Operations Desert Shield and Desert Storm. 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 trained to listen intently to all radio calls and respond 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 shown in Figure 5. 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 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 6) was classified as the "easy" mission. The flight was a single ship departure from Minot AFB. The


Figure 6. Minot Mission

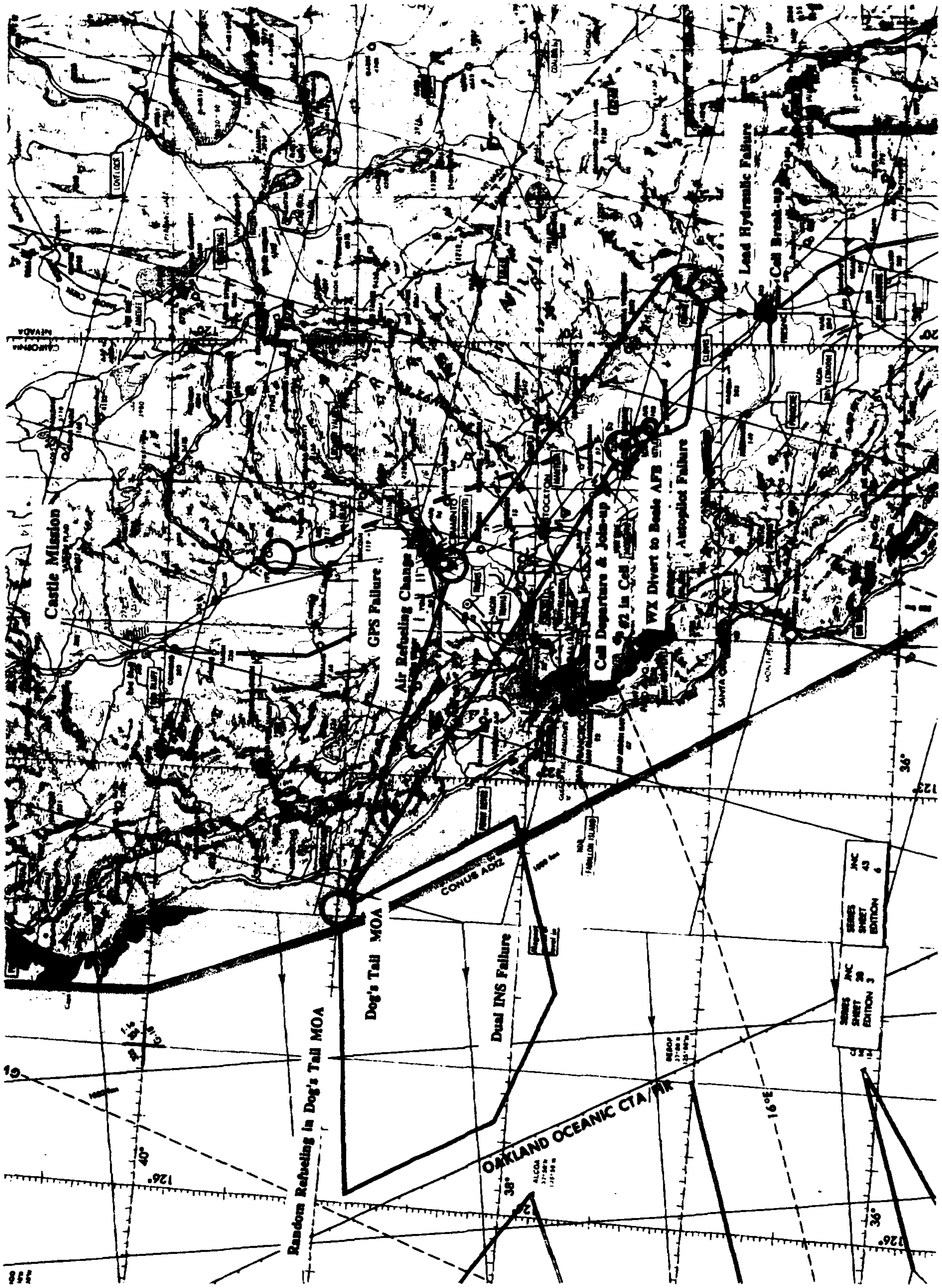


Figure 7. Castle Mission

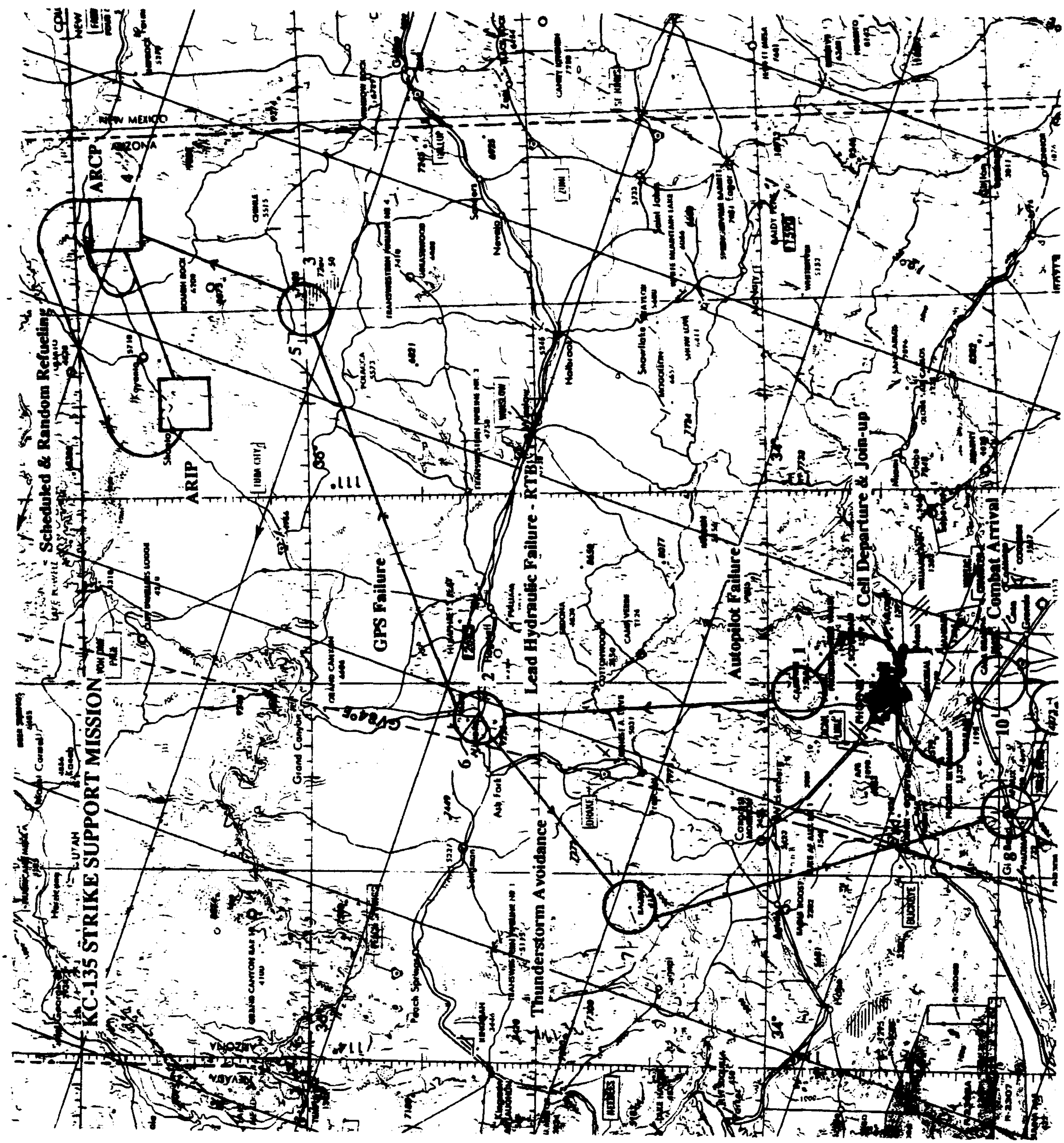


Figure 8. Desert Storm Mission

crew was either delayed nine minutes or given an air refueling change to make them nine minutes late. The receiver was a single B-52 scheduled for an enroute rendezvous at the ARIP for 106 HW. The offload was increased to 20K more than originally scheduled. Following the completion of air refueling, the crew experienced an hydraulic failure enroute to the Initial Approach Fix (IAF), handled the malfunction and landed.

**Castle Mission** This mission (Figure 7) was the medium difficulty 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 or Rowdy-1 Standard Instrument Departure (SID). Immediately following takeoff, the crew experienced an autopilot failure and was forced to hand fly the entire mission. Cell break-up was scheduled for the Sacramento TACAN; however, cell lead experienced a hydraulic problem after cell departure and join-up leaving the crew as a single ship.

Twenty-five nautical miles from the Sacramento TACAN, the crew received a mission change from AR 5WE to the Dogs Tail Military Operating Area (MOA-W260) due to weather. The scheduled receivers, a flight of two F-16s, showed up on time and requested an additional 5K each. Immediately following entry into the MOA, the crew lost both INSs and the GPS system.

Following air refueling, the crew requested landing weather and was given minimum weather required for a precision approach. The crew never broke out and was required to divert to an alternate airport. Throughout this mission, the crew was required to deal with and avoid thunderstorms along their route of flight.

**Desert Storm Mission** This mission (Figure 8) was labeled as the "hard" mission. The crew was given mission materials upon arrival at the CSEF instead of the night prior to flight in order to simulate the mission planning that occurred at Tanker OPS during Desert Storm missions. Following a weather briefing, the crew was given an intelligence report, a communications and navigation procedures briefing; crews were expected to use radio silent procedures and code words from locally developed Special Instructions (SPINS) as well as navigate using a short range TACAN during a SID and then transition to their INSs. All associated mission materials necessary for mission completion (charts, air refueling anchor areas, instrument approach plates) were distributed and all questions answered.

The crew took off as number two in a two-ship departure. After flying the SID, the lead aircraft checked the cell in with AWACS requesting area clearance. The lead aircraft then either experienced an engine failure or was given a mission change, making the crew a single ship.

After the first air refueling, the crew was diverted to a new anchor area via routing that would prevent them from meeting mission timing requirements. After the crew requested direct or quicker routing, the crew was informed of an additional receiver enroute to their area that needed refueling. As this aircraft approached, the crew was given an additional refueling of a battle damaged aircraft. After the completion of air refueling, the crew experienced a complete loss of all navigation systems (both the INSs and GPS systems failed); at this time AWACS was down for its own refueling. The crew was forced to recycle all navigation systems in order to return to 'homeplate". Enroute to their home base, the crew was informed that the Instrument Landing System (ILS) was out of service and that the TACAN was unreliable. This forced the crew to set up for a Flight Management System (FMS) approach. After inserting the new approach, the crew was cleared direct to the FMS IAF for approach and 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. The KIK-18 was simulated.

3. Celestial navigation was not required.

4. Global Positioning System (GPS) and associated satellites were available and used.

5. A dual Inertial Navigation System (INS) was available and used.

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

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

## Experimental Design

The primary objective of this study was to demonstrate the feasibility of the experimental cockpit design as it pertained to the upgraded navigator station as well as a direct comparison of the 2-man versus 3-man crew. In order to isolate the sources of workload in an effort to focus on specific areas of the cockpit design which may require further modification additional comparison 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. All subjects completed data collection with one cockpit configuration before beginning data collection with the second configuration. The order of the missions flown (Minot, Castle and Desert) 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 mission. 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: SACR 60-4, Vol IX)

2. Control Point or Steerpoint Deviations: Navigation deviation were monitored to ensure that crews did not miss designated control points (e.g., ARCP, RZ PT) by more than 10 NM (Ref: SACR 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: SACR 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, SAC 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 intent of the present evaluation was to serve two purposes. 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 conceptual baseline or tasks within the mission which may require additional attention. By using such an approach, CSEF personnel could validate system functional requirements by establishing a list of must have requirements without which workload could easily 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.

The debrief 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 pilot training, a set of 27 cards, representing all possible combinations of levels of the three dimensions were sorted by each pilot from lowest to highest workload. The resulting orderings were then used during data analysis to develop a baseline workload scale for the group. When reporting workload throughout the mission, pilots provided three separate ratings, one for each 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 rater was presented with a rating sheet (a complete listing of all SWORD sheets is shown in Appendix A) 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 (Appendices C-E) 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. In addition to the mission specific questionnaires, subjects were required to work on a systems questionnaire (Appendix F). It contained 115 multiple choice questions each asking specific questions about control panels, displays and switch location; each item also had a comments section which allowed the crewmember to fully explain or expand on his/her answers. This questionnaire was designed to identify specific functional requirements that crewmembers felt necessary for mission accomplishment.

## RESULTS AND DISCUSSION

The results section is broken up into three sections. The first section reviews the performance parameters monitored by the experimenters during each mission. This review was conducted in order to ensure that crew were performing within Federal Aviation Administration, Air Force and Air Mobility Command regulations. The second section looks at the subjective measures used in this study, SWAT and SWORD, to determine the feasibility of the conceptual design and high workload areas which may require additional analysis. The final section discusses the systems questionnaire in detail.

Throughout the three sections, the reader will be presented multiple figures for both the pilot group (without the navigator) 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, the three-man crew (3-MAN) represents the conceptual cockpit flown with a pilot, copilot and a navigator, 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=20) and navigators (n=10). For purposes of this study, pilots and copilots were grouped together for analysis.

## CREW PERFORMANCE

None of the objectives measured revealed any differences between the configurations or missions flown. Although there were some deviations from preferred performance levels, they could not be consistently identified with any one configuration or mission.

**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) to the end of Air Refueling. Only two deviations from the ten nautical mile corridor were noted. Both of these deviations were corrected without outside intervention.

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

**Altitude Deviations.** Only two deviations exceeded tolerances; all deviations were momentary and immediately corrected.

**Weather Deviation Distances.** Thunderstorm avoidance was measured during the entire flight. No crew had any difficulty in avoiding thunderstorms by the prescribed distance.

## Crew Workload

### Mission Difficulty

The three missions used during this study (Minot, Castle and Desert) 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 various mission difficulties were: (1) Easy (Minot), (2) medium (Castle) and (3) Hard (Desert).

The results of the analysis for the interaction between mission and cockpit configuration is presented in Figure 9; results showed a statistically significant effect, $F(2,34)= 9.28$, $p<0.001$. The effect indicates that pilots experienced higher workload during the Desert Mission than during the Castle Mission for the two-man cockpit; however, this trend was reversed for the three-man cockpit. In all cases, workload for the three-man crew was less than that for the two-man crew, as evidenced by a significant main effect for Mission, $F(1,17)=3.07$, $p<0.0002$.

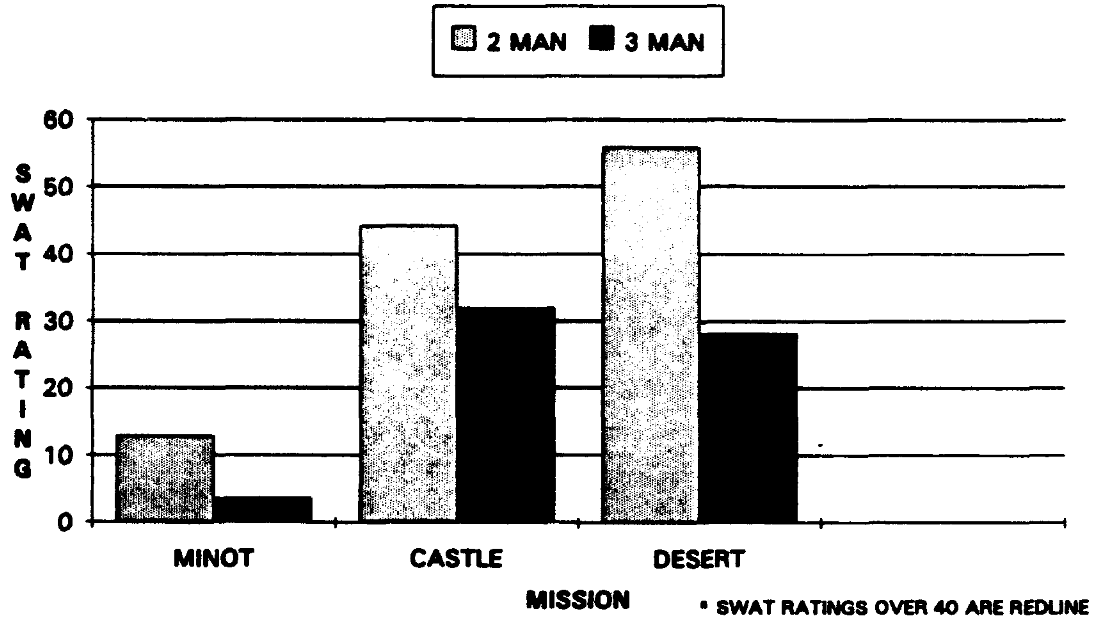


Figure 9. KC-135 Overall SWAT Workload Ratings

The general trend of the data follows the expected pattern of results. Mission difficulty increased from the Minot mission to the Castle mission to the Desert mission. However, the decrease in difficulty between the three-man Castle mission and three-man Desert mission was contrary to expected results. During their debriefings, crews indicated that during the Castle mission they were forced to monitor a variety of communications and navigation frequencies and avoid thunderstorms. During the Desert mission, there were no navigation aids available (outside of 25 NM) and communications were held to a minimum; weather was not a factor during this mission. Therefore, workload fell mainly onto the navigator and pilot workload decreased.

In summary, the increase in mission difficulty from the Minot mission to the Castle mission to the Desert mission was as expected for the two-man crew and proved that the manipulation of mission difficulty was successful. The increase in mission difficulty from the Minot mission to the Castle mission and then the sudden decrease to the Desert mission, while not predicted, was easily understandable. Additionally, these missions spanned the range of mission difficulty and were representative of current operational missions.

**Mission/Segment Workload**

Presented in Figures 10, 11 and 12 are the SWAT ratings for the Minot, Castle, and Desert Storms mission respectively and their associated mission segments.

A review of Figure 10 reveals that none of the Minot mission events received a rating of over 40 in either the two-man or three-man

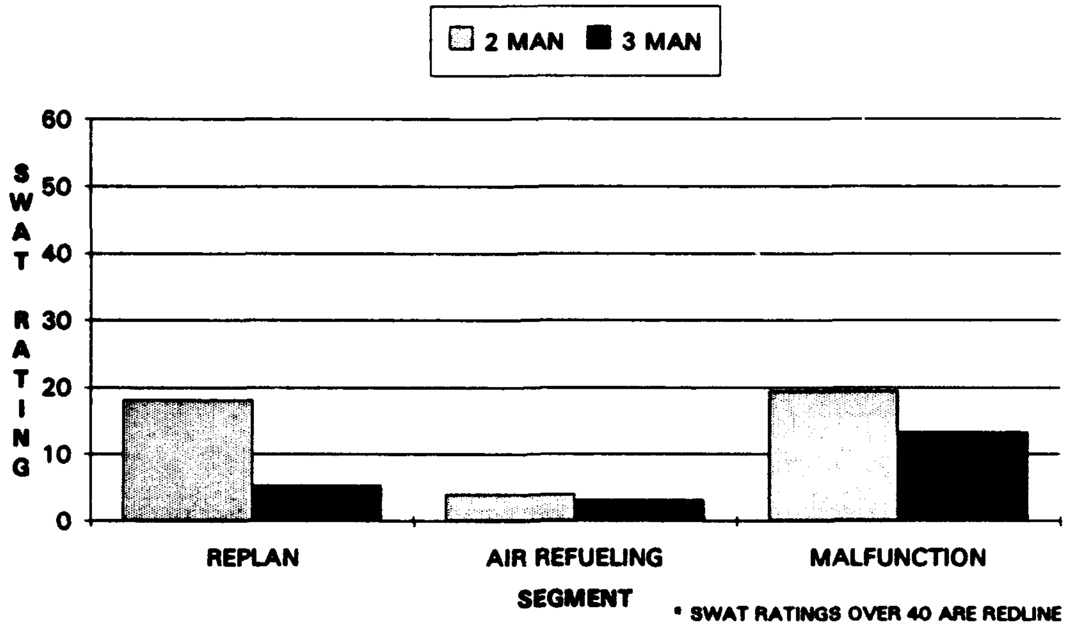


Figure 10. Minot Mission SWAT Ratings for various mission events

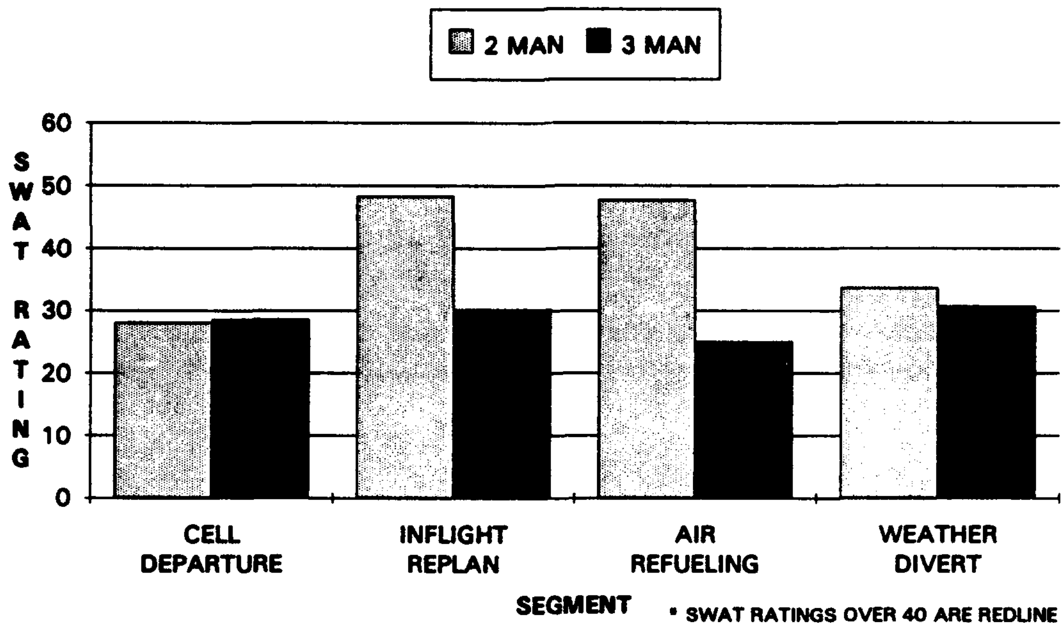


Figure 11. Castle Mission SWAT Ratings for various mission events

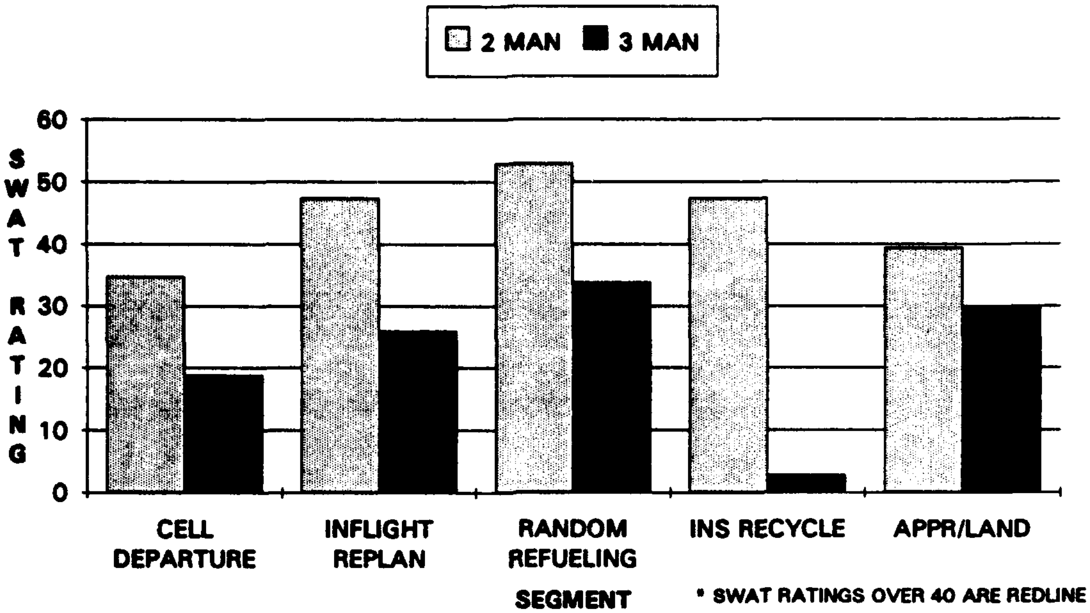


Figure 12. Desert Storm Mission SWAT Ratings for various mission events

configuration. This indicates that an "easy" mission such as this one would result in workloads that are manageable, given the CSEF conceptual cockpit design.

For the Castle mission, Figure 11 indicates that two of the four mission events are potential areas for concern. The inflight replanning and random refueling events both had ratings of over 40. This mission was intentionally designed to drive workloads over the redline limit of 40 in order to identify possible systems shortcomings. Thorough debriefings revealed that KC-135 pilots and copilots felt that additional training in navigation procedures and radar usage would improve proficiency. They also felt that the autopilot failure, which forced them to continually hand-fly the airplane, was a definite cause of a large portion of the workload they encountered.

Finally, analysis of the Desert Storm mission indicates that three of five events flown were possible areas of concern (Figure 12). This mission was also intentionally designed to drive workloads above the redline limits. Discussions with crewmembers revealed that, as previously noted, training was insufficient in both the navigation and radar usage areas to gain thorough proficiency. In addition, INS recycle procedures were not fully understood by the pilots and, when coupled with ambiguous CDU page orientation, detracted from overall mission performance. Once again, the failure of the autopilot was a significant source of workload encountered during the Desert mission.

## Segment/Task Workload

SWORD data were collected for three mission segments across the three different missions. The three mission segments for Minot, Castle and Desert 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 13 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, $F(2,36)=8.56$, $p<.001$. Post hoc analysis revealed that 1) significant workload differences between the two-man and three-man configuration existed and that 2) workload levels were not significantly different between the two-man cockpit and reference cockpit and three-man cockpit and reference cockpit.

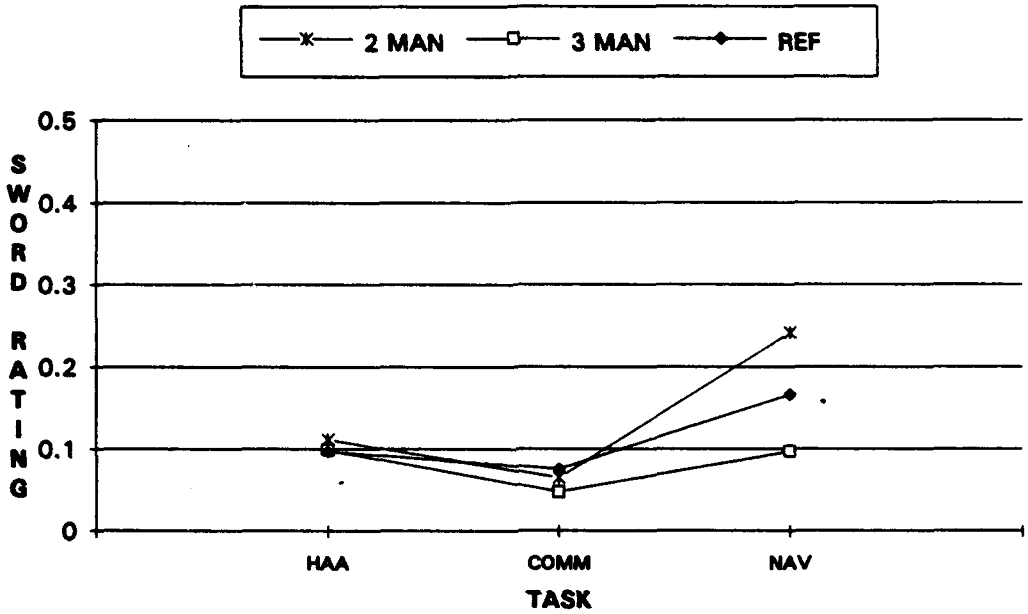


Figure 13. Minot SWORD Ratings for the Cruise Segment

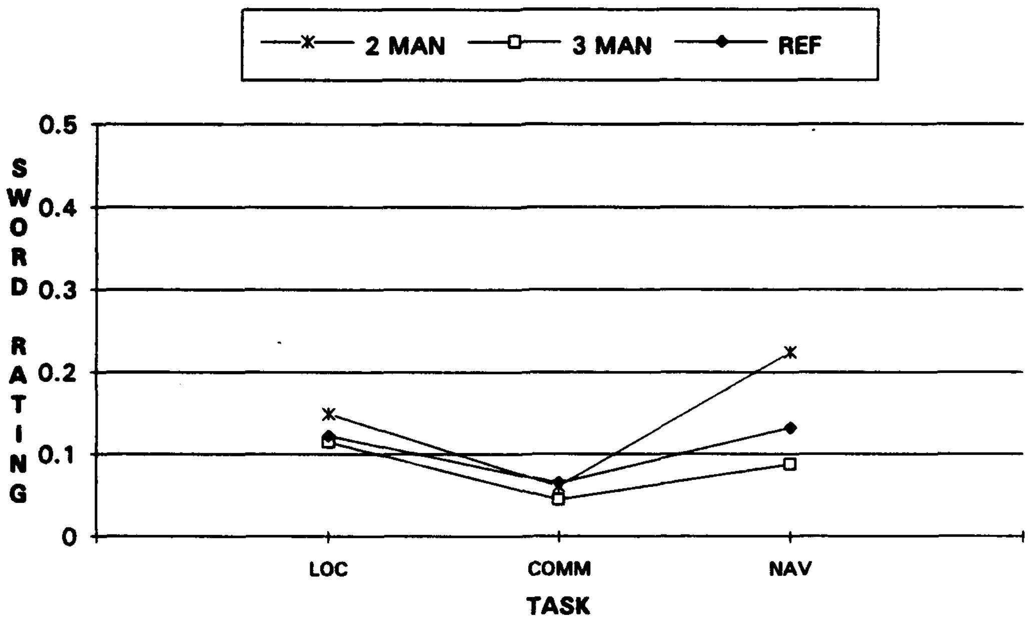


Figure 14. Minot SWORD Ratings for the Approach/Landing segment

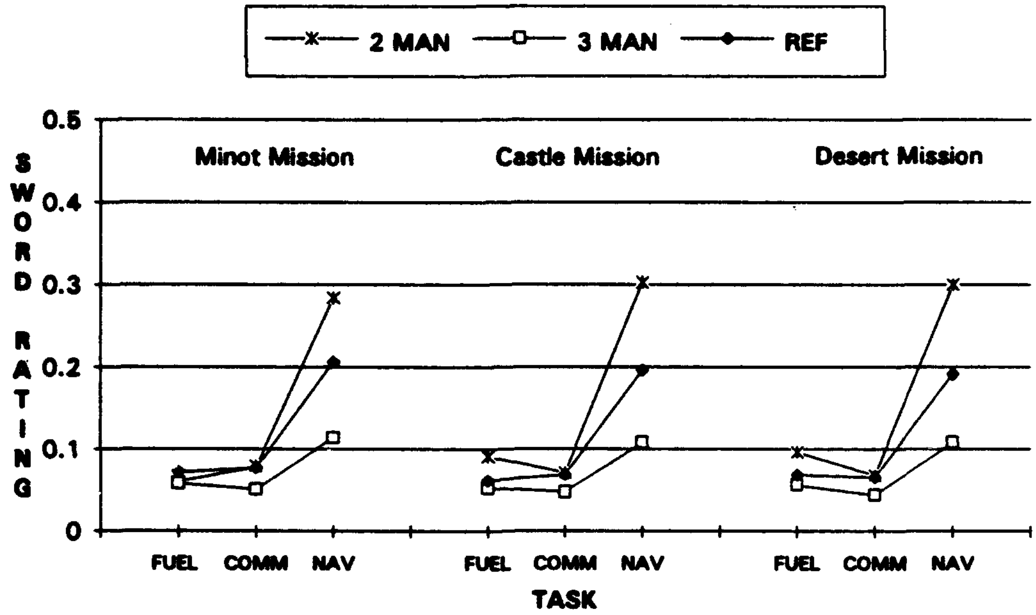


Figure 15. SWORD Ratings for the Air Refueling Segment

The SWORD ratings for the Approach and Landing segment of the Minot mission are presented in Figure 14. Results of an analysis of variance indicate the same findings as for the Cruise segment, with a significant main effect for cockpit configuration, $F(2,36)=10.10$, $p<.001$; and post hoc analysis indicating a significant difference between the two-man and three-man configurations only.

Figure 15 graphs the results of the Air Refueling segment for each of the missions. The fueling task (FUEL) included management of the fuel panel, transfer of fuel, maintenance of the proper center of gravity (CG) and the monitoring of the fuel flows. The communications task (COMM) and the navigation task (NAV) were similar to those previously noted.

As the graph indicates, the navigation portion of the air refueling segment was considered more difficult across all missions; $F(2,36)=10.79$ for Minot, 20.90 for Castle and 15.06 for the Desert Mission, $p<.001$. Post hoc analysis found that the two-man conceptual cockpit yielded significantly higher workload ratings than the reference aircraft which in turn were significantly higher than the three-man configuration. Pilots attributed this to a lack of familiarity with the radar and system setup, location of control panels and use of the control display unit (CDU) pages. No significant effects were found between the communications task and the fueling task for any of the missions.

The results of the cell departure and join-up segment of the Castle and Desert missions are presented in Figure 16. The radar task 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 configurations was found for both the radar (RADAR) and the navigation task (NAV), $F(2,36)=7.42$ and 16.43 for the Castle Mission and $F(2,36)=21.74$ and 26.25 for the Desert Mission, $p<.001$. Post hoc analyses revealed that the significant main effect was the resulted of differences between the two-man and three-man configurations. As previously mentioned, pilots felt these difficulties arose from a lack of familiarity with the radar system, the location of the navigation control panel and CDU page set-up and use.

Figure 17 shows the workload ratings for the Castle and Desert missions for the inflight replanning segment of the mission. This segment included all tasks necessary to determine the new route of flight, input the new route into the mission management system (MMS) 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 main effects for cockpit configuration for the navigation (NAV) and inflight planning (PLAN) tasks, F(2,36)=9.81 and 11.68 for the Castle Mission, and F(2,36)=18.34 and 25.68 for the Desert Mission, p<.001. Again the results show that the three-man CSEF cockpit produces the lowest workload, followed by the reference aircraft and the two-man cockpit. While there is no significant workload difference between the two-man cockpit and the reference aircraft or the three-man cockpit and the reference aircraft, there was a statistically significant workload difference between the two-man and three-man configurations. When asked about the workload differences, pilots felt this was a direct result of the CDU page setup, control panel location and lack of system familiarity.

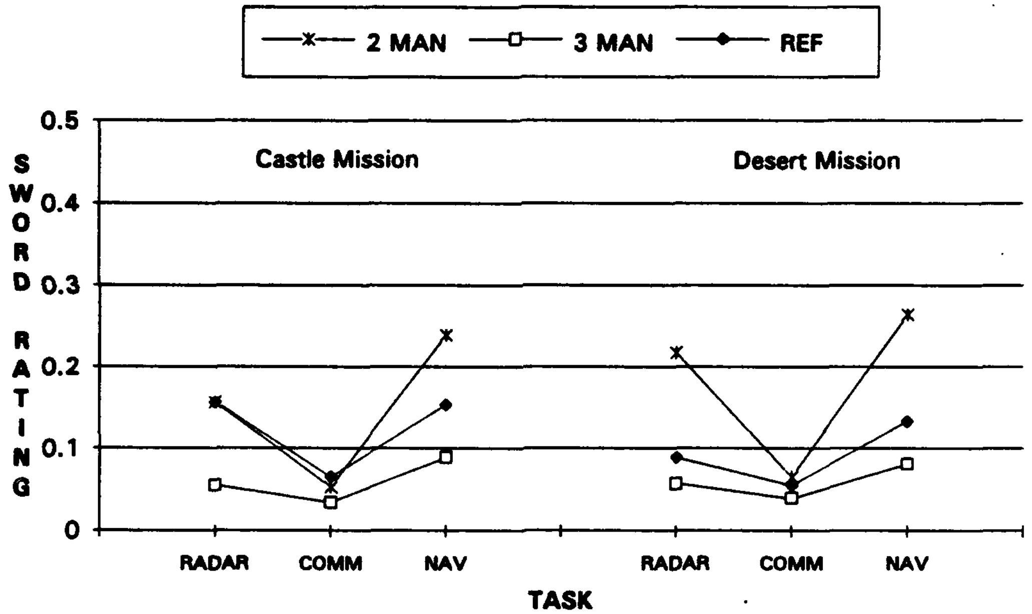


Figure 16. SWORD Ratings for the Cell Departure and Join-up Segment

Figure 18 depicts the ratings from the storm avoidance segment of the Castle mission. Again the results show the same trend as the Cell Departure and Join-up and Air Refueling segments. The results indicated that while there was no significant difference in workload for the communications task (COMM), there were statistically significant main effects for cockpit configuration for the storm avoidance task (STORM) and inflight planning (PLAN) tasks, F(2,36)=9.81 and 11.68 for the Castle Mission, and F(2,36)=18.34 and 25.68 for the Desert Mission, p<.001. Contrary to previous segments, these effects do not reflect a difference between the two-man and three-man configuration but rather between the modernized cockpits (i.e., two-man and three-man) and the reference aircraft.

During their debriefings, the pilots indicated this may be a direct result of the inclusion of a color weather radar into the CSEF conceptual cockpit design. One pilot stated that the color weather radar made it easier to see weather and, when combined with a moving map overlay, enhanced situational awareness.

Overall, SWORD results show that workload, when compared to the reference aircraft, was not significantly higher for the CSEF conceptual cockpit. In fact, the three-man configuration produced less workload in almost every task of the missions flown. For the two-man and reference aircraft comparison, workload levels were not significantly different with two exceptions - the navigation and/or replanning tasks and the radar usage.

Pilots unanimously stated that the major cause of workload during these missions was the failure of the autopilot which completely took one pilot out of the loop. This was largely due to the fact that, as one pilot put it, "All simulators are harder to fly; they just never trim up properly." When this malfunction was combined with the additional problems of CDU page orientation, control panel location and a general lack of training in radar usage, workload increased.

The most significant finding of these SWORD results is that relative workloads in the conceptual cockpit were not believed (as measured by crewmember responses) to be significantly higher than those encountered in the existing aircraft, despite the removal of the navigator from the crew.

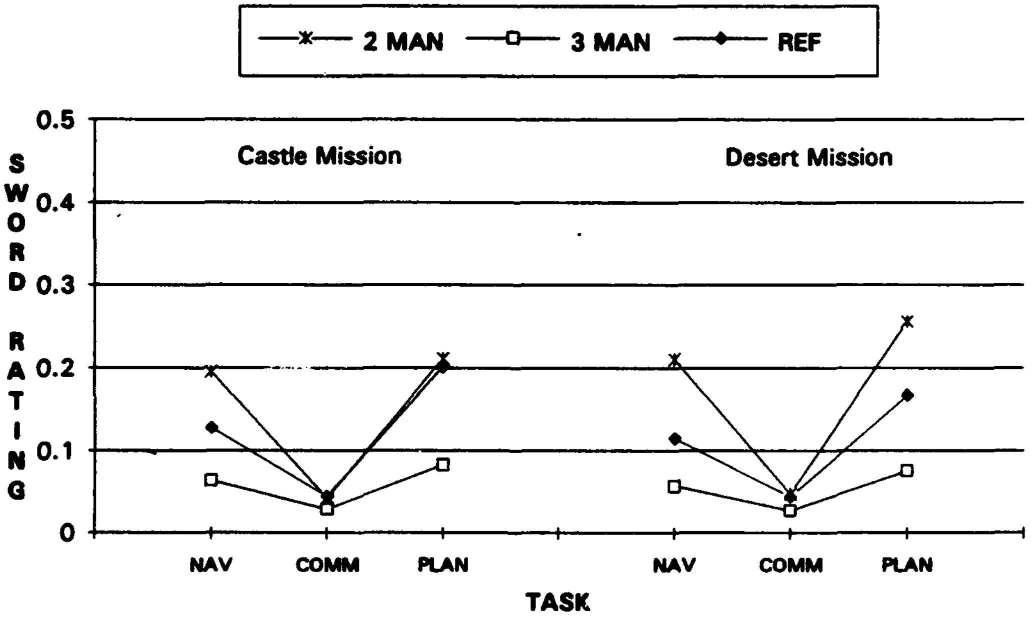


Figure 17. SWORD Ratings for the Inflight Replanning Segment

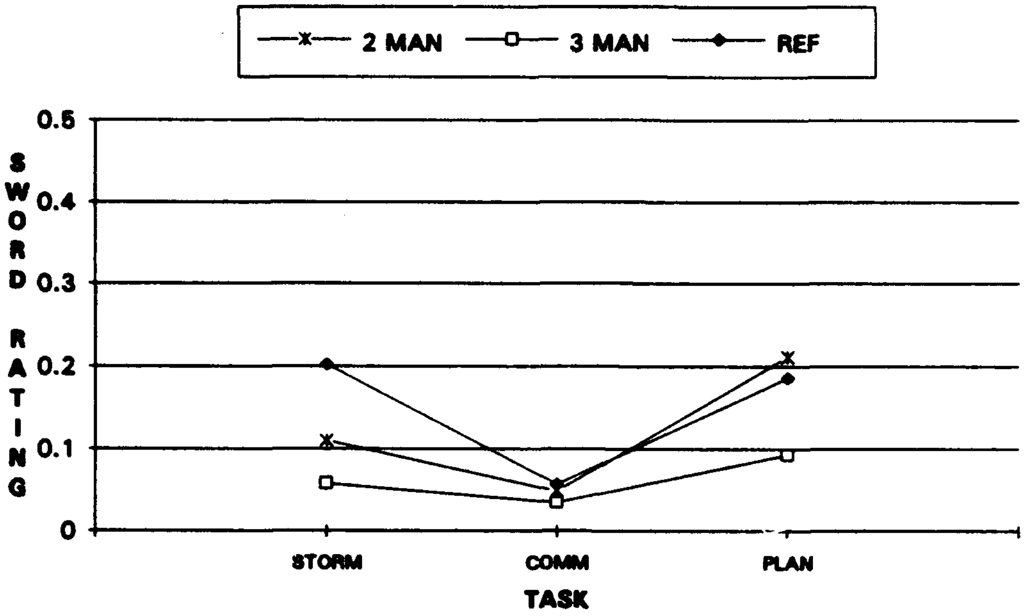


Figure 18. Castle Mission SWORD Ratings for Storm Avoidance

## PROGRAM FINDINGS

Results of the Subjective Workload Assessment Technique (SWAT), the Subjective WORkload Dominance (SWORD) technique, the mission questionnaires, systems 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 Desert mission was seen as the most difficult of the three missions flown.

2. Most crewmembers felt that a minimally qualified crew could have successfully completed the three sample missions flown, given the CSEF system capabilities.

3. Increased workloads were encountered during the inflight replanning, random refueling, navigation and radar tasks. While some of these workloads were outside the desired range, system familiarity, simple modifications to the CDU and Electronic Horizontal Situation Indicator (EHSI) and training on radar use should reduce workload to manageable levels.

## CONCLUSION

The findings of this study support the two-person (No Nav) cockpit, given the necessary modifications. Additionally, crew workload levels were significantly lower in the CSEF conceptual cockpit when compared to the version of the KC-135 currently flown.

The conclusions listed above are based upon using the final design, identical in system capabilities, as developed at the Crew Station Evaluation Facility. The key to the success of this program lies in the utilization of modifications discussed here and the proper implementation of those modifications in future KC-135 cockpits.

## RECOMMENDATIONS

The recommendations mentioned earlier have been separated into three categories in order of priority to aid program engineers in their development of system specifications. They are:

(1) Must Haves - equipment and system capabilities that are substantial workload reducers and deemed essential for mission success. Failure to include these capabilities in the final cockpit design could

result in workload levels that are unmanageable and jeopardize mission success.

(2) Should Haves - equipment and system capabilities that are moderate workload reducers and deemed necessary for mission success. Failure to include these capabilities could increase the potential for mission failure.

(3) Nice to Haves - equipment and system capabilities that, while being workload reducers, would not necessarily jeopardize mission success. However, crew workload may be increased.

The systems capabilities listed below were determined through analyses of both crewmember responses and systems questionnaires (Appendix E). Explanations for the categorization of a particular system capability are included. In addition, many issues were brought up by crewmembers during this study which were not directly covered in this study. These issues are discussed in detail in the Issues to consider section of this report.

**Must Haves**

1. A Mission Management System that provides:

a. Flight Plan database large enough to fly long missions. This database should be large enough to hold all waypoints for the intended route of flight. The current system calls for too many inputs increasing the chance for error and also increasing workload.

b. Mission database that enables crewmembers to identify points and/or routes-of-flight through the use of 3-, 4-, 5-letter ICAO identifiers (TACAN, VOR, airport identifiers), radial and DME points, air refueling tracks, Military Operating Areas (MOAs) and Restricted, Warning and Prohibited Area depictions. This capability would greatly increase situational awareness, lower workload, and ease the burden of inflight replanning. Crewmembers identified the ability to define points using these methods as critical to reducing the workload of inflight replanning.

c. Standard symbols and scrolling procedures across all pages to aid in their understanding and usage.

d. Pictorial representation of the intended rendezvous and orbit to include turn range information. Crews found this capability among the most important for reducing workload following the removal of the navigator. Stated one pilot, "Great feature! Now that I'm spoiled, I don't know how I'll live without it." It was noted that the turn range and offset should be calculated by the on board computer following the entry of receiver true airspeed. One pilot commented that, "If the system knows my speed and the winds, if I tell it the receiver's true airspeed then it should give me turn range and offset."

e. Air-to-Air TACAN and beacon information in order to positively identify the receiver. The ability to get the beacon and both distance and bearing information of the receivers location was deemed necessary to complete the air refueling mission. In addition, the beacon is also useful during formation flying and cell departures. One pilot said, "The beacon is essential during IFR/night formation flight to monitor closure rates and also for station keeping." With the removal of the navigator, this system must be controlled by the pilot team and the CDU provides that capability.

2. Control Display Units with the ability to control and automate many of the functions previously performed by the navigator. The CDUs provided a central location from which numerous on board tasks could be performed. Crews felt that two CDUs were necessary in order to allow each pilot to access the information he/she felt was needed. The labeling and functions of the various keys was deemed completely acceptable, however, some of the CDU page orientation and interaction were critiqued. More user friendliness was requested for the FMS Approach, INS and GPS displays and Flight Plan page interface. Crews felt that with these modifications, workload would have been significantly reduced.

3. A Mission Planning System capable of transferring all necessary database information to the aircraft via a floppy disk or being preloaded into the aircraft computers. During this study, it was assumed that there would be a MPS that would allow crews to mission plan as they do today and then bring the mission information to the aircraft for each flight. This system should be reliable and

highly accurate to prevent possible workload increases.

4. A reliable and accurate navigation system. In the CSEF cockpit design, it was assumed that two INSs and a GPS would replace the navigator. The loss of the GPS combined with the loss of both INSs caused a moderate increase in workload during the Castle mission and a significant workload increase during the Desert mission. This alone indicates the need for a reliable and accurate navigation system. Due to the fact that TACAN and VOR navigation are still available during routine missions, the loss of the INSs and GPS during routine missions is not nearly as critical as losing these systems during a wartime or Desert mission where no TACAN or VOR navigation aids exist.

5 An intercom system that allows each crewmember to tune the volume of each radio individually. Almost every crewmember felt a change to the current intercom system was necessary. By placing the radio control inside the CDU, volume control for the individual radios was then transferred to the individual intercom units. Claimed one pilot, "We've been fighting for this capability for years. With the removal of the navigator, there is also one less set of ears listening. Individual volume controls for each radio and each crewmember would help reduce the number of missed radio transmissions."

6. Color weather radar display that includes:

a. Radar display on the Electronic Horizontal Situation Indicator (EHSI). With the display of weather over a moving map on the EHSI, crewmembers felt that a dedicated radar was not necessary. 93% of the responses received indicated the preferred location for the radar display was on the EHSI. Replied one pilot, "This is the most significant addition to the cockpit. The ability to overlay the route and weather on the EHSI is a dramatic improvement to the current radar which is virtually useless in its present location during periods of extreme brightness."

b. Separate radar control panels for each pilot. 95% of the pilots polled agreed that separate radar controls were essential to mission success. The ability for one pilot to control both radar displays only increases the likelihood for error. One pilot stated that, "Separate radar control panels greatly increased the ability of the crew to monitor separate selections. For example, the pilot flying the airplane can monitor cell lead while the pilot not flying the airplane can monitor the weather."

c. Receiver information must be displayed on the EHSI along with the moving map and weather information. Although previously discussed, the need for both Air-to-Air TACAN information and beacon information cannot be overlooked. "There are times when a receiver leaves his beacon on after air refueling and the only means of identifying subsequent receivers is through the beacon - that information must be on our displays," replied one pilot.

7. An Electronic Horizontal Situation Indicator at both the pilot and copilot stations with the following capabilities:

a. The ability to overlay waypoints, navaids, airports, and weather. Without exception, crewmembers felt the ability to overlay this information on one clear and concise display was one of the keys to reducing workload and enhancing situational awareness. When asked which system capability helped most in the accomplishment of the mission, this capability was listed most often. Said one pilot, "Perhaps the best feature of the whole system. The ability to change scales and zoom in and out kept the big picture perfectly clear." The "big picture" and enhanced situational awareness greatly decreased crew workload.

b. Cross-track, track-angle error, course, distance and time-to-go readouts. Course and distance readouts should be continuous as they are on the current HSI. In addition, full time display of time to go information was deemed necessary for timing purposes following the removal of the navigator. The ability to call up both cross track and track angle error information must be easily accessible, especially during the rendezvous portion of the mission as a back-up to the automatic rendezvous function of the system. The display of this information would significantly reduce workload as it provides the crew with the information most often calculated by the navigator.

c. The ability to display a standard HSI as well as an expanded arc of that HSI (approximately 90 degrees). Both of these functions were deemed necessary for various mission segments. The HSI mode was necessary for approaches and raw data comparisons and the arc mode was seen as essential for cell departure and also Precision Approach Radar (PAR) approaches. Again, pilots stated that this capability gave them a boost in situational awareness as well as a more accurate view of their heading when flying approaches, thereby reducing their overall workload.

d. The ability to display ground speed, true airspeed, drift angle and wind direction and velocity. This information was deemed important for various mission segments. True airspeed is most often used at altitude for cruising flight. Ground speed is used during approach and landing for wind shear calculations and for precision timing in flight. Wind information is used inflight to calculate mission timing needs (used to back up computer system for timing), rendezvous requirements and in Pilot Reports (PIREPS). This information was believed to be very valuable to the crews and resulted in lower workloads.

**Should Haves**

1. A Warning, Caution and Advisory Panel The ability to display aircraft system malfunctions in one central location was seen as very beneficial by the pilots. This was generally seen as a way to reduce workload inside the cockpit that was caused by monitoring many systems with one less person (no navigator). The possibility of making this panel into a multi-function display (MFD) was also discussed in order to present checklist pages and other pertinent information needed during emergencies and malfunctions.

2. A Remote Readout Unit (RRU) with radio and navigation aid frequency change capability. Crewmembers expressed the need for the RRU to have the capability to input radio information by inserting either the ICAO identifier or the frequency. In addition, the unit should be a "smart" system in that it remembers the last tuned frequency and can easily recall it for the crew. Many pilots did, however, comment that the RRU was larger than necessary (see issues to consider).

3. Back up Attitude Direction Indicator. Many pilots felt that the need for back up ADI information was essential especially for night and weather flying. The possibility of moving displays (i.e. moving the pilot's ADI "picture" onto the CRT normally used to display the HSI or moving the co-pilots displays onto the pilots side) was discussed as a possibility as was the possible use of an analog ADI as a back up. Slightly fewer pilots felt that the back up ADI needed to have flight director capability.

4. Engine Indication and Crew Alerting System (EICAS) The ability to display engine information and call malfunctions to the attention of the pilots was seen as being a significant workload reducer, especially in the two person cockpit. In addition, the maintainability of the current gauges was a concern of many crewmembers. This system would allow for the simultaneous display of many engine readings and flag any out of tolerance condition. Said one pilot, "Displaying the gauges graphically on screen for easy reference is a great aid when flying. I use this on the B757/B767 and it's great!"

5. Information Distribution System With the current worldwide use of the tanker, the ability to monitor both intra-cell as well as inter-cell position was seen as essential to mission success especially in a no or minimum communications environment. Every crewmember expressed concern over the tankers lack of tactical information during the recent Persian Gulf conflict. With the removal of the navigator, this information becomes crucial to survival. The display should be clear, concise and display all known friendly and enemy targets.

**Nice to Haves**

1. A dedicated clock at each crew position capable of both count up and count down functions. Timing functions, primarily a navigator function, necessitate the placement of a dedicated clock at each crew position. Pilots stated that a dedicated clock was needed for back up timing during rendezvous as well as during approaches. They felt that with one less crewmember, both pilots needed a dedicated clock for timing requirements.

2. Electronic Attitude Direction Indicator (EADI) display tapes. The current CSEF EADI design incorporates altitude, airspeed, vertical velocity decision height and radar altimeter information onto one screen. Pilots felt that the representation of this information in a pitch tape format would be easier to understand and monitor as compared to the current digital format. While not essential to mission success, this modification was believed to be a necessary change to reduce workload in the cockpit.

**Issues to Consider**

During this study several issues were raised that, while not specifically addressed, require attention for the success of the KC-135 Modernization Program.

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. With the removal of the navigator, pilots felt the autopilot as vital to mission success.

2. Increased Training for Pilots. As previously mentioned, much of the workload encountered by the crews in this study was a caused by a lack of system familiarity or inadequate training in navigator specific tasks. System familiarity and proper training were seen as crucial to the successful removal of the navigator from the KC-135 and also to the success of the KC-135 Cockpit Modernization Program.

3. NVG Compatibility. With the introduction of NVG's in to many mission scenarios, crews expressed concern over the use of cathode ray tubes and other light emitting displays in the modernized cockpit. Future KC-135 cockpit modernization efforts must address these concerns to ensure mission success.

**SUMMARY**

This study was part four of a four-phase effort to demonstrate the feasibility of a two person (no-navigator) conceptual cockpit developed at the Crew Station Evaluation Facility (CSEF). Ten KC-135 crews participated in this study for two weeks each over a four 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). The resulting requirements were then categorized based on mission impact. A summary of these requirements is shown in the following table. In addition, several issues of concern were mentioned. While not specifically covered in this study, they must be addressed in order to ensure the success of the KC-135 Cockpit Modernization Program.

| MUST HAVES | SHOULD HAVES | NICE TO HAVES |
|---|---|---|
| Mission Management System | Warning Caution Advisory Panel | EADI Display Tapes |
| Control Display Units | Back-up ADI System | Dedicated Clocks |
| Mission Planning System | EICAS Display | |
| Reliable Navigation System | Remote Readout Unit | |
| Individual Interphone System | Information Distribution System | |
| Color Weather Radar | | |
| EHSI | | |

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# APPENDIX A

# SWORD RATING FORMS

# MINOT Mission # ☐
# Cruise Segment (1,1)

CREW # ☐

PILOT (1)
COPILOT (2)
Nav (3) ☐

| Task | Absolute | | Very Strong | | Strong | | Weak | | EQUAL | | Weak | | Strong | | Very Strong | | Absolute | Task |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-C-HAA | | | | | | | | | | | | | | | | | | 2-C-Comm |
| 2-C-HAA | | | | | | | | | | | | | | | | | | 2-C-Nav |
| 2-C-HAA | | | | | | | | | | | | | | | | | | REF-HAA |
| 2-C-HAA | | | | | | | | | | | | | | | | | | REF-Comm |
| 2-C-HAA | | | | | | | | | | | | | | | | | | REF-Nav |
| 2-C-HAA | | | | | | | | | | | | | | | | | | 3-C-HAA |
| 2-C-HAA | | | | | | | | | | | | | | | | | | 3-C-Comm |
| 2-C-HAA | | | | | | | | | | | | | | | | | | 3-C-Nav |
| 2-C-Comm | | | | | | | | | | | | | | | | | | 2-C-Nav |
| 2-C-Comm | | | | | | | | | | | | | | | | | | REF-HAA |
| 2-C-Comm | | | | | | | | | | | | | | | | | | REF-Comm |
| 2-C-Comm | | | | | | | | | | | | | | | | | | REF-Nav |
| 2-C-Comm | | | | | | | | | | | | | | | | | | 3-C-HAA |
| 2-C-Comm | | | | | | | | | | | | | | | | | | 3-C-Comm |
| 2-C-Comm | | | | | | | | | | | | | | | | | | 3-C-Nav |
| 2-C-Nav | | | | | | | | | | | | | | | | | | REF-HAA |
| 2-C-Nav | | | | | | | | | | | | | | | | | | REF-Comm |
| 2-C-Nav | | | | | | | | | | | | | | | | | | REF-Nav |
| 2-C-Nav | | | | | | | | | | | | | | | | | | 3-C-HAA |
| 2-C-Nav | | | | | | | | | | | | | | | | | | 3-C-Comm |
| 2-C-Nav | | | | | | | | | | | | | | | | | | 3-C-Nav |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: HAA = Maintain Heading/Altitude/Airspeed
Comm = Communications
Nav = Navigation

| CREW # | |
|---|---|
| | |

# MINOT Mission # ☐
## Cruise Segment (1,1)

| PILOT (1) COPILOT (2) Nav (3) | |
|---|---|
| | |

| | Absolute | | Very Strong | | Strong | | Weak | | EQUAL | | Weak | | Strong | | Very Strong | | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REF-HAA | | | | | | | | | | | | | | | | | | REF-Comm |
| REF-HAA | | | | | | | | | | | | | | | | | | REF-Nav |
| REF-HAA | | | | | | | | | | | | | | | | | | 3-C-HAA |
| REF-HAA | | | | | | | | | | | | | | | | | | 3-C-Comm |
| REF-HAA | | | | | | | | | | | | | | | | | | 3-C-Nav |
| REF-Comm | | | | | | | | | | | | | | | | | | REF-Nav |
| REF-Comm | | | | | | | | | | | | | | | | | | 3-C-HAA |
| REF-Comm | | | | | | | | | | | | | | | | | | 3-C-Comm |
| REF-Comm | | | | | | | | | | | | | | | | | | 3-C-Nav |
| REF-Nav | | | | | | | | | | | | | | | | | | 3-C-HAA |
| REF-Nav | | | | | | | | | | | | | | | | | | 3-C-Comm |
| REF-Nav | | | | | | | | | | | | | | | | | | 3-C-Nav |
| 3-C-HAA | | | | | | | | | | | | | | | | | | 3-C-Comm |
| 3-C-HAA | | | | | | | | | | | | | | | | | | 3-C-Nav |
| 3-C-Comm | | | | | | | | | | | | | | | | | | 3-C-Nav |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: HAA = Maintain Heading/Altitude/Airspeed
Comm = Communications
Nav = Navigation

CREW # [ ]

# MINOT Mission # [ ]
## Air Refueling (1,2)

PILOT (1)
COPILOT (2)
Nav (3) [ ]

| | Absolute | | Very Strong | | Strong | | Weak | | EQUAL | | Weak | | Strong | | Very Strong | | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-C-Fuel | | | | | | | | | | | | | | | | | | 2-C-Comm |
| 2-C-Fuel | | | | | | | | | | | | | | | | | | 2-C-Nav |
| 2-C-Fuel | | | | | | | | | | | | | | | | | | REF-Fuel |
| 2-C-Fuel | | | | | | | | | | | | | | | | | | REF-Comm |
| 2-C-Fuel | | | | | | | | | | | | | | | | | | REF-Nav |
| 2-C-Fuel | | | | | | | | | | | | | | | | | | 3-C-Fuel |
| 2-C-Fuel | | | | | | | | | | | | | | | | | | 3-C-Comm |
| 2-C-Fuel | | | | | | | | | | | | | | | | | | 3-C-Nav |
| 2-C-Comm | | | | | | | | | | | | | | | | | | 2-C-Nav |
| 2-C-Comm | | | | | | | | | | | | | | | | | | REF-Fuel |
| 2-C-Comm | | | | | | | | | | | | | | | | | | REF-Comm |
| 2-C-Comm | | | | | | | | | | | | | | | | | | REF-Nav |
| 2-C-Comm | | | | | | | | | | | | | | | | | | 3-C-Fuel |
| 2-C-Comm | | | | | | | | | | | | | | | | | | 3-C-Comm |
| 2-C-Comm | | | | | | | | | | | | | | | | | | 3-C-Nav |
| 2-C-Nav | | | | | | | | | | | | | | | | | | REF-Fuel |
| 2-C-Nav | | | | | | | | | | | | | | | | | | REF-Comm |
| 2-C-Nav | | | | | | | | | | | | | | | | | | REF-Nav |
| 2-C-Nav | | | | | | | | | | | | | | | | | | 3-C-Fuel |
| 2-C-Nav | | | | | | | | | | | | | | | | | | 3-C-Comm |
| 2-C-Nav | | | | | | | | | | | | | | | | | | 3-C-Nav |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: Fuel = Manage Fuel
Comm = Communications
Nav = Navigation

| CREW # | |
|---|---|
| | |

# MINOT Mission #
# Air Refueling (1,2)

| PILOT (1) COPILOT (2) Nav (3) | |
|---|---|
| | |

| | Absolute | | Very Strong | | Strong | | Weak | | EQUAL | | Weak | | Strong | | Very Strong | | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REF-Fuel | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Comm |
| REF-Fuel | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Nav |
| REF-Fuel | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Fuel |
| REF-Fuel | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Comm |
| REF-Fuel | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Nav |
| REF-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Nav |
| REF-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Fuel |
| REF-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Comm. |
| REF-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Nav |
| REF-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Fuel |
| REF-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Comm |
| REF-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Nav |
| 3-C-Fuel | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Comm |
| 3-C-Fuel | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Nav |
| 3-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Nav |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: Fuel = Manage Fuel
Comm = Communications
Nav = Navigation

CREW #

# MINOT Mission #
## Approach & Landing (1,3)

PILOT (1)
COPILOT (2)
Nav (3)

| | Absolute | Very Strong | Strong | Weak | EQUAL | Weak | Strong | Very Strong | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|
| REF-LOC | | | | | | | | | | REF-Comm |
| REF-LOC | | | | | | | | | | REF-Nav |
| REF-LOC | | | | | | | | | | 3-C-LOC |
| REF-LOC | | | | | | | | | | 3-C-Comm |
| REF-LOC | | | | | | | | | | 3-C-Nav |
| REF-Comm | | | | | | | | | | REF-Nav |
| REF-Comm | | | | | | | | | | 3-C-LOC |
| REF-Comm | | | | | | | | | | 3-C-Comm |
| REF-Comm | | | | | | | | | | 3-C-Nav |
| REF-Nav | | | | | | | | | | 3-C-LOC |
| REF-Nav | | | | | | | | | | 3-C-Comm |
| REF-Nav | | | | | | | | | | 3-C-Nav |
| 3-C-LOC | | | | | | | | | | 3-C-Comm |
| 3-C-LOC | | | | | | | | | | 3-C-Nav |
| 3-C-Comm | | | | | | | | | | 3-C-Nav |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: LOC = Maintatin LOC/GS
Comm = Communications
Nav = Nav igation Aid Set-up

| CREW # | |
|---|---|
| | |

# MINOT Mission #
## Approach & Landing (1,3)

| PILOT (1)<br>COPILOT (2)<br>Nav (3) | |
|---|---|
| | |

| | Absolute | Very Strong | Strong | Weak | EQUAL | Weak | Strong | Very Strong | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2-C-LOC | | | | | | | | | | 2-C-Comm |
| 2-C-LOC | | | | | | | | | | 2-C-Nav |
| 2-C-LOC | | | | | | | | | | REF-LOC |
| 2-C-LOC | | | | | | | | | | REF-Comm |
| 2-C-LOC | | | | | | | | | | REF-Nav |
| 2-C-LOC | | | | | | | | | | 3-C-LOC |
| 2-C-LOC | | | | | | | | | | 3-C-Comm |
| 2-C-LOC | | | | | | | | | | 3-C-Nav |
| 2-C-Comm | | | | | | | | | | 2-C-Nav |
| 2-C-Comm | | | | | | | | | | REF-LOC |
| 2-C-Comm | | | | | | | | | | REF-Comm |
| 2-C-Comm | | | | | | | | | | REF-Nav |
| 2-C-Comm | | | | | | | | | | 3-C-LOC |
| 2-C-Comm | | | | | | | | | | 3-C-Comm |
| 2-C-Comm | | | | | | | | | | 3-C-Nav |
| 2-C-Nav | | | | | | | | | | REF-LOC |
| 2-C-Nav | | | | | | | | | | REF-Comm |
| 2-C-Nav | | | | | | | | | | REF-Nav |
| 2-C-Nav | | | | | | | | | | 3-C-LOC |
| 2-C-Nav | | | | | | | | | | 3-C-Comm |
| 2-C-Nav | | | | | | | | | | 3-C-Nav |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: LOC = Maintain LOC/GS
Comm = Communications
Nav = Navigation Aid Set-up

# CASTLE Mission # ☐

## Cell Departure and Join-up (2,1)

| CREW # | |
|---|---|
| | |

| PILOT (1) COPILOT (2) Nav (3) | |
|---|---|
| | |

| | Absolute | Very Strong | Strong | Weak | EQUAL | Weak | Strong | Very Strong | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2-C-Radar | | | | | | | | | | 2-C-Comm |
| 2-C-Radar | | | | | | | | | | 2-C-Nav |
| 2-C-Radar | | | | | | | | | | REF-Radar |
| 2-C-Radar | | | | | | | | | | REF-Comm |
| 2-C-Radar | | | | | | | | | | REF-Nav |
| 2-C-Radar | | | | | | | | | | 3-C-Radar |
| 2-C-Radar | | | | | | | | | | 3-C-Comm |
| 2-C-Radar | | | | | | | | | | 3-C-Nav |
| 2-C-Comm | | | | | | | | | | 2-C-Nav |
| 2-C-Comm | | | | | | | | | | REF-Radar |
| 2-C-Comm | | | | | | | | | | REF-Comm |
| 2-C-Comm | | | | | | | | | | REF-Nav |
| 2-C-Comm | | | | | | | | | | 3-C-Radar |
| 2-C-Comm | | | | | | | | | | 3-C-Comm |
| 2-C-Comm | | | | | | | | | | 3-C-Nav |
| 2-C-Nav | | | | | | | | | | REF-Radar |
| 2-C-Nav | | | | | | | | | | REF-Comm |
| 2-C-Nav | | | | | | | | | | REF-Nav |
| 2-C-Nav | | | | | | | | | | 3-C-Radar |
| 2-C-Nav | | | | | | | | | | 3-C-Comm |
| 2-C-Nav | | | | | | | | | | 3-C-Nav |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: Radar = Radar Operations
Comm = Communications
Nav = Navigation

CREW #

# CASTLE Mission #
## Cell Departure and Join-up (2,1)

PILOT (1)
COPILOT (2)
Nav (3)

| | Absolute | Very Strong | Strong | Weak | EQUAL | Weak | Strong | Very Strong | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|
| REF-Radar | | | | | | | | | | REF-Comm |
| REF-Radar | | | | | | | | | | REF-Nav |
| REF-Radar | | | | | | | | | | 3-C-Radar |
| REF-Radar | | | | | | | | | | 3-C-Comm |
| REF-Radar | | | | | | | | | | 3-C-Nav |
| REF-Comm | | | | | | | | | | REF-Nav |
| REF-Comm | | | | | | | | | | 3-C-Radar |
| REF-Comm | | | | | | | | | | 3-C-Comm |
| REF-Comm | | | | | | | | | | 3-C-Nav |
| REF-Nav | | | | | | | | | | 3-C-Radar |
| REF-Nav | | | | | | | | | | 3-C-Comm |
| REF-Nav | | | | | | | | | | 3-C-Nav |
| 3-C-Radar | | | | | | | | | | 3-C-Comm |
| 3-C-Radar | | | | | | | | | | 3-C-Nav |
| 3-C-Comm | | | | | | | | | | 3-C-Nav |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: Radar = Radar Operations
Comm = Communications
Nav = Navigation

CREW #

# CASTLE Mission #
# Inflight Replan (2,2)

PILOT (1)
COPILOT (2)
Nav (3)

| | Absolute | | Very Strong | | Strong | | Weak | | EQUAL | | Weak | | Strong | | Very Strong | | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 2-C-Comm |
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 2-C-Plan |
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Nav |
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Comm |
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Plan |
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Nav |
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Comm |
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Plan |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 2-C-Plan |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Nav |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Comm |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Plan |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Nav |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Comm |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Plan |
| 2-C-Plan | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Nav |
| 2-C-Plan | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Comm |
| 2-C-Plan | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Plan |
| 2-C-Plan | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Nav |
| 2-C-Plan | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Comm |
| 2-C-Plan | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Plan |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: Nav = Navigation
Comm = Center Communications/Coordination
Plan = Adjust Flight Plan

CREW #

# CASTLE Mission #
# Inflight Replan (2,2)

PILOT (1)
COPILOT (2)
Nav (3)

| | Absolute | | Very Strong | | Strong | | Weak | | EQUAL | | Weak | | Strong | | Very Strong | | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REF-Nav | | | | | | | | | | | | | | | | | | REF-Comm |
| REF-Nav | | | | | | | | | | | | | | | | | | REF-Plan |
| REF-Nav | | | | | | | | | | | | | | | | | | 3-C-Nav |
| REF-Nav | | | | | | | | | | | | | | | | | | 3-C-Comm |
| REF-Nav | | | | | | | | | | | | | | | | | | 3-C-Plan |
| REF-Comm | | | | | | | | | | | | | | | | | | REF-Plan |
| REF-Comm | | | | | | | | | | | | | | | | | | 3-C-Nav |
| REF-Comm | | | | | | | | | | | | | | | | | | 3-C-Comm |
| REF-Comm | | | | | | | | | | | | | | | | | | 3-C-Plan |
| REF-Plan | | | | | | | | | | | | | | | | | | 3-C-Nav |
| REF-Plan | | | | | | | | | | | | | | | | | | 3-C-Comm |
| REF-Plan | | | | | | | | | | | | | | | | | | 3-C-Plan |
| 3-C-Nav | | | | | | | | | | | | | | | | | | 3-C-Comm |
| 3-C-Nav | | | | | | | | | | | | | | | | | | 3-C-Plan |
| 3-C-Comm | | | | | | | | | | | | | | | | | | 3-C-Plan |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: Nav = Navigation
Comm = Center Communications/Coordination
Plan = Adjust Flight Plan

CREW # [ ]

# CASTLE Mission # [ ]
## Air Refueling (2,3)

PILOT (1)
COPILOT (2)
Nav (3)
[ ]

| | Absolute | Very Strong | Strong | Weak | EQUAL | Weak | Strong | Very Strong | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2-C-Fuel | | | | | | | | | | 2-C-Comm |
| 2-C-Fuel | | | | | | | | | | 2-C-Nav |
| 2-C-Fuel | | | | | | | | | | REF-Fuel |
| 2-C-Fuel | | | | | | | | | | REF-Comm |
| 2-C-Fuel | | | | | | | | | | REF-Nav |
| 2-C-Fuel | | | | | | | | | | 3-C-Fuel |
| 2-C-Fuel | | | | | | | | | | 3-C-Comm |
| 2-C-Fuel | | | | | | | | | | 3-C-Nav |
| 2-C-Comm | | | | | | | | | | 2-C-Nav |
| 2-C-Comm | | | | | | | | | | REF-Fuel |
| 2-C-Comm | | | | | | | | | | REF-Comm |
| 2-C-Comm | | | | | | | | | | REF-Nav |
| 2-C-Comm | | | | | | | | | | 3-C-Fuel |
| 2-C-Comm | | | | | | | | | | 3-C-Comm |
| 2-C-Comm | | | | | | | | | | 3-C-Nav |
| 2-C-Nav | | | | | | | | | | REF-Fuel |
| 2-C-Nav | | | | | | | | | | REF-Comm |
| 2-C-Nav | | | | | | | | | | REF-Nav |
| 2-C-Nav | | | | | | | | | | 3-C-Fuel |
| 2-C-Nav | | | | | | | | | | 3-C-Comm |
| 2-C-Nav | | | | | | | | | | 3-C-Nav |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: Fuel = Manage Fuel
Comm = Communications
Nav = Navigation

| CREW # | |
|---|---|
| | |

# CASTLE Mission # ☐
## Air Refueling (2,3)

| PILOT (1)<br>COPILOT (2)<br>Nav (3) | |
|---|---|
| | |

| | Absolute | | Very Strong | | Strong | | Weak | | EQUAL | | Weak | | Strong | | Very Strong | | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REF-Fuel | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Comm |
| REF-Fuel | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Nav |
| REF-Fuel | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Fuel |
| REF-Fuel | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Comm |
| REF-Fuel | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Nav |
| REF-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Nav |
| REF-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Fuel |
| REF-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Comm |
| REF-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Nav |
| REF-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Fuel |
| REF-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Comm |
| REF-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Nav |
| 3-C-Fuel | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Comm |
| 3-C-Fuel | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Nav |
| 3-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Nav |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: Fuel = Manage Fuel
Comm = Communications
Nav = Navigation

CREW # 

# CASTLE Mission # 
## Weather Avoidance (2,4)

PILOT (1)
COPILOT (2)
Nav (3)

| | Absolute | | Very Strong | | Strong | | Weak | | EQUAL | | Weak | | Strong | | Very Strong | | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-C-Storm | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 2-C-Comm |
| 2-C-Storm | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 2-C-Plan |
| 2-C-Storm | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | REF-Storm |
| 2-C-Storm | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | REF-Comm |
| 2-C-Storm | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | REF-Plan |
| 2-C-Storm | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 3-C-Storm |
| 2-C-Storm | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 3-C-Comm |
| 2-C-Storm | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 3-C-Plan |
| 2-C-Comm | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 2-C-Plan |
| 2-C-Comm | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | REF-Storm |
| 2-C-Comm | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | REF-Comm |
| 2-C-Comm | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | REF-Plan |
| 2-C-Comm | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 3-C-Storm |
| 2-C-Comm | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 3-C-Comm |
| 2-C-Comm | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 3-C-Plan |
| 2-C-Plan | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | REF-Storm |
| 2-C-Plan | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | REF-Comm |
| 2-C-Plan | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | REF-Plan |
| 2-C-Plan | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 3-C-Storm |
| 2-C-Plan | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 3-C-Comm |
| 2-C-Plan | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 3-C-Plan |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: Storm = ID Thunderstorm/Tune Radar
Comm = Center Communications/Coordination
Plan = Adjust Flight Plan

CREW #

# CASTLE Mission #
# Weather Avoidance (2,4)

PILOT (1)
COPILOT (2)
Nav (3)

| | Absolute | Very Strong | Strong | Weak | EQUAL | Weak | Strong | Very Strong | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|
| REF-Storm | | | | | | | | | | REF-Comm |
| REF-Storm | | | | | | | | | | REF-Plan |
| REF-Storm | | | | | | | | | | 3-C-Storm |
| REF-Storm | | | | | | | | | | 3-C-Comm |
| REF-Storm | | | | | | | | | | 3-C-Plan |
| REF-Comm | | | | | | | | | | REF-Plan |
| REF-Comm | | | | | | | | | | 3-C-Storm |
| REF-Comm | | | | | | | | | | 3-C-Comm |
| REF-Comm | | | | | | | | | | 3-C-Plan |
| REF-Plan | | | | | | | | | | 3-C-Storm |
| REF-Plan | | | | | | | | | | 3-C-Comm |
| REF-Plan | | | | | | | | | | 3-C-Plan |
| 3-C-Storm | | | | | | | | | | 3-C-Comm |
| 3-C-Storm | | | | | | | | | | 3-C-Plan |
| 3-C-Comm | | | | | | | | | | 3-C-Plan |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
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TASKS: Storm = ID Thunderstorm/Tune Radar
Comm = Center Communications/Coordination
Plan = Adjust Flight Plan

# DESERT Mission # ☐

# Cell Departure and Join-up (3,1)

CREW # ☐

PILOT (1)
COPILOT (2)
Nav (3)
☐

| | Absolute | | Very Strong | | Strong | | Weak | | EQUAL | | Weak | | Strong | | Very Strong | | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-C-Radar | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 2-C-Comm |
| 2-C-Radar | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 2-C-Nav |
| 2-C-Radar | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Radar |
| 2-C-Radar | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Comm |
| 2-C-Radar | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Nav |
| 2-C-Radar | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Radar |
| 2-C-Radar | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Comm |
| 2-C-Radar | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Nav |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 2-C-Nav |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Radar |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Comm |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Nav |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Radar |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Comm |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Nav |
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Radar |
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Comm |
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Nav |
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Radar |
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Comm |
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Nav |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: Radar = Radar Operations
Comm = Communications
Nav = Navigation

CREW # [ ]

# DESERT Mission # [ ]
## Cell Departure and Join-up (3,1)

PILOT (1)
COPILOT (2)
Nav (3)

| | Absolute | Very Strong | Strong | Weak | EQUAL | Weak | Strong | Very Strong | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|
| REF-Radar | | | | | | | | | | REF-Comm |
| REF-Radar | | | | | | | | | | REF-Nav |
| REF-Radar | | | | | | | | | | 3-C-Radar |
| REF-Radar | | | | | | | | | | 3-C-Comm |
| REF-Radar | | | | | | | | | | 3-C-Nav |
| REF-Comm | | | | | | | | | | REF-Nav |
| REF-Comm | | | | | | | | | | 3-C-Radar |
| REF-Comm | | | | | | | | | | 3-C-Comm |
| REF-Comm | | | | | | | | | | 3-C-Nav |
| REF-Nav | | | | | | | | | | 3-C-Radar |
| REF-Nav | | | | | | | | | | 3-C-Comm |
| REF-Nav | | | | | | | | | | 3-C-Nav |
| 3-C-Radar | | | | | | | | | | 3-C-Comm |
| 3-C-Radar | | | | | | | | | | 3-C-Nav |
| 3-C-Comm | | | | | | | | | | 3-C-Nav |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: Radar = Radar Operations
Comm = Communications
Nav = Navigation

CREW #

# DESERT Mission #
## Inflight Replan (3,2)

PILOT (1)
COPILOT (2)
Nav (3)

| | Absolute | | Very Strong | | Strong | | Weak | | EQUAL | | Weak | | Strong | | Very Strong | | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 2-C-Comm |
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 2-C-Plan |
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Nav |
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Comm |
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Plan |
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Nav |
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Comm |
| 2-C-Nav | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Plan |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 2-C-Plan |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Nav |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Comm |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Plan |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Nav |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Comm |
| 2-C-Comm | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Plan |
| 2-C-Plan | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Nav |
| 2-C-Plan | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Comm |
| 2-C-Plan | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-Plan |
| 2-C-Plan | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Nav |
| 2-C-Plan | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Comm |
| 2-C-Plan | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-Plan |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: Nav = Navigation
Comm = Center Communications/Coordination
Plan = Adjust Flight Plan

CREW # 

# DESERT Mission # 
## Inflight Replan (3,2)

PILOT (1)
COPILOT (2)
Nav (3)

| | Absolute | Very Strong | Strong | Weak | EQUAL | Weak | Strong | Very Strong | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|
| REF-Nav | | | | | | | | | | REF-Comm |
| REF-Nav | | | | | | | | | | REF-Plan |
| REF-Nav | | | | | | | | | | 3-C-Nav |
| REF-Nav | | | | | | | | | | 3-C-Comm |
| REF-Nav | | | | | | | | | | 3-C-Plan |
| REF-Comm | | | | | | | | | | REF-Plan |
| REF-Comm | | | | | | | | | | 3-C-Nav |
| REF-Comm | | | | | | | | | | 3-C-Comm |
| REF-Comm | | | | | | | | | | 3-C-Plan |
| REF-Plan | | | | | | | | | | 3-C-Nav |
| REF-Plan | | | | | | | | | | 3-C-Comm |
| REF-Plan | | | | | | | | | | 3-C-Plan |
| 3-C-Nav | | | | | | | | | | 3-C-Comm |
| 3-C-Nav | | | | | | | | | | 3-C-Plan |
| 3-C-Comm | | | | | | | | | | 3-C-Plan |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: Nav = Navigation
Comm = Center Communications/Coordination
Plan = Adjust Flight Plan

# DESERT Mission # ☐
# Air Refueling (3,3)

CREW # ☐

PILOT (1)
COPILOT (2)
Nav (3) ☐

| | Absolute | Very Strong | Strong | Weak | EQUAL | Weak | Strong | Very Strong | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2-C-Fuel | | | | | | | | | | 2-C-Comm |
| 2-C-Fuel | | | | | | | | | | 2-C-Nav |
| 2-C-Fuel | | | | | | | | | | REF-Fuel |
| 2-C-Fuel | | | | | | | | | | REF-Comm |
| 2-C-Fuel | | | | | | | | | | REF-Nav |
| 2-C-Fuel | | | | | | | | | | 3-C-Fuel |
| 2-C-Fuel | | | | | | | | | | 3-C-Comm |
| 2-C-Fuel | | | | | | | | | | 3-C-Nav |
| 2-C-Comm | | | | | | | | | | 2-C-Nav |
| 2-C-Comm | | | | | | | | | | REF-Fuel |
| 2-C-Comm | | | | | | | | | | REF-Comm |
| 2-C-Comm | | | | | | | | | | REF-Nav |
| 2-C-Comm | | | | | | | | | | 3-C-Fuel |
| 2-C-Comm | | | | | | | | | | 3-C-Comm |
| 2-C-Comm | | | | | | | | | | 3-C-Nav |
| 2-C-Nav | | | | | | | | | | REF-Fuel |
| 2-C-Nav | | | | | | | | | | REF-Comm |
| 2-C-Nav | | | | | | | | | | REF-Nav |
| 2-C-Nav | | | | | | | | | | 3-C-Fuel |
| 2-C-Nav | | | | | | | | | | 3-C-Comm |
| 2-C-Nav | | | | | | | | | | 3-C-Nav |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: Fuel = Manage Fuel
Comm = Communications
Nav = Navigation

CREW #

# DESERT Mission #
## Air Refueling (3,3)

PILOT (1)
COPILOT (2)
Nav (3)

| | Absolute | Very Strong | Strong | Weak | EQUAL | Weak | Strong | Very Strong | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|
| REF-Fuel | | | | | | | | | | REF-Comm |
| REF-Fuel | | | | | | | | | | REF-Nav |
| REF-Fuel | | | | | | | | | | 3-C-Fuel |
| REF-Fuel | | | | | | | | | | 3-C-Comm |
| REF-Fuel | | | | | | | | | | 3-C-Nav |
| REF-Comm | | | | | | | | | | REF-Nav |
| REF-Comm | | | | | | | | | | 3-C-Fuel |
| REF-Comm | | | | | | | | | | 3-C-Comm |
| REF-Comm | | | | | | | | | | 3-C-Nav |
| REF-Nav | | | | | | | | | | 3-C-Fuel |
| REF-Nav | | | | | | | | | | 3-C-Comm |
| REF-Nav | | | | | | | | | | 3-C-Nav |
| 3-C-Fuel | | | | | | | | | | 3-C-Comm |
| 3-C-Fuel | | | | | | | | | | 3-C-Nav |
| 3-C-Comm | | | | | | | | | | 3-C-Nav |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: Fuel = Manage Fuel
Comm = Communications
Nav = Navigation

CREW #

# DESERT Mission #
# INS Update (3,4)

PILOT (1)
COPILOT (2)
Nav (3)

| | Absolute | Very Strong | Strong | Weak | EQUAL | Weak | Strong | Very Strong | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2-C-HAA | | | | | | | | | | 2-C-Radar |
| 2-C-HAA | | | | | | | | | | 2-C-Nav |
| 2-C-HAA | | | | | | | | | | REF-HAA |
| 2-C-HAA | | | | | | | | | | REF-Radar |
| 2-C-HAA | | | | | | | | | | REF-Nav |
| 2-C-HAA | | | | | | | | | | 3-C-HAA |
| 2-C-HAA | | | | | | | | | | 3-C-Radar |
| 2-C-HAA | | | | | | | | | | 3-C-Nav |
| 2-C-Radar | | | | | | | | | | 2-C-Nav |
| 2-C-Radar | | | | | | | | | | REF-HAA |
| 2-C-Radar | | | | | | | | | | REF-Radar |
| 2-C-Radar | | | | | | | | | | REF-Nav |
| 2-C-Radar | | | | | | | | | | 3-C-HAA |
| 2-C-Radar | | | | | | | | | | 3-C-Radar |
| 2-C-Radar | | | | | | | | | | 3-C-Nav |
| 2-C-Nav | | | | | | | | | | REF-HAA |
| 2-C-Nav | | | | | | | | | | REF-Radar |
| 2-C-Nav | | | | | | | | | | REF-Nav |
| 2-C-Nav | | | | | | | | | | 3-C-HAA |
| 2-C-Nav | | | | | | | | | | 3-C-Radar |
| 2-C-Nav | | | | | | | | | | 3-C-Nav |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: HAA = Maintain Heading, Altitude, Airspeed
Radar = Radar Operation
Nav = Navigation

CREW #

# DESERT Mission #
# INS Update (3-4)

PILOT (1)
COPILOT (2)
Nav (3)

| | Absolute | Very Strong | Strong | Weak | EQUAL | Weak | Strong | Very Strong | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|
| REF-HAA | | | | | | | | | | REF-Radar |
| REF-HAA | | | | | | | | | | REF-Nav |
| REF-HAA | | | | | | | | | | 3-C-HAA |
| REF-HAA | | | | | | | | | | 3-C-Radar |
| REF-HAA | | | | | | | | | | 3-C-Nav |
| REF-Radar | | | | | | | | | | REF-Nav |
| REF-Radar | | | | | | | | | | 3-C-HAA |
| REF-Radar | | | | | | | | | | 3-C-Radar |
| REF-Radar | | | | | | | | | | 3-C-Nav |
| REF-Nav | | | | | | | | | | 3-C-HAA |
| REF-Nav | | | | | | | | | | 3-C-Radar |
| REF-Nav | | | | | | | | | | 3-C-Nav |
| 3-C-HAA | | | | | | | | | | 3-C-Radar |
| 3-C-HAA | | | | | | | | | | 3-C-Nav |
| 3-C-Radar | | | | | | | | | | 3-C-Nav |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

TASKS: HAA = Maintain Heading, Altitude, Airspeed
Radar - Radar Operation
Nav = Navigation

| CREW # | |
|---|---|
| | |

# ALL Missions
# Overall Workload

| PILOT (1) COPILOT (2) Nav (3) | |
|---|---|
| | |

| | Absolute | Very Strong | Strong | Weak | EQUAL | Weak | Strong | Very Strong | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2-C MINOT | | | | | | | | | | 3-C MINOT |
| 2-C MINOT | | | | | | | | | | REF MINOT |
| 2-C MINOT | | | | | | | | | | 2-C CASTLE |
| 2-C MINOT | | | | | | | | | | 3-C CASTLE |
| 2-C MINOT | | | | | | | | | | REF CASTLE |
| 2-C MINOT | | | | | | | | | | 2-C DESERT |
| 2-C MINOT | | | | | | | | | | 3-C DESERT |
| 2-C MINOT | | | | | | | | | | REF DESERT |
| 3-C MINOT | | | | | | | | | | REF MINOT |
| 3-C MINOT | | | | | | | | | | 2-C CASTLE |
| 3-C MINOT | | | | | | | | | | 3-C CASTLE |
| 3-C MINOT | | | | | | | | | | REF CASTLE |
| 3-C MINOT | | | | | | | | | | 2-C DESERT |
| 3-C MINOT | | | | | | | | | | 3-C DESERT |
| 3-C MINOT | | | | | | | | | | REF DESERT |
| REF MINOT | | | | | | | | | | 2-C CASTLE |
| REF MINOT | | | | | | | | | | 3-C CASTLE |
| REF MINOT | | | | | | | | | | REF CASTLE |
| REF MINOT | | | | | | | | | | 2-C DESERT |
| REF MINOT | | | | | | | | | | 3-C DESERT |
| REF MINOT | | | | | | | | | | REF DESERT |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

MISSIONS: MINOT
CASTLE
DESERT

| CREW # | |
|---|---|
| | |

# ALL Missions
# Overall Workload

| PILOT (1) COPILOT (2) Nav (3) | |
|---|---|
| | |

| | Absolute | | Very Strong | | Strong | | Weak | | EQUAL | | Weak | | Strong | | Very Strong | | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-C CASTLE | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C CASTLE |
| 2-C CASTLE | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-CASTLE |
| 2-C CASTLE | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 2-C-DESERT |
| 2-C CASTLE | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-DESERT |
| 2-C CASTLE | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-DESERT |
| 3-C CASTLE | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-CASTLE |
| 3-C CASTLE | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 2-C-DESERT |
| 3-C CASTLE | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-DESERT |
| 3-C CASTLE | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-DESERT |
| REF-CASTLE | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 2-C-DESERT |
| REF-CASTLE | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-DESERT |
| REF-CASTLE | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-DESERT |
| 2-C-DESERT | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | 3-C-DESERT |
| 2-C-DESERT | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-DESERT |
| 3-C-DESERT | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | ___ | REF-DESERT |

AIRCRAFT: 2-C= 2 PERSON CREW KC-135 SIM
3-C= 2 PERSON CREW KC-135 SIM
REF = ACTUAL KC-135

NISSIONS: MINOT
CASTLE
DESERT

| CREW # | |
|---|---|
| | |

# ALL Missions
# Overall Workload

| PILOT (1) COPILOT (2) Nav (3) | |
|---|---|
| | |

| | Absolute | Very Strong | Strong | Weak | EQUAL | Weak | Strong | Very Strong | Absolute | |
|---|---|---|---|---|---|---|---|---|---|---|
| SIM-Minot | | | | | | | | | | SIM-Castle |
| SIM-Minot | | | | | | | | | | SIM-Desert |
| SIM-Minot | | | | | | | | | | REF-Minot |
| SIM-Minot | | | | | | | | | | REF-Castle |
| SIM-Minot | | | | | | | | | | REF-Desert |
| SIM-Castle | | | | | | | | | | SIM-Desert |
| SIM-Castle | | | | | | | | | | REF-Minot |
| SIM-Castle | | | | | | | | | | REF-Castle |
| SIM-Castle | | | | | | | | | | REF-Desert |
| SIM-Desert | | | | | | | | | | REF-Minot |
| SIM-Desert | | | | | | | | | | REF-Castle |
| SIM-Desert | | | | | | | | | | REF-Desert |
| REF-Minot | | | | | | | | | | REF-Castle |
| REF-Minot | | | | | | | | | | REF-Desert |
| REF-Castle | | | | | | | | | | REF-Desert |

AIRCRAFT: SIM = Simulated KC-135
REF = Actual KC-135

MISSIONS: MINOT
CASTLE
DESERT

# APPENDIX B

# PERSONAL DATA QUESTIONNAIRE

## PERSONAL DATA QUESTIONNAIRE

**CREW # ____**
**CREW POSITION____**

**Name (Optional):**________________________________________

**Grade:** O-1 O-2 O-3 O-4 O-5 0-6

**Age:**____

**Aeronautical Rating:** Pilot / Nav Senior Pilot / Senior Nav Master Pilot / Master Nav

**Crew Position:** Nav IN CP P/AC IP

**Organization:**________________________________________

**Duty Station:**________________________________________

**Total Flying Hours:**____________________________________

**Total KC-135 Flying Hours:**______________________________

**Total Hours Current Crew Position:**________________________

**Time Since Last Flight:**________ **Months** ________**Days**

**KC-135 Aircraft Model Currently Flying:**________

**Total Hours using Electronic Flight Instruments:**________

# APPENDIX C

# MINOT MISSION QUESTIONNAIRE

CREW #____
CREW POSITION____

# Minot Mission

# Questionnaire

This questionnaire is a mission specific questionnaire concerning the various events and actions undergone during the last mission. You should answer the questionnaire from your own individual 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. However, do not feel you must comment on every question. 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 late takeoff caused (a) _______ increase in mission difficulty/aircrew workload.**

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

**Comments:** ________________________________________

________________________________________

________________________________________

________________________________________

2. **Were you able to identify your receiver on radar prior to your turn inbound to the ARIP?**

    **a. Yes    b. No**

**Comments:** ________________________________________

________________________________________

________________________________________

________________________________________

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

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

**Comments:** ________________________________________

________________________________________

________________________________________

________________________________________

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

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

**Comments:** ________________________________________

________________________________________

________________________________________

________________________________________

**5. The hydraulic failure caused (a) _______ increase in mission difficulty/aircrew workload.**

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

Comments: ________________________________________

________________________________________

________________________________________

________________________________________

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

Comments: ________________________________________

________________________________________

________________________________________

________________________________________

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

a. Yes b. No

Comments: ________________________________________

________________________________________

________________________________________

________________________________________

**8. Which pieces of equipment and/or design functions were particularly helpful in accomplishing this mission?** (Please explain in comment sections)

Comments: ________________________________________

________________________________________

________________________________________

________________________________________

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

Comments: ____________________________________________

____________________________________________

____________________________________________

____________________________________________

**10. Please recommend any improvements to the current equipment design/interface that you feel would improve aircrew efficiency and reduce aircrew workload?**

Comments: ____________________________________________

____________________________________________

____________________________________________

____________________________________________

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

a. Easy b. Medium c. Hard

**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

Comments: ____________________________________________

____________________________________________

____________________________________________

____________________________________________

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

a. Yes b. No

**Comments:** ________________________________________

________________________________________

________________________________________

________________________________________

**14. Given the mission just flown, could a single pilot (i.e., one pilot is incapacitated) have performed this mission?**

a. Yes b. No

**Comments:** ________________________________________

________________________________________

________________________________________

**15. 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.**

________________________________________

________________________________________

________________________________________

________________________________________

________________________________________

________________________________________

________________________________________

________________________________________

# APPENDIX D

# CASTLE MISSION QUESTIONNAIRE

CREW # ____
CREW POSITION ____

# Castle Mission

# Questionnaire

This questionnaire is a mission specific questionnaire concerning the various events and actions undergone during the last mission. You should answer the questionnaire from your own individual 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. However, do not feel you must comment on every question. 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 #3

1. **The autopilot failure caused (a) _____ increase in mission difficulty/aircrew workload.**

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

**Comments:** ________________________________________

________________________________________

________________________________________

________________________________________

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

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

**Comments:** ________________________________________

________________________________________

________________________________________

________________________________________

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

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

**Comments:** ________________________________________

________________________________________

________________________________________

________________________________________

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

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

**Comments:** ________________________________________

________________________________________

________________________________________

________________________________________

**5. Prior to GPS failure, did you detect your INSs were drifting?** (Please explain when and how you detected your INSs were drifting in the Comments section).

a. Yes b. No

Comments: ____________________________________________

____________________________________________

____________________________________________

____________________________________________

**6. The failure of the GPS system caused (a) _______ increase in mission difficulty/aircrew workload.**

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

Comments: ____________________________________________

____________________________________________

____________________________________________

____________________________________________

**7. The failure of both INS systems caused (a) _______ increase in mission difficulty/aircrew workload.**

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

Comments: ____________________________________________

____________________________________________

____________________________________________

____________________________________________

**8. The weather divert to Beale AFB caused (a) _______ increase in mission difficulty/aircrew workload.**

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

Comments: ____________________________________________

____________________________________________

____________________________________________

____________________________________________

**9. The ability to call up individual air refueling tracks/military operating areas caused (a) _________ decrease in aircrew workload.**

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

**Comments:** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

**10. The ability to fly to an airport/IAF by the insertion of the airport/IAF identifier during a weather divert caused (a) ______ decrease in aircrew workload.**

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

**Comments:** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

**11. The increased volume of radio traffic and radio frequency changes caused (a)________ increase in mission difficulty/aircrew workload.**

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

**Comments:** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

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

**Comments:** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

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

a. Yes b. No

**Comments:** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

**14. Which pieces of equipment and/or design functions were particularly helpful in accomplishing this mission? (Please explain in comment sections)**

**Comments:** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

**15. Which pieces of equipment and/or design functions were extremely hard to use and, consequently, caused a high workload? (Please explain in comments section)**

**Comments:** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

**16. Please recommend any improvements to the current equipment design/interface that you feel would improve aircrew efficiency and reduce aircrew workload?**

**Comments:** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

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

a. Easy b. Medium c. Hard

**18. 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

Comments: ________________________________________

________________________________________

________________________________________

________________________________________

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

a. Yes b. No

Comments: ________________________________________

________________________________________

________________________________________

**20. Given the mission just flown, could a single pilot (i.e., one pilot is incapacitated) have performed this mission?**

a. Yes b. No

Comments: ________________________________________

________________________________________

________________________________________

**21. The following space is provided for you to elaborate on questions 1-20 or for you to identify any other concerns that you might have.**

# APPENDIX E

# DESERT MISSION QUESTIONNAIRE

CREW # ____
CREW POSITION ____

# Desert Mission Questionnaire

This questionnaire is a mission specific questionnaire concerning the various events and actions undergone during the last mission. You should answer the questionnaire from your own individual 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. However, do not feel you must comment on every question. 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 #5

**1. The Autopilot failure caused (a) _____ increase in mission difficulty/aircrew workload?**

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

**Comments:** ____________________________________________

____________________________________________

____________________________________________

____________________________________________

**2. The GPS failure caused (a) _________ increase in mission difficulty/aircrew workload?**

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

**Comments:** ____________________________________________

____________________________________________

____________________________________________

____________________________________________

**3. The INS update using the ground map radar caused (a) _______ increase in mission difficulty/aircrew workload.**

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

**Comments:** ____________________________________________

____________________________________________

____________________________________________

____________________________________________

**4. The visual depiction of a point parallel rendezvous on the EHSI caused (a) _______ decrease in mission difficulty/aircrew workload.**

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

Comments: ____________________________________________

____________________________________________

____________________________________________

**5. The AR Track change and the additional refuelings caused (a) _______ increase in mission difficulty/aircrew workload.**

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

**Comments:** ____________________________________________

____________________________________________

____________________________________________

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

Comments: ____________________________________________

____________________________________________

____________________________________________

____________________________________________

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

a. Yes b. No

Comments: ____________________________________________

____________________________________________

____________________________________________

____________________________________________

**8. Which pieces of equipment and/or design functions were particularly helpful in accomplishing this mission?** (Please explain in comment sections)

Comments: ____________________________________________

____________________________________________

____________________________________________

____________________________________________

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

**Comments:** ____________________________________________

____________________________________________

____________________________________________

____________________________________________

**10. Please recommend any improvements to the current equipment design/interface that you feel would improve aircrew efficiency and reduce aircrew workload?**

Comments: ____________________________________________

____________________________________________

____________________________________________

____________________________________________

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

a. Easy     b. Medium     c. Hard

**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

Comments: ____________________________________________

____________________________________________

____________________________________________

____________________________________________

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

a. Yes b. No

**Comments:** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

**14. Given the mission just flown, could a single pilot (i.e., one pilot is incapacitated) have performed this mission?**

a. Yes b. No

**Comments:** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

**15. Based on your experience, was this mission similar to the type of mission flown in the Middle East theatre?**

**(DO NOT INCLUDE ANY CLASSIFIED MATERIAL IN YOUR ANSWER)**

a. Yes b. No

**Comments:** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

**16. 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.**

# APPENDIX F

# SYSTEMS QUESTIONNAIRE

# Analog Flight Instruments

1. (P/C/N) Please answer Yes (Y) or No (N) to the following questions for each of the analog flight instruments (those that are currently in the KC-135) listed below.
**Please comment on all "No" answers.**

Size: Is the size of the instrument adequate for the application?
Number: Are there enough of the instruments (as backups) in the cockpit?
Location: Is the location of the instrument adequate?
Necessity: Is the the instrument necessary or critical?

Pilot / Copilot

| Instrument | Size | Number | Location | Necessity |
|---|---|---|---|---|
| Attitude Director Indicator (ADI) | ______ | ______ | ______ | ______ |
| Horizontal Situation Indicator (HSI) | ______ | ______ | ______ | ______ |
| Altimeter | ______ | ______ | ______ | ______ |
| Angle of Attack (AOA) Indicator | ______ | ______ | ______ | ______ |
| Clock | ______ | ______ | ______ | ______ |
| Indicated Airspeed (IAS) | ______ | ______ | ______ | ______ |
| Mach Indicator | ______ | ______ | ______ | ______ |
| Radio Altimeter | ______ | ______ | ______ | ______ |
| Radio Magnetic Indicator (RMI) | ______ | ______ | ______ | ______ |
| Vertical Velocity Indicator (VVI) | ______ | ______ | ______ | ______ |
| Free-Air Temperature Gauge | ______ | ______ | ______ | ______ |
| Radar Scope | ______ | ______ | ______ | ______ |

**Navigator**

| Instrument | Size | Number | Location | Necessity |
|---|---|---|---|---|
| N-1 Master Compass | | | | |
| Altimeter | | | | |
| Clock | | | | |
| True Airspeed (TAS) | | | | |
| Radio Magnetic Indicator (RMI) | | | | |
| Free-Air Temperature Gauge | | | | |
| Radar Scope | | | | |

**Comments:**

1. (P/C) Should the backup ADI have flight direction capability?

Yes No

Comments:___

___

___

___

2. (P/C) Would a digital clock adequately replace the analog clock in a 2-man crew?

Yes No

3. (P/C/N) Would a digital clock adequately replace the analog clock in a 3-man crew?

Yes No

4. (P/C) Is a chronograph (count up) function needed in a 2-man crew?

Yes No

5. (P/C/N) Is a chronograph (count up) function needed in a 3-man crew?

Yes No

6. (P/C) Is a timer (count down ) function needed in a 2-man crew?

Yes No

7. (P/C/N) Is a timer (count down ) function needed in a 3-man crew?

Yes No

Comments (QUESTIONS 2 - 7): ___

___

___

8. (P/C) Should the Mach and Indicated Airspeed instruments be combined?

Yes No

Comments:___

___

___

**9. (N) Based on your experience, the reliability of the current altimeter display at the Nav station is ________.**

**a. Completely unacceptable**
**b. Moderately unacceptable**
**c. Slightly unacceptable**
**d. Borderline**
**e. Slightly acceptable**
**f. Moderately acceptable**
**g. Completely acceptable**

**10. (N)** The Navigator's Altimeter in the conceptual cockpit ___ mission difficulty/aircrew workload.

**a. Substantially decreased**
**b. Moderately decreased**
**c. Slightly decreased**
**d. Did not increase or decrease**
**e. Slightly increased**
**f. Moderately increased**
**g. Substantially increased**

**Comments (Questions 9 & 10):**________________________________

____________________________________________________________

____________________________________________________________

____________________________

# Digital Warning Caution Advisory (WCA) Display

**11. (P/C/N) The size of the Warning Caution Advisory (WCA) display was __________, considering its possible application.**

**Too small    About right    Too large**

**Comments:** ________________________________________

________________________________________

________________________________________

________________________________________

**12. (P/C/N) The location (between the pilot and copilot CDUs) of the display was ____________. (Please explain below.)**

**a. Completely unacceptable**
**b. Moderately unacceptable**
**c. Slightly unacceptable**
**d. Borderline**
**e. Slightly acceptable**
**f. Moderately acceptable**
**g. Completely acceptable**

**Comments:** ________________________________________

________________________________________

________________________________________

________________________________________

**13. (P/C/N) What specific warnings, cautions, and/or advisories would you like to see on this display?**

**Comments:** ________________________________________

________________________________________

________________________________________

________________________________________

________________________________________

________________________________________

________________________________________

**14. (P/C/N) What warnings, cautions, and/or advisories would you prefer not be displayed?**

**Comments:**________________________________________

**15. (P/C/N) Was the Master Caution light effective?**

**Yes No**

**Comments:**________________________________________

**16. (P/C/N) The implementation of the Warning, Caution, Advisory display and Master Caution light _ mission difficulty/aircrew workload.**

- **a. Substantially decreased**
- **b. Moderately decreased**
- **c. Slightly decreased**
- **d. Did not increase or decrease**
- **e. Slightly increased**
- **f. Moderately increased**
- **g. Substantially increased**

**Comments :**________________________________________

**17. (P/C/N) Would you prefer a multiple-sensory WCA message system?**

- **a. No, light only.**
- **b. Yes, light and tone.**
- **c. Yes, light and voice.**
- **d. Yes, light , tone, and voice.**

**Comments:**________________________________________

**18. (P/C/N)** **Digital Engine Displays (not used in the conceptual cockpit) have the capability to change color, alerting the crew to an out-of-tolerance condition. They can also integrate WCA information with the instruments. Do you feel digitally displayed engine instruments are necessary for the KC-135?**

**Yes No**

**Comments:**______________________________________________________

**19. (P/C/N)** The implementation of Digital Engine Displays would ____ mission difficulty/aircrew workload.

a. **Substantially decrease**
b. **Moderately decrease**
c. **Slightly decrease**
d. **not increase or decrease**
e. **Slightly increase**
f. **Moderately increase**
g. **Substantially increase**

**Comments :**______________________________________________________

# Mission Management System Operation

This section will address the Control Display Unit (CDU) and operating procedures associated with the functions of the Mission Management System (MMS). All crewmembers should answer all of the questions in this section.

20. The location of the CDU for optimal use of the Mission Management System (MMS) was ________? (Consider the CDU that was located at your crew station only)

a. Completely unacceptable
b. Moderately unacceptable
c. Slightly unacceptable
d. Borderline
e. Slightly acceptable
f. Moderately acceptable
g. Completely acceptable

Comments:________________________________________

________________________________________

________________________________________

________________________________________

21. Were any of the CDU pages cluttered?

Yes No (If yes, please list below.)

Comments:________________________________________

________________________________________

________________________________________

________________________________________

**22. In general, the CDU and the functions that are integrated with it (the mission management system) ______ mission difficulty/aircrew workload.**

**a. Substantially decreased**
**b. Moderately decreased**
**c. Slightly decreased**
**d. Did not increase or decrease**
**e. Slightly increased**
**f. Moderately increased**
**g. Substantially increased**

**Comments:**______________________________________________

_______________________________________________________

_______________________________________________________

**23. Were the symbol conventions (e.g., colons, arrows, etc.) easy to use and understand?**

**Yes No (If no, please explain below.)**

**Comments:**______________________________________________

_______________________________________________________

_______________________________________________________

_______________________________________________________

**24. The ________ should be used when slewing between display pages within a Function (i.e. TOLD, POWER, & INAV).**

**a. Up/Down arrow keys b. Right/Left arrow keys**

**Comments:**______________________________________________

_______________________________________________________

_______________________________________________________

**25. The ________ should be used when slewing between Functions. (i.e. POWER, START).**

**a. Up/Down arrow keys b. Right/Left arrow keys**

**Comments:** ________________________________________

________________________________________

________________________________________

________________________________________

**26. The flight plan loading, modification, and correction options were __________. (Please explain below.)**

**a. Completely unacceptable**
**b. Moderately unacceptable**
**c. Slightly unacceptable**
**d. Borderline**
**e. Slightly acceptable**
**f. Moderately acceptable**
**g. Completely acceptable**

**Comments:** ________________________________________

________________________________________

________________________________________

________________________________________

**27. (P/C/N) The flight plan loading, modification and correction implementation __________ mission difficulty/aircrew workload.**

**a. Substantially decreased**
**b. Moderately decreased**
**c. Slightly decreased**
**d. Did not increase or decrease**
**e. Slightly increased**
**f. Moderately increased**
**g. Substantially increased**

**Comments:** ________________________________________

________________________________________

________________________________________

________________________________________

**28.** (P/C/N) The Direct-To implementation ___________ mission difficulty/aircrew workload.

a. Substantially decreased
b. Moderately decreased
c. Slightly decreased
d. Did not increase or decrease
e. Slightly increased
f. Moderately increased
g. Substantially increased

Comments:_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

**29.** The INS "OVERFLY" update capability of this system was __________.

a. Completely unacceptable
b. Moderately unacceptable
c. Slightly unacceptable
d. Borderline
e. Slightly acceptable
f. Moderately acceptable
g. Completely acceptable

(Please explain what you liked or disliked about this capability below.)

Comments:_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

**30.** The INS "OVERFLY" update capability ___________ mission difficulty/aircrew workload.

a. Substantially decreased
b. Moderately decreased
c. Slightly decreased
d. Did not increase or decrease
e. Slightly increased
f. Moderately increased
g. Substantially increased

Comments:_______________________________________________

_______________________________________________

_______________________________________________

31. The INS "TACAN" update capability of this system was _____.

a. Completely unacceptable
b. Moderately unacceptable
c. Slightly unacceptable
d. Borderline
e. Slightly acceptable
f. Moderately acceptable
g. Completely acceptable

(Please explain what you liked or disliked about this capability below.)

Comments:______________________________________________

______________________________________________

______________________________________________

______________________________________________

32. The INS "TACAN" update capability ___________ mission difficulty/aircrew workload.

a. Substantially decreased
b. Moderately decreased
c. Slightly decreased
d. Did not increase or decrease
e. Slightly increased
f. Moderately increased
g. Substantially increased

Comments:______________________________________________

______________________________________________

______________________________________________

______________________________________________

33. The INS "RADAR" update capability of this system was _____.

a. Completely unacceptable
b. Moderately unacceptable
c. Slightly unacceptable
d. Borderline
e. Slightly acceptable
f. Moderately acceptable
g. Completely acceptable

(Please explain what you liked or disliked about this capability below.)

Comments:______________________________________________

34. The INS "RADAR" update capability __________ mission difficulty/aircrew workload.

a. Substantially decreased
b. Moderately decreased
c. Slightly decreased
d. Did not increase or decrease
e. Slightly increased
f. Moderately increased
g. Substantially increased

Comments:

35. Was the holding/orbit pattern set-up capability beneficial for the 2-man crew?

Yes No

36. Was the holding/orbit pattern set-up capability beneficial for the 3-man crew?

Yes No

37. The holding/orbit pattern set-up capability ___________ mission difficulty/aircrew workload.

a. Substantially decreased
b. Moderately decreased
c. Slightly decreased
d. Did not increase or decrease
e. Slightly increased
f. Moderately increased
g. Substantially increased

Comments (Questions 35-37): ________________________________________

________________________________________

________________________________________

________________________________________

38. Was the Rendezvous (Point Parallel) set-up capability beneficial for the 2-man crew?

Yes No

39. Was the Rendezvous (Point Parallel) set-up capability beneficial for the 3-man crew?

Yes No

40. The implementation of the Rendezvous (Point Parallel) capability ___________ mission difficulty/aircrew workload.

a. Substantially decreased
b. Moderately decreased
c. Slightly decreased
d. Did not increase or decrease
e. Slightly increased
f. Moderately increased
g. Substantially increased

Comments (Questions 38-40): ________________________________________

________________________________________

________________________________________

________________________________________

41. Was the Intercept set-up capability beneficial for the 2-man crew?

Yes No

42. Was the Intercept set-up capability beneficial for the 3-man crew?

Yes No

43. The implementation of the Intercept capability __________ mission difficulty/Aircrew workload.

a. Substantially decreased
b. Moderately decreased
c. Slightly decreased
d. Did not increase or decrease
e. Slightly increased
f. Moderately increased
g. Substantially increased

Comments (41-43): ________________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

44. The operational utility of the Flight Management System (FMS) Approach used in this simulator __________ mission difficulty/aircrew workload?

a. Substantially decreased
b. Moderately decreased
c. Slightly decreased
d. Did not increase or decrease
e. Slightly increased
f. Moderately increased
g. Substantially increased

Comments : ________________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

**45. Were the set-up procedures of the Flight Management System Approach understandable and easy to use?**

**Yes No (If no, please explain below.)**

**Comments :**________________________________________

**46. Were the avionics system Power Pages (under Index (IDX)) understandable and easy to use?**

**Yes No (If no, please explain below.)**

**Comments :**

**47. Were the Start Pages (under Index (IDX)) understandable and easy to use?**

**Yes No (If no, please explain below.)**

**Comments :**

**48. Were the Index (IDX) Pages understandable and easy to use? (includes mission loading page, TOLD pages, Wt & Bal, Clock & Timers, lock & zeroize. START and POWER are addressed elsewhere)**

**Yes No (If no, please explain below.)**

**Comments :**

49. Were the Communication (COM) Pages understandable and easy to use?

Yes No (If no, please explain below.)

Comments : ____________________________________________

____________________________________________

____________________________________________

____________________________________________

50. Were the Navigation (NAV) Pages understandable and easy to use?

Yes No (If no, please explain below.)

Comments : ____________________________________________

____________________________________________

____________________________________________

____________________________________________

51. Were the IFF Pages understandable and easy to use?

Yes No (If no, please explain below.)

Comments : ____________________________________________

____________________________________________

____________________________________________

____________________________________________

52. Were the Integrated Navigation Solution (INAV) Pages understandable and easy to use?

Yes No (If no, please explain below.)

Comments : ____________________________________________

____________________________________________

____________________________________________

____________________________________________

**53. Were the Flightplan (FPLN) Pages understandable and easy to use?**

**Yes No (If no, please explain below.)**

**Comments :**________________________________________

**54. Was the Direct To (DIR) Page understandable and easy to use?**

**Yes No (If no, please explain below.)**

**Comments :**________________________________________

# Weather Radar System

**55. The location of the radar control panels (between the pilot and copilot and under the nav's Display control panel) were ___________.**

- **a. Completely unacceptable**
- **b. Moderately unacceptable**
- **c. Slightly unacceptable**
- **d. Borderline**
- **e. Slightly acceptable**
- **f. Moderately acceptable**
- **g. Completely acceptable**

Comments :___________________________________________

___________________________________________

___________________________________________

___________________________________________

**56. The implementation of and inclusion of two separate radar control panels with a selection switch to select the active control panel was ___________.**

- **a. Completely unacceptable**
- **b. Moderately unacceptable**
- **c. Slightly unacceptable**
- **d. Borderline**
- **e. Slightly acceptable**
- **f. Moderately acceptable**
- **g. Completely acceptable**

Comments :___________________________________________

___________________________________________

___________________________________________

___________________________________________

**57. Should the RADAR range control also control the range on the EHSI display or should the EHSI display have a separate range control? If so, which EHSI display ranges should the radar control be tied to (Pilot, Copilot or Nav)?**

**Yes No**

Comments :___________________________________________

___________________________________________

**58. Are the various Radar ranges provided adequate for mission accomplishment?**

**YES NO**

**If NO, what ranges would be preferred, and Why?**

**Comments :**________________________________________

**59. Are there any functions not included on the radar control panel that you feel would effectively reduce mission difficulty/aircrew workload for a 2-man crew?**

**Yes No**

**60. Are there any functions not included on the radar control panel that you feel would effectively reduce mission difficulty/aircrew workload for a 3-man crew?**

**Yes No**

**Comments for questions 5 & 6:**________________________________

**61. The implementation of color weather radar ____ mission difficulty/aircrew workload.**

- **a. Substantially decreased**
- **b. Moderately decreased**
- **c. Slightly decreased**
- **d. Did not increase or decrease**
- **e. Slightly increased**
- **f. Moderately increased**
- **g. Substantially increased**

**Comments :**________________________________________

**62. Should a separate, dedicated display be installed for the radar return presentation for a 2-man crew?**

**Yes No**

**Comments :**____________________________________________________________

**63. Should a separate, dedicated display be installed for the radar return presentation for a 3-man crew?**

**Yes No**

**Comments :**____________________________________________________________

**64. Do you feel the need for a weather radar as necessary for mission accomplishment with a 2-man crew?**

**Yes No**

**65. Do you feel the need for a weather radar as necessary for mission accomplishment with a 3-man crew?**

**Yes No**

**66. Would a monochrome radar presentation be adequate?**

**Yes No**

**Comments questions 7 -9:**__________________________________________________

**67. Do you feel the need still exists for the APN-69 with a 2-man crew?**

**Yes No Why?**

**68. Do you feel the need still exists for the APN-69 with a 3-man crew?**

**Yes No Why?**

**Comments :**____________________________________________________________

**69.** Do you prefer the Mission Management System (MMS) procedure or the current APN-69 code selectors for setting the beacon code?

a. MMS  b. APN-69

Comments : ____________________

____________________

____________________

____________________

**70.** Do you feel the Air-to-Air TACAN capability alone would be sufficient to perform an air refueling rendezvous with a 2-man crew?

Yes  No  Why?

**71.** Do you feel the Air-to-Air TACAN capability alone would be sufficient to perform an air refueling rendezvous with a 3-man crew?

Yes  No  Why?

Comments : ____________________

____________________

____________________

**72.** Do you feel the Beacon capability is necessary for mission accomplishment with a 2-man crew?

Yes  No  Why?

**73.** Do you feel the Beacon capability is necessary for mission accomplishment with a 3-man crew?

Yes  No  Why?

Comments : ____________________

____________________

____________________

**74.** Do you feel the radar Skinpaint capability is necessary for mission accomplishment with a 2-man crew?

Yes  No  Why?

**75. Do you feel the radar Skinpaint capability is necessary for mission accomplishment with a 3-man crew?**

**Yes No Why?**

**Comments :**________________________________________

________________________________________________

________________________________________________

________________________________________________

**76. Do you feel the ground map radar is necessary for mission accomplishment with a 2-man crew?**

**Yes No Why?**

**77. Do you feel the ground map radar is necessary for mission accomplishment with a 3-man crew?**

**Yes No Why?**

**Comments :**________________________________________

________________________________________________

________________________________________________

________________________________________________

# Electronic Attitude Director Indicator (EADI)

**78. The pitch scale is configured to display approximately 25$^{o}$ of pitch at any given time as opposed to approximately 55$^{o}$ in the FD-109 currently used in the KC-135. The scaling of the EADI was ___________.**

- **a. Completely unacceptable**
- **b. Moderately unacceptable**
- **c. Slightly unacceptable**
- **d. Borderline**
- **e. Slightly acceptable**
- **f. Moderately acceptable**
- **g. Completely acceptable**

Comments: ________________________________________

________________________________________________

________________________________________________

________________________________________________

**79. The bank scaling tic marks at the 45$^{o}$, 60$^{o}$ and 135$^{o}$ positions were ___________.**

- **a. Completely unacceptable**
- **b. Moderately unacceptable**
- **c. Slightly unacceptable**
- **d. Borderline**
- **e. Slightly acceptable**
- **f. Moderately acceptable**
- **g. Completely acceptable**

Comments: ________________________________________

________________________________________________

________________________________________________

________________________________________________

**80.** Pitch scale numbering on only one end of the scale lines was ___________. (Please explain below.)

a. **Completely unacceptable**
b. **Moderately unacceptable**
c. **Slightly unacceptable**
d. **Borderline**
e. **Slightly acceptable**
f. **Moderately acceptable**
g. **Completely acceptable**

Comments: ______________________________________________

______________________________________________

______________________________________________

______________________________________________

**81.** The dashed line positioned at the -3° position on the pitch scale to aid in glideslope/path control on precision approaches was ___________.

a. **Helpful during all segments of the approach**
b. **Helpful only on final approach**
c. **Useful only on precision approaches**
d. **Not useful**

Comments: ______________________________________________

______________________________________________

______________________________________________

______________________________________________

**82.** The radar altimeter information display located in the bottom right hand corner of the EADI was ___________.

a. **Completely unacceptable**
b. **Moderately unacceptable**
c. **Slightly unacceptable**
d. **Borderline**
e. **Slightly acceptable**
f. **Moderately acceptable**
g. **Completely acceptable**

83. The Decision Height information display located below the radar altimeter information in the bottom right hand corner of the EADI was ___________.

a. Completely unacceptable
b. Moderately unacceptable
c. Slightly unacceptable
d. Borderline
e. Slightly acceptable
f. Moderately acceptable
g. Completely acceptable

84. The airspeed information display located in the upper left hand corner of the EADI was ___________.

a. Completely unacceptable
b. Moderately unacceptable
c. Slightly unacceptable
d. Borderline
e. Slightly acceptable
f. Moderately acceptable
g. Completely acceptable

85. The altimeter information display located in the upper right hand corner of the EADI was ___________.

a. Completely unacceptable
b. Moderately unacceptable
c. Slightly unacceptable
d. Borderline
e. Slightly acceptable
f. Moderately acceptable
g. Completely acceptable

86. The VVI information display located in the upper right hand corner of the EADI was ___________.

a. Completely unacceptable
b. Moderately unacceptable
c. Slightly unacceptable
d. Borderline
e. Slightly acceptable
f. Moderately acceptable
g. Completely acceptable

87. The AOA information display located in the upper left hand corner of the EADI was ___________.

a. Completely unacceptable
b. Moderately unacceptable
c. Slightly unacceptable
d. Borderline
e. Slightly acceptable
f. Moderately acceptable
g. Completely acceptable

**88.** Having the information discussed in questions 83-87 above displayed on the EADI _____ mission difficulty/aircrew workload.

a. Substantially decreased
b. Moderately decreased
c. Slightly decreased
d. Did not increase or decrease
e. Slightly increased
f. Moderately increased
g. Substantially increased

Comments: ________________________________________________

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________________________________________________

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**89.** Identify any specific changes you might have concerning the EADI:

Comments: ________________________________________________

________________________________________________

________________________________________________

________________________________________________

________________________________________________

# Electronic Horizontal Situation Indicator (EHSI)

**90. The location of the EHSI display control panel (overhead for pilot & copilot, left of EHSI display for navigator) was ___________ for inflight use?**

- **a. Completely unacceptable**
- **b. Moderately unacceptable**
- **c. Slightly unacceptable**
- **d. Borderline**
- **e. Slightly acceptable**
- **f. Moderately acceptable**
- **g. Completely acceptable**

Comments :______________________________________________

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**91. The readability of the pilot & copilot EHSI display control panel nomenclature was ________.**

- **a. Completely unacceptable**
- **b. Moderately unacceptable**
- **c. Slightly unacceptable**
- **d. Borderline**
- **e. Slightly acceptable**
- **f. Moderately acceptable**
- **g. Completely acceptable**

Comments :______________________________________________

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92. The readability of the navigator EHSI display control panel nomenclature was ________.

a. Completely unacceptable
b. Moderately unacceptable
c. Slightly unacceptable
d. Borderline
e. Slightly acceptable
f. Moderately acceptable
g. Completely acceptable

Comments : ________________________________________

________________________________________

________________________________________

________________________________________

93. The ability to overlay Waypoints on the EHSI map display ___________ mission difficulty/aircrew workload?

a. Substantially decreased
b. Moderately decreased
c. Slightly decreased
d. Did not increase or decrease
e. Slightly increased
f. Moderately increased
g. Substantially increased

Comments : ________________________________________

________________________________________

________________________________________

________________________________________

94. The ability to overlay Navaids (TACANs/VORs) on the EHSI map display ___________ mission difficulty/aircrew workload?

a. Substantially decreased
b. Moderately decreased
c. Slightly decreased
d. Did not increase or decrease
e. Slightly increased
f. Moderately increased
g. Substantially increased

Comments : ________________________________________

________________________________________

**95. The ability to overlay airports on the EHSI map display __________ mission difficulty/aircrew workload?**

a. **Substantially decreased**
b. **Moderately decreased**
c. **Slightly decreased**
d. **Did not increase or decrease**
e. **Slightly increased**
f. **Moderately increased**
g. **Substantially increased**

**Comments :** ________________________________________

________________________________________

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________________________________________

**96. The ability to overlay Radar returns (weather, ground map, skinpaint, and beacon) on the EHSI map display __________ mission difficulty/aircrew workload?**

a. **Substantially decreased**
b. **Moderately decreased**
c. **Slightly decreased**
d. **Did not increase or decrease**
e. **Slightly increased**
f. **Moderately increased**
g. **Substantially increased**

**Comments :** ________________________________________

________________________________________

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________________________________________

**97.** The ability to overlay Range Lines on the EHSI map display __________ mission difficulty/aircrew workload?

a. Substantially decreased
b. Moderately decreased
c. Slightly decreased
d. Did not increase or decrease
e. Slightly increased
f. Moderately increased
g. Substantially increased

Comments : ____________________________________________

____________________________________________

____________________________________________

____________________________________________

**98.** Do you feel the capability to display either a full compass rose or an arc segment ($80^{\circ}$) individually on the EHSI is necessary?

Yes No

Comments : ____________________________________________

____________________________________________

____________________________________________

____________________________________________

**99.** Do you feel the capability to display either an HSI format or a MAP format individually on the EHSI is necessary?

Yes No

Comments : ____________________________________________

____________________________________________

____________________________________________

____________________________________________

**100.** Do you feel the capability to display the currently tuned radio aids on the EHSI MAP format display, regardless of the position of the NAVAIDs overlay button, as beneficial?

Yes No

Comments : ____________________

____________________

____________________

**101.** Do you feel that the NAVAIDs which are used to identify Waypoints in the Flight Plan should appear with the Waypoints overlay?

Yes No

Comments : ____________________

____________________

____________________

**102.** The implementation of the Primary and Secondary Course Arrows and Transfer Function ____________ mission difficulty/aircrew workload.

a. Substantially decreased
b. Moderately decreased
c. Slightly decreased
d. Did not increase or decrease
e. Slightly increased
f. Moderately increased
g. Substantially increased

Comments: ____________________

____________________

____________________

____________________

**103.** Do you feel that having 1 Course Arrow is sufficient with a 2-man crew?

Yes No

3-man crew? Yes No

Comments : ____________________

____________________

**104.** Do you feel that the Course Arrows should be declutterable on the HSI Format?

Yes No

on the MAP Format?

Yes No

Comments : ______________________________________________

______________________________________________

**105.** Do you feel that having 1 Bearing Pointers is sufficient?

2-man crew? Yes No

3-man crew? Yes No

Comments : ______________________________________________

______________________________________________

______________________________________________

**106.** Do you feel that the Bearing Pointers should be declutterable on the HSI Format?

Yes No

on the MAP Format?

Yes No

Comments : ______________________________________________

______________________________________________

______________________________________________

**107.** Were the ranges available for the EHSI display sufficient?

Yes No Why?

Comments : ______________________________________________

______________________________________________

______________________________________________

**108. Was the NAV DATA displayed in the lower right corner helpful? Which information was not? Any information that should be added?**

**Yes No Why?**

**Comments :**________________________________________

______________________________________________

______________________________________________

**109. The level of workload required to monitor fuel flow and fuel quantity information was ____________.**

a. Extremely difficult
b. Moderately difficult
c. Slightly difficult
d. Borderline
e. Slightly easy
f. Moderately easy
g. Extremely easy

**Comments:** ______________________________________________

______________________________________________________

______________________________________________________

______________________________________________________

# Remote Display Unit (RDU)

**110. Would an RDU which displays command airspeed and altitude as a digital readout be useful?**

**YES NO**

**Comments:** ______________________________

______________________________

______________________________

______________________________

# Remote Radio Unit (RRU)

111. The operational utility of the RRU was _________.

a. **Completely unacceptable**
b. **Moderately unacceptable**
c. **Slightly unacceptable**
d. **Borderline**
e. **Slightly acceptable**
f. **Moderately acceptable**
g. **Completely acceptable**

Comments: ____________________________________________

____________________________________________

____________________________________________

____________________________________________

112. The location of the RRU was ___________.

a. **Completely unacceptable**
b. **Moderately unacceptable**
c. **Slightly unacceptable**
d. **Borderline**
e. **Slightly acceptable**
f. **Moderately acceptable**
g. **Completely acceptable**

Comments: ____________________________________________

____________________________________________

____________________________________________

____________________________________________

113. The information displayed on the RRU was __________.

a. Completely unacceptable
b. Moderately unacceptable
c. Slightly unacceptable
d. Borderline
e. Slightly acceptable
f. Moderately acceptable
g. Completely acceptable

Comments: ______________________________________________

______________________________________________

______________________________________________

______________________________________________

114. The implementation of the Remote Readout Units for changing and referencing Communication frequencies, Navigation frequencies; and for the navigator the TACAN channel and IFF Mode 3A code _____ mission difficulty/aircrew workload.

a. Substantially decreased
b. Moderately decreased
c. Slightly decreased
d. Did not increase or decrease
e. Slightly increased
f. Moderately increased
g. Substantially increased

Comments: ______________________________________________

______________________________________________

______________________________________________

______________________________________________