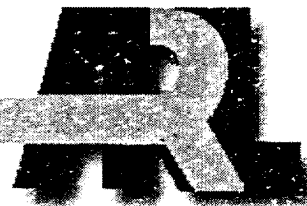


ARMY RESEARCH LABORATORY



Assessment of Crew Workload for the RAH-66 Comanche Force Development Experiment 1

David B. Durbin

ARL-TN-183

OCTOBER 2001

20011105 014

Nintendo® is a registered trademark of Nintendo of America.

Polhemus™ is a trademark of Rockwell Collins.

ProView 50™ is a trademark of Kaiser Electro-Optics, Inc.

The findings in this report are not to be construed as an official Department of the Army position
unless so designated by other authorized documents.

Citation of manufacturer's or trade names does not constitute an official endorsement or approval of
the use thereof.

Destroy this report when it is no longer needed. Do not return it to the originator.

Army Research Laboratory

Aberdeen Proving Ground, MD 21005-5425

ARL-TN-183

October 2001

Assessment of Crew Workload for the RAH-66 Comanche Force Development Experiment 1

David B. Durbin
Human Research & Engineering Directorate

Approved for public release; distribution is unlimited.

Abstract

Crew workload was assessed during the RAH-66 Comanche Force Development Experiment (FDE) 1. The purpose was to determine if (a) the pilots experienced tolerable and comparable workload levels when flying the aircraft versus operating the mission equipment package (MEP), and (b) workload levels contribute to a need to "battle roster" Comanche pilots. Workload data were collected via the Bedford Workload Rating Scale and a cockpit controls and displays usability questionnaire.

Results of the assessment indicate that (a) workload was tolerable for the pilots, (b) workload was moderately higher for the pilots when they operated the MEP, and (c) there is no compelling need to prescribe battle rostering because pilots experienced only moderate differences in workload when they flew the aircraft versus when they operated the MEP.

Contents

Executive Summary	1
1. Introduction	3
1.1 Purpsoe and Overview	3
1.2 Assessment of Crew Workload	3
1.3 FDE 1 Experimental Procedure	4
1.4 System Description	5
2. Method	8
2.1 Participants	8
2.2 Data Collection	9
2.3 Data Analysis	9
2.4 Limitations of Workload Assessment	10
3. Results	10
3.1 Workload When Pilots Performed Crew Member Tasks	10
3.2 Spare Workload Capacity When Pilots Performed Crew Member Tasks	10
3.3 Comparative Workload Levels Between Front Seat and Back Seat	13
3.4 Pilot Responses to Controls and Displays Usability Questionnaire	13
3.5 HMD Symbology	13
4. Summary	14
4.1 Cockpit Workload	14
4.2 Battle Rostering of Comanche Pilots	15
5. Recommendations	15
References	17
Appendices	
A. FDE 1 Crew Member Tasks	19
B. Bedford Workload Rating Scale	23
C. Summary of Pilot Responses About the Usability Characteristics of the Crew Station Controls and Displays	27
D. Collective, Side Arm Controller, and Right Armrest Switches	39
E. Summary of Pilot Responses to Bedford Workload Rating Scale	43
Distribution List	51
Report Documentation Page	57

Figures

1. CPC Cockpit	6
2. Kaiser ProView 50™	8

Tables

1. Phases of Force Development Experiment 1	5
2. Demographic Characteristics of Pilots	8
3. Summary of Workload Ratings	11
4. Impact of Usability Characteristics of Cockpit Controls and Displays on Workload	12

Executive Summary

An assessment of crew workload was conducted during the RAH-66 Comanche Force Development Experiment (FDE) 1. Workload data were collected via the Bedford Workload Rating Scale and a cockpit controls and displays usability questionnaire. The data were analyzed to determine if the pilot flying the aircraft (pilot on controls) and the pilot operating the mission equipment package (MEP) experienced tolerable and comparable workload levels when performing 35 crew member tasks (see Appendix A). The data were also analyzed to determine whether workload levels contribute to a need to "battle roster"¹ Comanche pilots.

Results indicate that

- Workload was tolerable for the pilots when they performed 33 of the 35 crew member tasks.
- Workload was moderately higher for pilots when they operated the MEP.
- There is no compelling need to prescribe battle rostering for Comanche pilots because (a) workload levels were tolerable when they performed all but one crew member task, and (b) differences in workload levels between the pilot flying the aircraft and the pilot operating the MEP were moderate.

¹Battle rostering is defined as "the designation of two or more individuals to routinely perform as a crew" (Headquarters, Department of the Army, 1995).

INTENTIONALLY LEFT BLANK

ASSESSMENT OF CREW WORKLOAD FOR THE RAH-66 COMANCHE FORCE DEVELOPMENT EXPERIMENT 1

1. Introduction

1.1 Purpose and Overview

The RAH-66 Comanche Force Development Experiment (FDE) 1 was conducted from June 6 to 29 2000 with two Comanche portable cockpit (CPC) devices at the Air Maneuver Battle Laboratory, Fort Rucker, Alabama. It was the first of six Force Development Test and Experimentation (FDTE) events that are scheduled to occur from Fiscal Year (FY) 2000 through FY 2006. The purpose of FDE 1 was to assess whether (a) the Comanche pilot and crew procedures are viable for reconnaissance, security, and attack missions in a variety of tactical scenarios; (b) workload levels are evenly and appropriately distributed among crew members; and (c) crew workload levels contribute to a need to "battle roster"² Comanche pilots.

The Training and Doctrine Command (TRADOC) System Manager – Comanche (TSM-C) was the sponsor for FDE 1. The TSM-C requested the Human Research and Engineering Directorate of the U.S. Army Research Laboratory (ARL) to assess crew workload during FDE 1. ARL collected crew workload data via the Bedford Workload Rating Scale (see Appendix B) and a cockpit controls and displays usability questionnaire (Appendix C). The data were analyzed to determine if the pilot flying the aircraft (pilot on controls) and the pilot operating the mission equipment package (MEP) experienced tolerable and comparable workload levels when they performed 35 crew member tasks (see Appendix A). Additionally, ARL assessed whether workload levels contribute to a need to battle roster Comanche pilots.

1.2 Assessment of Crew Workload

A common definition of pilot workload is "the integrated mental and physical effort required to satisfy the perceived demands of a specified flight task" (Roscoe, 1985). It is important to assess pilot workload because mission accomplishment is related to the mental and physical ability of the crew to effectively perform their flight and mission tasks. If one or both pilots experience high workload while performing flight and mission tasks, the tasks may be performed ineffectively or may be abandoned. In order to assess whether cockpit workload is evenly and appropriately distributed in the Comanche, the level of workload for each pilot must be evaluated.

²Battle rostering is defined as "the designation of two or more individuals to routinely perform as a crew" (Headquarters, Department of the Army, 1995).

1.2.1 Bedford Workload Rating Scale

The Bedford Workload Rating Scale has been used extensively by the military, civil, and commercial aviation communities for pilot workload estimation (Roscoe & Ellis, 1990). It requires pilots to rate the level of workload associated with a task, based on the amount of spare capacity they feel they have to perform additional tasks. Spare workload capacity is an important commodity for pilots because they are often required to perform several tasks concurrently. For example, pilots often perform navigational tasks, monitor radios, and assist the pilot on controls with flight tasks (e.g., maintain air space surveillance) within the same time interval. Mission performance is reduced if pilots are task saturated and have little or no spare capacity to perform other tasks. Design of the Comanche pilot-vehicle interface should help ensure that pilots can maintain adequate spare workload capacity for flight and mission tasks.

1.2.2 Battle Rostering

Battle rostering is believed to improve aircrew workload management by enhancing crew coordination. This is because of increased familiarization and confidence between pilots who routinely train together. If workload levels for Comanche pilots are consistently high or are disproportionately distributed, battle rostering may help them manage their workload more effectively. However, a study by the Army Research Institute (Grubb, Simon, Leedom, & Zeller, 1995) has questioned the benefits of battle rostering. The study identified potential drawbacks, including crew overconfidence, increased use of informal and non-standard procedures, and increased reliance on implicit coordination rather than on explicit coordination behavior between pilots.

1.3 FDE 1 Experimental Procedure

Pilots received 4 weeks of intensive training before the FDE. The training consisted of classroom instruction and "hands-on" flight experience in the CPCs. The pilots flew the same missions (e.g., route reconnaissance) during training that they later flew during the FDE. The mission scenario was based on battlefield environments simulating those depicted in the Comanche operational mode summary and mission profile. The scenario was conducted in four phases (see Table 1). Each successive phase increased in difficulty in order to challenge crew workload. The pilots performed specific planning and in-flight tasks (see Appendix A) during each mission. Each task had prescribed conditions and standards that both crew members had to perform to help ensure mission accomplishment.

Pilots were systematically rotated throughout the missions so that every pilot flew equally often with each of the other pilots. For all missions, the pilot flying the aircraft was assigned to the front seat, and the pilot operating the MEP was assigned to the back seat. Pilots alternated between the front seat and back seat

positions during each phase. A total of 30 missions was conducted during the FDE.

Table 1. Phases of Force Development Experiment 1

Phase	Mission description	Mission objectives
1	Conduct route reconnaissance Conduct point reconnaissance (bridges) Fly to holding area	Navigation, basic mission equipment manipulation, and aircraft control. Arrive at holding area undetected.
2	Conduct route reconnaissance Conduct area reconnaissance Provide security (screen) Engage enemy with artillery	Navigation, advanced mission equipment manipulation, digital communications, call for fire
3	Conduct security operations (screen) Conduct deep reconnaissance Attack theater ballistic missiles React to mission change React to changes in weather	All the above, react to mission changes, and execute procedures for inadvertent entry into instrument meteorological conditions
4 ^a	Conduct zone reconnaissance React to mission change React to changes in weather	All the above

^aNOTE: Crews were battle rostered

1.4 System Description

1.4.1 Comanche Portable Cockpit (CPC)

The CPC (see Figure 1) consists of two (non-motion) cockpits arranged in a tandem configuration and mounted in a transport trailer. The front and rear cockpits are identical, allowing each pilot to perform all crew member tasks. The CPC contains the hardware, MEP, and software that simulate the controls, flight characteristics, and functionality of the Comanche aircraft. The primary cockpit controls and displays are the system management display (SMD), tactical situation display (TSD), cockpit interactive keyboard (CIK), side arm controller (SAC), collective, and the Kaiser ProView 50™ head-mounted display (HMD).

Two CPCs were used during FDE 1. They were programmed with the latest version of flight and mission software in January 2000. The major differences between the CPCs that were used for the FDE and the Comanche aircraft are

- The Kaiser ProView 50™ HMD was used in lieu of the Helmet Integrated Display and Sighting Subsystem (HIDSS). The HIDSS is being developed and will be the production HMD used by Comanche pilots.
- The cockpit geometry of the CPCs was similar but not identical to that of the Comanche aircraft.
- CPCs were not equipped with a motion system.

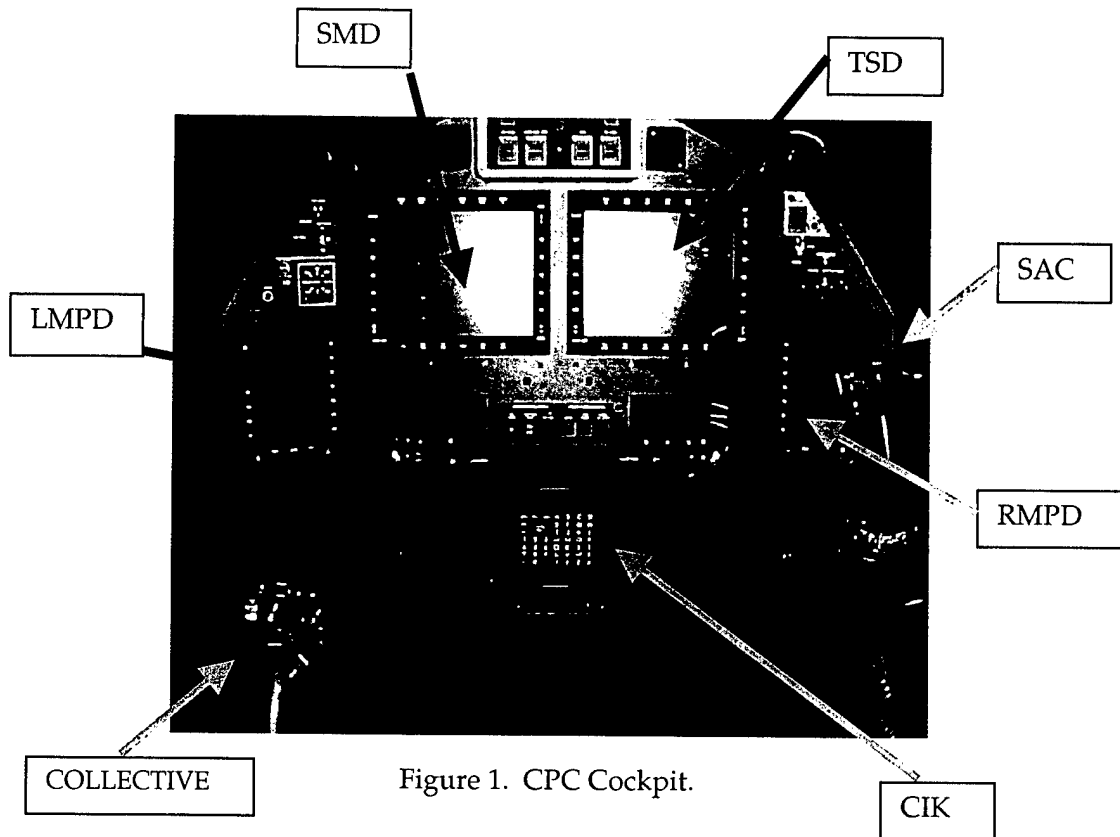


Figure 1. CPC Cockpit.

1.4.2 System Management Display (SMD) and Tactical Situation Display (TSD)

The SMD is a multi-function color display. In one mode, it provides sensor imagery from the target acquisition system (TAS). In other modes, it provides aircraft subsystem control and status information. The TSD is also a multi-function display. It provides a color map and navigational information, including the location of threat and friendly forces. The SMD and TSD each have a bezel incorporating 12 dedicated switches (called mode select keys) in two horizontal rows above and below each of the displays. The six mode select keys on the upper bezel of the SMD are used to select communication functions, while the six mode select keys on the lower bezel allow selection of the main menu of the SMD or aircraft and mission subsystems. The six mode select keys on the upper row of the TSD bezel are used to select HMD functions. The six mode

select keys on the lower TSD bezel allow manipulation of map modes and display characteristics. Switches in the corners of the bezels are used to adjust screen brightness, symbol brightness, and contrast. There are 10 switches in two vertical rows on the right and left of the SMD and TSD. The function and use of these keys vary, depending on the system or subsystem being viewed.

1.4.3 Left and Right Multipurpose Displays (MPDs)

The left MPD (LMPD) is located outboard of the SMD, and the right MPD (RMPD) is located outboard of the TSD. The lower segment of the LMPD contains line address keys, and the upper segment presents the status of selections made from the tactical interactive annunciator panel. The lower segment of the RMPD provides selective monitoring of vehicle subsystems and displays the current settings (frequency, channel preset, transmitter, and ciphony) of the communication radios. The upper segment of the RMPD screen provides information about the operational status and modes of the weapon system and mission equipment.

1.4.4 Collective and Sidearm Controller (SAC)

The collective is located to the left of the crew member's seat, and the SAC is located on the right armrest. The SAC allows pilots to control the pitch, roll, and yaw of the aircraft. It also allows 10% authority vertical input. The collective permits full authority vertical input. Both the collective and SAC grips contain switches that allow hands-on control of critical flight and mission functions. The right armrest also contains switches that control mission functions. The collective, SAC, and right armrest switches are listed in Appendix D.

1.4.5 Cockpit Interactive Keyboard (CIK)

The CIK enables crew members to enter data into the computer system. The data include radio frequencies, coordinates, targets, and text messages.

1.4.6 Helmet-Mounted Display (HMD)

The Kaiser ProView 50™ (see Figure 2) was the HMD used by pilots during FDE 1. It had two liquid crystal displays with 28° (V) by 49° (H) field of view (FOV) (25% binocular overlap), 1024 by 768 resolution, inter-pupillary distance adjustment, eye relief adjustment, adjustable headband and strap, an electronic control unit, and a Polhemus™ head-tracking sensor. The weight of the HMD was 1.3 pounds. The HMD displayed monochrome symbology overlaid on the synthetic visual scene. When used in the night vision pilotage system (NVPS) mode, the HMD displayed the forward-looking infrared (FLIR) scene overlaid by the monochrome symbology. The HMD also displayed an image intensification (I²) scene overlaid by the monochrome symbology. Pilots selected which scene (FLIR or I²) was displayed on the HMD. A headset was placed over the HMD to provide the pilots with the capability for radio and inter-cockpit communication.

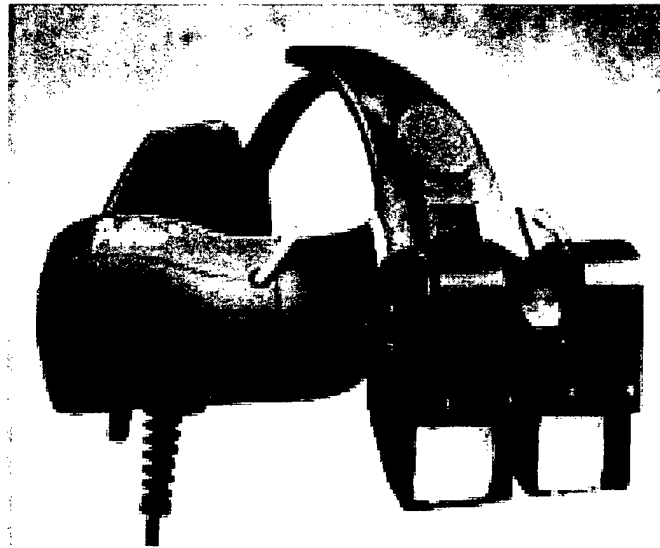


Figure 2. Kaiser ProView 50™.

2. Method

2.1 Participants

Participants were six male Army pilots from the following units: 8-101st Aviation Regiment, Fort Campbell, Kentucky, 1-82nd Aviation Regiment, Fort Bragg, North Carolina, 2-17th Cavalry Squadron, Fort Campbell (two pilots), 3-229th Aviation Regiment, Fort Bragg, and 1-3rd Aviation Regiment, Fort Stewart, Georgia. Three participants were OH-58D pilots who held the rank of CW2. The other three participants were AH-64A pilots who held the rank of CW3. They represented a group of moderately experienced pilots with total flight hours that ranged from 785 hours to 2,170 hours in Army aircraft. None of the participants had previous experience flying a Comanche simulator or aircraft. The relevant demographic characteristics of the pilots are listed in Table 2.

Table 2. Demographic Characteristics of Pilots
(N = 6)

Summary of demographic characteristics	Age (yrs)	Flight hours in primary aircraft	Total flight hours in Army aircraft	Flight hours with night vision devices
Average	34	910	1292	480
Median	34	800	1180	435
Range	26-41	620-1500	785-2170	352-707

2.2 Data Collection

Two questionnaires were developed in order to assess workload for the crew member tasks listed in Appendix A. One of the questionnaires required the pilots to rate their perceived level of workload for each crew member task via the Bedford Workload Rating Scale. The other questionnaire required pilots to rate whether (a) usability features of the cockpit controls and displays impacted their workload levels during the mission, and (b) workload was higher for the pilot flying the aircraft (front seat) or the pilot operating the MEP (back seat). The purpose of this questionnaire was to highlight any usability problems that contributed to excessive workload during the mission and to help determine if workload was evenly distributed between pilots.

The questionnaires were developed in accordance with published guidelines for proper format and content (Babbitt & Nystrom, 1989). A brief pre-test was conducted to refine the questionnaires and to ensure that they could be easily understood and completed by pilots. Before experimentation, the FDE pilots were briefed about the purpose of the workload assessment. They also received instruction about completing both questionnaires.

The pilots provided workload ratings for each applicable crew member task immediately after every mission. They completed the cockpit controls and displays usability questionnaire at the end of each phase. Questionnaire results were clarified with information obtained during post-flight discussions with pilots.

2.3 Data Analysis

Pilot responses to the workload rating questionnaire and cockpit controls and displays usability questionnaire were analyzed with averages and percentages. In addition, the sign test was used to identify any statistically significant differences in workload ratings between the pilot on controls and the pilot operating the MEP. The chi-square goodness-of-fit and binomial tests were used to identify any statistically significant response trends to questionnaire items regarding whether the usability characteristics of the cockpit controls and displays impacted workload. Statistically significant trends indicate that the responses provided by the pilots to the questionnaire items were not random but were attributable to factors such as strong favorable or unfavorable opinions about usability characteristics of the cockpit controls and displays. Because of the small number of pilots who participated in the FDE, probability values were computed via Fisher's Exact Test.

Because the pilots had limited experience with the CPCs before experimentation began, correlation coefficients were computed to identify any significant changes in their responses to the controls and displays usability questionnaire over the course of the FDE. This was done to help determine if increased experience with

the system significantly affected pilot responses to questionnaire items. For example, pilots might rate a component as much easier to use toward the end of the FDE because of increased experience with using it during previous missions. Significant changes in their responses might indicate that (a) pilots would have benefited from additional training, and (b) the additional training would have allowed the pilots to provide more valid responses during the early phases of the FDE.

2.4 Limitations of Workload Assessment

Limitations included the small sample size of pilots ($N = 6$) who participated in the FDE, their limited experience (2 months) with the CPCs, and the lack of 100% fidelity between the CPCs and the Comanche aircraft. Information and data listed in the Results and Summary sections of this report should be interpreted on the basis of these limitations.

3. Results

3.1 Workload When Pilots Performed Crew Member Tasks

As summarized in Table 3 and Appendix E, pilots reported that workload was tolerable when they performed all front and back seat tasks except “maintaining air space surveillance”. Pilots in the back seat could not maintain air space surveillance at night because they had no night vision device (FLIR or night vision goggles) to see outside the cockpit while they conducted a scan with the TAS.

3.2 Spare Workload Capacity When Pilots Performed Crew Member Tasks

Pilots reported that they experienced no reduction in spare workload capacity while they performed 24 (69%) crew member tasks in the front seat and 17 (63%) tasks in the back seat. When flying the aircraft from the front seat, pilots reported that they experienced “insufficient spare workload capacity for *easy* attention to additional tasks” while they performed 11 (31%) crew member tasks. This is understandable for 8 of the 11 tasks because they are inherently workload-intensive events because pilots are (a) attempting to engage or avoid the threat or (b) responding to an emergency or unexpected event. The other three tasks (digital communications, data entry procedures, and data management operations) received this rating primarily because of usability problems with the CIK and the TSD (see Table 4). Pilots reported that entering data on the CIK was time consuming and required excessive steps. Specific items that were reported as being difficult to enter included radio frequencies, targets, and coordinates. The slow processing speed of the CIK was also cited as a usability problem.

Pilots reported that labeling targets on the TSD was time consuming because of the excessive number of steps required to perform the task.

Table 3. Summary of Workload Ratings

Pilot on controls (front seat)	Pilot operating the MEP (back seat)
Workload was tolerable when pilots performed all tasks	Workload was tolerable when pilots performed all tasks except "maintaining air space surveillance"
Pilots experienced no reduction in spare workload capacity when performing 24 of 35 tasks (69%)	Pilots experienced no reduction in spare workload capacity when performing 17 of 27 tasks (63%)
Pilots experienced "insufficient spare workload capacity for <i>easy</i> attention to additional flight and mission tasks" when performing	Pilots experienced "insufficient spare workload capacity for <i>easy</i> attention to additional flight and mission tasks" when performing
• Evasive maneuvers • Firing techniques • Inadvertent IMC procedures • Data management operations • Target engagement with AWS • Target engagement with PTWS • Actions on contact • Firing position operations • Emergency procedures • Data entry procedures • Digital communications	• Radio communications • TSD operations • Target engagement with AWS • Identification of major U.S.-allied equipment and major threat equipment • Operation of the NVPS • Inadvertent IMC procedures Pilots experienced "reduced spare workload capacity." Additional tasks could not be given the desired amount of attention when performing: • Data management operations Pilots experienced "little spare workload capacity; their level of effort allowed little attention to additional tasks" when performing • Digital communications • Data entry procedures Pilots could not perform the following task at night because they did not have a night vision device to see outside the cockpit while conducting a scan with the TAS • Maintaining air space surveillance
IMC = instrumented meteorological conditions AWS = area weapon system PTWS = point target weapon system	

Table 4. Impact of Usability Characteristics of Cockpit Controls and Displays on Workload

CIK	MPDs	SMD	TSD
Steps to accomplish task			
Pilots reported that using the CIK was significantly time consuming for most missions because steps required to accomplish functions were excessive and not logical or consistent. Pilots reported that the CIK should be modified to decrease workload.	Pilots reported that using the MPDs was not significantly time consuming (for most missions) because of the steps required to complete a function. Pilots reported that some modifications should be made in the MPDs to help decrease workload.	Pilots reported that using the SMD was not significantly time consuming (for most missions) because of the steps required to complete a function. Pilots reported that some modifications should be made in the SMD to help decrease workload.	Pilots reported that using the TSD was significantly time consuming for 50% of missions because steps required to accomplish functions were excessive and not logical or consistent. Pilots reported that modifications should be made in the TSD to decrease workload.
Menu navigation			
Not applicable	Pilots were able to quickly navigate through the menu screens for 96% of missions.	Pilots were able to quickly navigate through the menu screens for 91% of missions.	Pilots were able to quickly navigate through the menu screens for 71% of missions.
Not applicable	Pilots seldom or never had trouble remembering where they were in the menu system for all missions.	Pilots seldom or never had trouble remembering where they were in the menu system for all missions.	Pilots seldom or never had trouble remembering where they were in the menu system for all missions.
Symbolology			
Not applicable	Not applicable	Pilots reported that they could quickly and easily understand symbology displayed on the SMD during all missions.	Pilots reported that they could quickly and easily understand symbology displayed on the TSD for 65% of missions. Pilots reported that some modifications of the symbology should be made to decrease workload.

When operating the MEP in the back seat, pilots reported that they experienced “insufficient spare workload capacity for *easy* attention to additional tasks” while they performed six (22%) crew member tasks. This is understandable for four of the six tasks because they are inherently workload-intensive events because pilots are (a) attempting to identify, engage, or avoid the threat or (b) responding to an unexpected event (inadvertent IMC). The other two tasks (radio communications and TSD operations) received this rating primarily because of usability problems with the CIK and the TSD. The usability problems are the

same as those identified by the pilots when they flew the aircraft from the front seat (see previous paragraph). Pilots reported that they experienced "reduced spare workload capacity" while they performed data management operations and "little spare workload capacity" while they performed digital communications and data entry procedures. Again, pilots cited usability problems with the CIK and TSD as the primary reasons for assigning these ratings to the tasks. Finally, pilots could not maintain air space surveillance at night because they did not have a night vision device to see outside the cockpit while they conducted a scan with the TAS.

3.3 Comparative Workload Levels Between Front Seat and Back Seat

No statistically significant differences in workload ratings were provided by pilots when they flew the aircraft versus when they operated the MEP. However, when asked to rate whether overall workload was higher for the front or back seat for the missions they performed, pilots reported that workload was somewhat higher (54%) or much higher (22%) for the back seat compared to the front seat. The primary reason given by the pilots was that operating the MEP required the crew member to perform more tasks in the same time interval than the crew member who was flying the aircraft. Also, pilots reported during post-flight discussions that usability problems with the CIK, TSD, and "slew" hook-FOV switches on the collective grip contributed to higher workload for the pilot in the back seat. The pilot operating the MEP uses the CIK, TSD, and FOV-slew switches more often during the mission than does the pilot flying the aircraft.

3.4 Pilot Responses to Controls and Displays Usability Questionnaire

Increased experience with the CPC over the course of the FDE did not affect pilot responses to the controls and displays usability questionnaire items. No significant correlation coefficients were obtained when pilot responses were analyzed. The ratings provided by the pilots were consistent between each phase of the FDE. This indicates that the training they received before the FDE was sufficient for them to identify the usability characteristics of cockpit controls and displays that contributed to increased workload. Discussions with pilots also indicated that they were able to easily identify (early in training) the usability characteristics of the controls and displays that contributed to higher workload.

3.5 HMD Symbology

Pilots reported that it was difficult to quickly and easily understand the heading tape displayed in the HMD when they flew the aircraft or operated the MEP. They unanimously requested that the heading tape be stabilized and not move when the pilot moves his head. The pilots also requested that pitch ladder and bank angle symbols be added to the HMD symbology set.

4. Summary

4.1 Cockpit Workload

Results indicate that (a) workload was tolerable for pilots when they performed all but one crew member task; (b) pilots experienced no reduction in spare workload capacity for 69% of tasks when they flew the aircraft and for 61% of tasks when they operated the MEP; and (c) workload was moderately higher for pilots when they operated the MEP versus when they flew the aircraft. Following is a brief summary of the results:

- Pilots experienced tolerable workload levels for all tasks when they flew the aircraft. They experienced tolerable workload levels for all but one task when they operated the MEP. Workload was not tolerable for the task of “maintaining air space surveillance” at night for the pilot operating the MEP. This was because there was no night vision device for seeing outside the cockpit when the pilots conducted a scan with the TAS.

- Pilots experienced no reduction in spare workload capacity for 69% of tasks when they flew the aircraft and for 61% of tasks when they operated the MEP. For tasks in which a reduction in spare workload capacity was experienced, the primary reasons were

- The tasks were inherently workload intensive because pilots were identifying, engaging, or avoiding a threat or responding to an emergency or unexpected event.

- Usability problems with the CIK, TSD, and FOV-slew switches on the collective.

- Workload levels were higher for pilots when they operated the MEP. The primary reasons were

- Operating the MEP required pilots to perform more tasks during the mission than when they flew the aircraft.

- Usability problems with the CIK, TSD, and FOV-slew switches on the collective increased workload for pilots when they operated the MEP. The pilot operating the MEP uses the CIK, TSD, and FOV-slew switches more often during the mission than does the pilot flying the aircraft.

- Pilots unanimously requested that the heading tape displayed in the HMD be stabilized and not move when the pilot moves his head. They also requested that pitch ladder and bank angle symbols be added to the HMD symbology set.

4.2 Battle Rostering of Comanche Pilots

Results indicate that there is no compelling need to prescribe battle rostering because of high or disproportionately distributed workload between Comanche pilots. This is because (as summarized on the previous page)

- Workload was tolerable for all but one of the crew member tasks performed by pilots.

- Pilots experienced no reduction in spare workload capacity for 69% of tasks when they flew the aircraft and for 61% of tasks when they operated the MEP.

- Only moderate differences in workload levels were reported between pilots when they flew the aircraft versus when they operated the MEP.

5. Recommendations

Data obtained during FDE 1 provide useful insights about workload levels that Comanche pilots may experience when performing crew member tasks. The data also identified usability limitations with the CIK, TSD, slew hook and FOV switches on the collective, and symbology on the HMD (see Appendix C). These usability limitations should be addressed and resolved as soon as possible. Additionally, the pilot operating the MEP should be provided with a night vision device to see outside the cockpit at night when he conducts a scan with the TAS.

The scope of FDE 1 did not allow a comprehensive evaluation of workload for Comanche pilots. To fully assess the design of the Comanche, future FDTE events should include comprehensive evaluations of pilot workload. Other (related) performance measures such as crew coordination, situational awareness, and decision making should be evaluated to help assess workload and fully develop the pilot-vehicle interface.

INTENTIONALLY LEFT BLANK

References

- Babbitt, B., & Nystrom, C. (1989). Questionnaire construction manual. Fort Hood, TX: U.S. Army Research Institute.
- Grubb, G.N., Simon, R.A., Leedom, D.K., & Zeller, J.L. (1995). Effect of crew composition on AH-64 attack helicopter mission performance and flight safety. Fort Rucker, AL: Army Research Institute.
- Headquarters, Department of the Army (1995). Aircrew training program commander's guide to individual and crew standardization (Training Circular 1-210). Washington, DC: Author.
- Roscoe, A.H. (1985). The airline pilots view of flight deck workload: A preliminary study using a questionnaire (Technical Memorandum No. FS (B) 465). Bedford, UK: Royal Aircraft Establishment.
- Roscoe, A.H., & Ellis, G.A. (1990). A subjective rating scale for assessing pilot workload in flight: A decade of practical use. Bedford, UK: Royal Aerospace Establishment.

INTENTIONALLY LEFT BLANK

APPENDIX A
FDE 1 CREW MEMBER TASKS

INTENTIONALLY LEFT BLANK

FDE 1 Crew Member Tasks		
Task 1035 – Perform Before Flight Checks	Task 1162 - Perform Actions On Contact	Task 1442 - Perform HIDSS Operations
Task 1042 - Maintain Airspace Surveillance	Task 1168 – Select Landing Zone/Holding Area	Task 1448 - Perform EOTADS Sensor Operations
Task 1100 - Perform Radio Communications	Task 1173 - Perform VMC Approach and Roll-on Landing	Task 1449 - Perform Digital Communications
Task 1107 - Perform Hovering Flight	Task 1230 - Perform Inadvertent IMC Procedures	Task 1454 – Perform Data Entry Procedures
Task 1109 - Perform VMC Takeoff	Task 1300 - Perform Emergency Procedures	Task 1455 - Perform Data Management Operations
Task 1117 - Perform VMC Flight Maneuvers	Task 1410 - Perform TSD Operations	Task 1458 – Engage Target With PTWS
Task 1127 - Perform Electronically Aided Navigation	Task 1414 – Perform Target Handover	Task 1464 - Engage Target With The AWS Turreted Gun
Task 1136 - Perform Terrain Flight Navigation	Task 1422 – Perform Firing Techniques	Task 1500 - Perform Aerial Observation
Task 1146 - Perform Terrain Flight	Task 1426 - Perform Firing Position Operations	Task 1805 - Identify Major US-Allied Equipment and Threat Equipment
Task 1148 - Perform Terrain Flight Deceleration	Task 1427 – Select A Combat Position	Task 1823 - Operate Aircraft Survivability Equipment
Task 1151 - Perform Masking And Unmasking	Task 1428 - Select Appropriate Weapon System	Task 1837 - Operate Night Vision Pilotage System
Task 1153 - Perform Evasive Maneuvers	Task 1440 - Perform HIDSS Boresight	

VMC = visual meteorological conditions

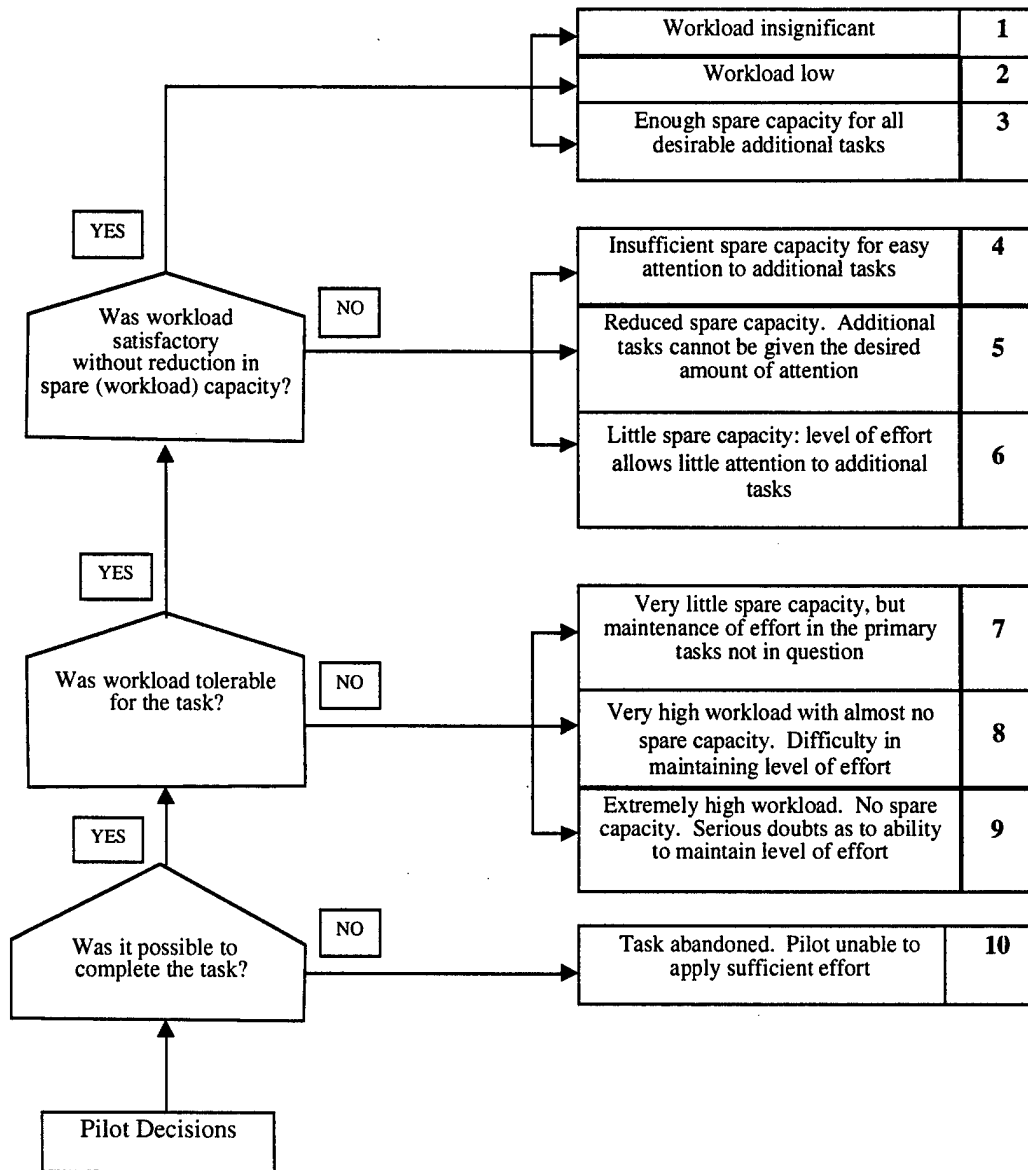
EOTADS = electro-optical target acquisition designation system

INTENTIONALLY LEFT BLANK

APPENDIX B
BEDFORD WORKLOAD RATING SCALE

INTENTIONALLY LEFT BLANK

Workload Description "Rating"



INTENTIONALLY LEFT BLANK

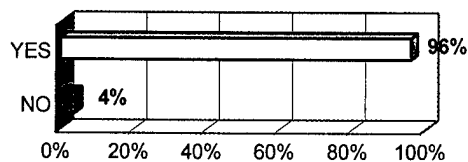
APPENDIX C

SUMMARY OF PILOT RESPONSES ABOUT THE USABILITY
CHARACTERISTICS OF THE CREW STATION
CONTROLS AND DISPLAYS

INTENTIONALLY LEFT BLANK

SUMMARY OF PILOT RESPONSES REGARDING USABILITY CHARACTERISTICS OF CREW STATION CONTROLS AND DISPLAYS

**Any CIK Functions That Were Significantly
Time Consuming to Accomplish Due to
Excessive Number of Steps**?**

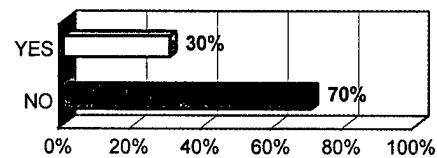


Pilot Comments:

Problems when using the CIK:

- CIK is too cumbersome (4 comments).
- CIK is too cumbersome when data are entered.
- The CIK is cumbersome and slow.
- Cumbersome- would like voice interaction
- Excessive number of steps for CIK use.
- All (CIK, MPDs, SMD, and TSD) required an excessive number of steps.
- Too many steps to enter anything in the CIK.
- Location and interface difficult.
- Need quicker method of entering manual frequencies and waypoints for direct to.
- CIK should be enabled for direct waypoint entry by 8-digit grid.
- Manual entry at grid for FLT plan, direct waypoints (should be more interactive.).
- Trying to make sentences takes too long.
- Keyboard needs to be able to be interactive with more functions, such as entering a direct waypoint, or a manual radio frequency.
- Difficult to interact with. Would like a manual selection to enter commo, freqs, or grid locations. Very slow and not user friendly when interacting with commo and NAV package.
- Changing radio frequencies, it would be nice to have a control head. It would be a lot easier to change a manual frequency.
- Key positioning requires "hunt and peck."
- It is too slow.

**Any MPD Functions That Were Significantly
Time Consuming to Accomplish Due to
Excessive Number of Steps?**

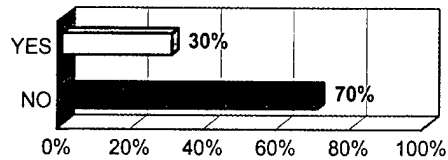


Pilot Comments:

- RMPD- Fuel quantity indicator is very hard to focus on. When checking fuel, I find myself "inside the cockpit" far too long.
- Fuel display.
- RMPD is cluttered and is very hard to disseminate info.
- When selecting a radio, I spent too much time looking down at RFD. Difficult to see the display and forced to look at it when selecting radio.
- Multi-level menus are sometimes too deep.
- When selecting a hard bezel should always go to top TMI. Recognition of what level you are in requires time.
- Visual indication of 20 mm deployed (picture).

**Significant at $\alpha .01$

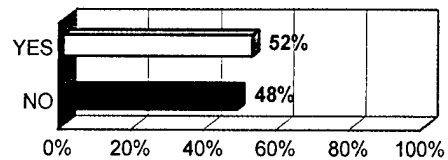
**Any SMD Functions That Were Significantly
Time Consuming to Accomplish Due to
Excessive Number of Steps?**



Pilot Comments:

- Any hard bezel selection should kick you out of the slaved function. (4 comments)
- Windows and digital communications
- Communication pages
- Windows.
- TAS manual/use.
- TAS sensitive to aircraft in main slew mode.

**Any TSD Functions That Were Significantly
Time Consuming to Accomplish Due to
Excessive Number of Steps?**



Pilot Comments:

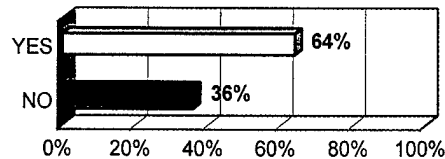
Problems with labeling of targets:

- TGT labeling.
- Labeling targets is time consuming. Suggest a selectable bar on TSD.
- Labeling function too time consuming and cumbersome/windows.
- Labeling takes too long.
- Labels.
- Label function excessive.
- Labeling targets is very time consuming.
- Labeling of TGTS should be a selection on LMPD. Current method is time consuming and awkward.

Other comments:

- Icons should be scaled to map. (2 comments)
- Threat ID classification. Right slew hook and design should be moved to a time menu item on LMPD.
- MAP is cluttered.
- Hook function and picking between two targets that are very close together.

Any CIK Functions That Were Significantly Time Consuming to Accomplish Due to Steps That Were Not Logical or Consistent?

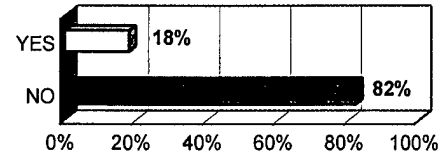


Pilot Comments:

Problems when using the CIK:

- Too cumbersome. (2 comments)
- All CIK functions. (2 comments)
- The keyboard needs to be designed with a "PC style layout. (2 comments)
- Too many steps.
- Too many steps for use.
- This CIK takes too long to utilize.
- Too slow.
- The CIK takes too long to input data.
- Manual entry for both frequencies and waypoints.
- Should always be able to activate keyboard for grids-spot reports

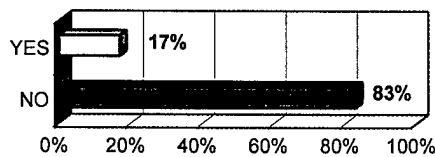
Any MPD Functions That Were Significantly Time Consuming to Accomplish Due to Steps That Were Not Logical or Consistent?***



Pilot Comments:

- The direct to function in NAV-CUR is not in logical sequence when using in conjunction with locate.
- Multiple level menus.
- There were too many items that are split between the TIMI menu structure and hard bezels on the MPD's.
- When selecting hard bezel, should always go to top TMI.

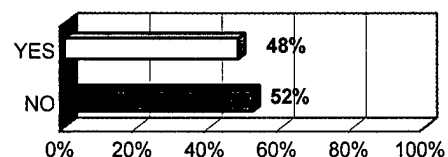
Any SMD Functions That Were Significantly Time Consuming to Accomplish Due to Steps That Were Not Logical or Consistent?***



Pilot Comments:

- Windows. (2 comments)
- Using any function on SMD, you lose sight of target in TAS.
- Communication systems.

Any TSD Functions That Were Significantly Time Consuming to Accomplish Due to Steps That Were Not Logical or Consistent?

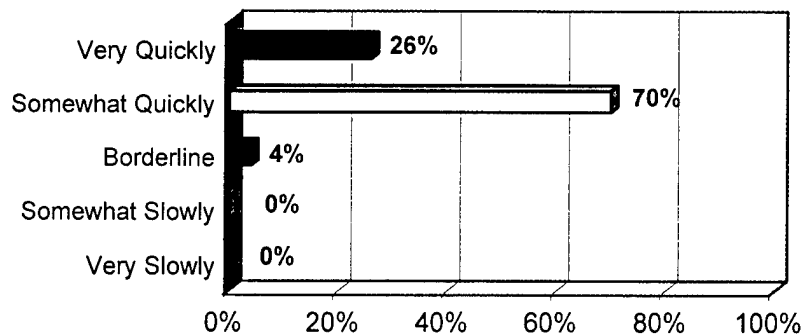


Pilot Comments:

- Labeling function is slow. (3 comments)
- Labels. (2 comments)
- Labeling takes too long.
- Labeling targets.
- Direct-to and show on map.

**Significant at $\alpha .01$

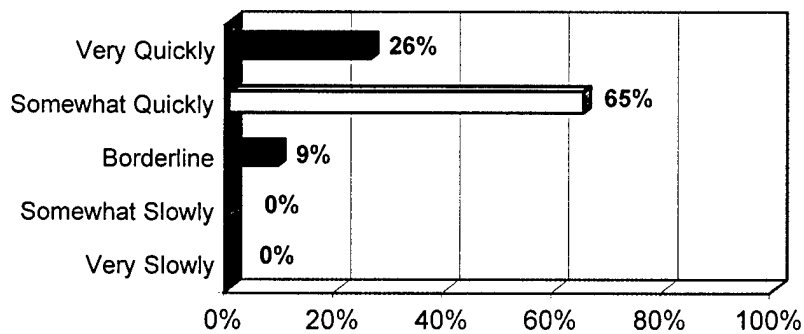
How Quickly Were You Able to Navigate Through the Menu Screens on the MPDs?**



Pilot Comments:

- No comments provided by pilots.

How Quickly Were You Able to Navigate Through the Menu Screens on the SMD?**

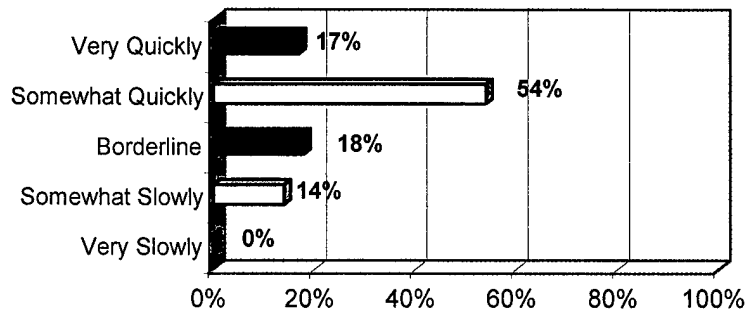


Pilot Comments:

- I would like to have more menu selections displayed on either the TIMI or SMD and not both. There is no logical reason why a selection is on either the TIMI or SMD.

**Significant at $\alpha .01$

**How Quickly Were You Able to Navigate Through
the Menu Screens on the TSD**?**



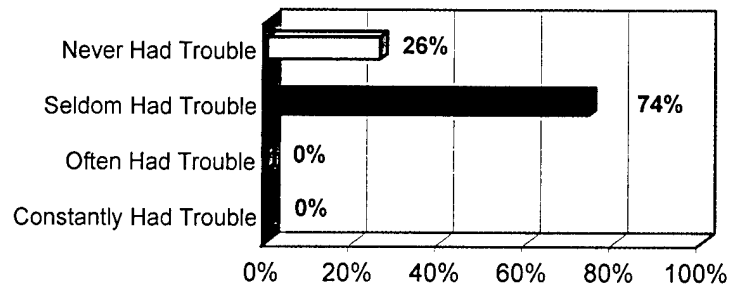
Pilot Comments:

Problems with labeling of targets:

- Target labeling.
- Labeling slow.
- The labeling function and TSD windows function are very slow. As well as plotting a direct waypoint.
- Labeling and windows.
- TGT labeling.
- Only in labeling menus.
- The menu structure for TSD labeling is very poor.
- Threat ID classification with right slew hook- too much time. Should be choices on SMD and TSD.

**Significant at $\alpha .01$

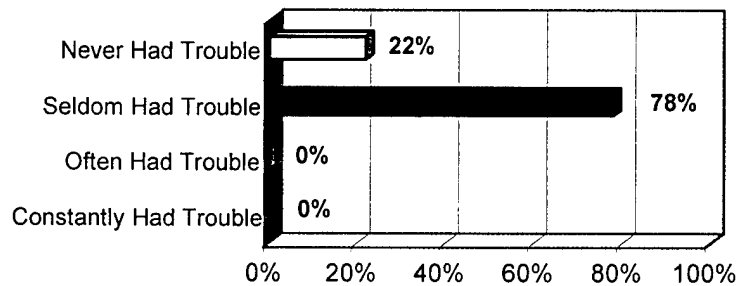
**How Often Did You Have Trouble Remembering
Where You Were in the MPD Menu System**?**



Pilot Comments:

- No comments provided by pilots.

**How Often Did You Have Trouble Remembering
Where You Were in the SMD Menu System**?**

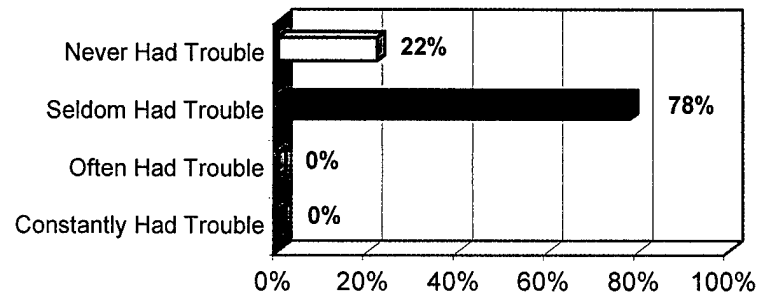


Pilot Comments:

- No comments provided by pilots.

**Significant at $\alpha .01$

**How Often Did You Have Trouble Remembering
Where You Were in the TSD Menu System**?**

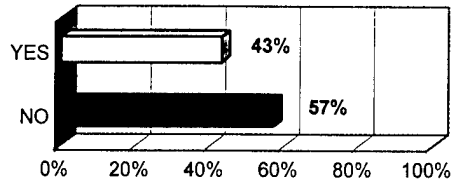


Pilot Comments:

- TSD windows can get confusing sometimes. I like the purpose of windows, however I think it could be easier to use.

**Significant at $\alpha .01$

**Were Any Switches on the Collective Grip
Time Consuming to Use ?**



Pilot Comments:

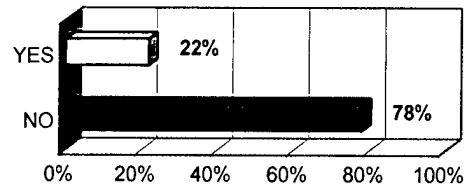
Problems with slew hook and FOV switches:

- Slew hook functions.
- Both slew hooks and FOV zoom select switch.
- Slew Hook/ FOV switches.
- The FOV selection switch on the collective is not in logical order. The optics are displayed as follows: MWN. The order they should follow is WMN.
- Field of view needs logical order.
- Front/Back: the FOV selection switch does not select between narrow, medium and wide in a logical order.

Other comments:

- Map Scale- include 18 and 32 k scales.
- Front/Back: the map scale switch should also have option for 18K map scale.
- The "no target" and "details" are difficult to find without visual verification. Both seats.
- Radio selection - Would like five position switch.

**Were Any Switches on the Sidearm Controller
Time Consuming to Use* ?**

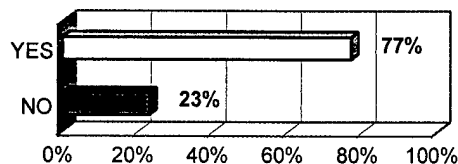


Pilot Comments:

- Right arm controller very difficult to use.
- Arm and cyclic inputs difficult.
- Need detachable controller (Nintendo®).
- AFCS difficult to reach/slant control force.
- Finding the "take flight control" is difficult.
- The SAC needs to be more user friendly. That is, easier to hold on to and use the switch at the same time.

*Significant at $\alpha .05$

Was There Any Symbology on the HMD That Was Difficult to Quickly and Easily Understand**?



Pilot Comments:

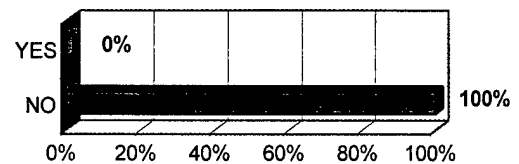
Problems with heading tape:

- Heading tape should be screen stabilized (6 comments)
- Heading tape should be fixed (not moving). (2 comments)
- Heading tape should be HMD stabilized. (2 comments)
- Heading tape needs to be fixed to the aircraft.
- I still do not like the moving heading tape. It should be fixed.
- Heading tape should be stable.
- The heading tape needs to be stable. It can cause vertigo.

Other comments:

- Need to add pitch ladder (4 comments)
- Need to add bank angle. (3 comments)
- No TAS LOS bearing indicator.
- False horizon nearly impossible to use for any turn rate or A/C attitude determination. Excessive movement of symbology confusing almost imparting the desire to input an incorrect change in A/C attitude.
- WCA not easily identified without audio.
- Cannot see outside when operating TAS.
- Symbology for NVS flight predictor worse than all others as previously stated.
- 20 mm ownership not displayed.
- Hellfire ownership not displayed.

Was There Any Symbology on the SMD That Was Difficult to Quickly and Easily Understand**?



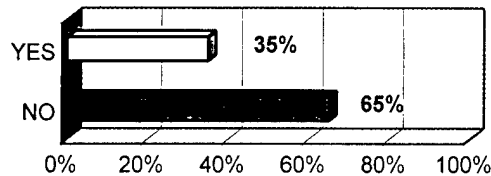
Pilot Comments:

- No comments provided by pilots.

*Significant at α .05

**Significant at α .01

**Was There Any Symbology on the TSD That
Was Difficult to Quickly and Easily
Understand*?**



Pilot Comments:

- 18th K view targets close to one another; difficult to break out and overlaid symbology selects when hooked. That is, hook difficult to pick between two different items that occupy the same space on the MAP.
- Wires and roads are red.
- Digital map symbols are different than the chart symbols that every aviator is familiar with. Icon should also be scaled proportionally to map scale.
- ADA searching symbol difficult to see. Sensor shading on map. Line of sight with terrain shading for line of sight inter-visibility.
- Visual alert of ADA (ASE radar or laser warning) on map. - I would like to have the symbols red instead of black. I would like to have it flashing to catch my attention if it is a new system searching.
- The non-labeled vehicle icons are hard to tell the difference between a wheeled and tracked vehicle icon. They should look more like a truck and a tank.
- WCA not noticed without audio alarm (move to bottom).
- Target icons in proximity to graphics and each other; hard to separate.

APPENDIX D

COLLECTIVE, SIDE ARM CONTROLLER, AND
RIGHT ARMREST SWITCHES

INTENTIONALLY LEFT BLANK

COLLECTIVE, SIDE ARM CONTROLLER, AND RIGHT ARMREST SWITCHES

Collective switches	Side arm controller switches
Searchlight Trim Guarded jettison release Sensor FOV/sensor control Cursor control for TAS (left slew hook) No target designation switch Target select and sensor locking Location designation switch Cursor control for TSD (right slew hook) Map selection/scale selection Slew to own helmet sensor control Collective trim release Radio/preset select switch Warning, caution, advisory acknowledge Laser activation switch Hover return	Automatic flight control system Coupler release NVPS I ² /IR and polarity select Station deselect Trigger guard Weapon release Weapon select Yaw trim release Integrated flight-fire control (IFFC)
Right armrest switches	
Right slew hook Left slew hook Laser Details Find	

INTENTIONALLY LEFT BLANK

APPENDIX E

SUMMARY OF PILOT RESPONSES TO BEDFORD
WORKLOAD RATING SCALE

INTENTIONALLY LEFT BLANK

SUMMARY OF PILOT RESPONSES TO BEDFORD WORKLOAD RATING SCALE

Crew Member Tasks	Front Seat Workload Rating	Back Seat Workload Rating	Crew Member Tasks	Front Seat Workload Rating	Back Seat Workload Rating
Perform Before Flight Checks	1.82	2.07	Perform Terrain Flight Deceleration	3.23	NA
Maintain Airspace Surveillance	2.56	a	Perform Masking And Unmasking	2.96	NA
Perform Radio Communications	3.30	3.60	Perform Evasive Maneuvers	4.28	NA
Perform Hovering Flight	2.13	NA	Perform Actions on Contact	4.00	3.37
Perform VMC Takeoff	2.42	NA	Select Landing Zone/Holding Area	3.20	3.09
Perform VMC Flight Maneuvers	2.58	NA	Perform VMC Approach	2.73	NA
Perform Electronically Aided Navigation	2.93	2.72	Perform Inadvertent IMC Procedures	3.77 ^b	3.62 ^b
Perform Terrain Flight Navigation	2.96	2.66	Perform Emergency Procedures	3.80 ^b	3.20 ^b
Perform Terrain Flight	3.23	NA	Perform TSD Operations	3.21	3.89

^aTask could not be completed at night because there was no night vision device for use while pilots conducted a scan with the TAS.

^bBased on ratings from fewer than 10 missions.

Crew Member Tasks	Front Seat Workload Rating	Back Seat Workload Rating	Crew Member Tasks	Front Seat Workload Rating	Back Seat Workload Rating
Perform Target Handover	2.76	3.00	Perform Digital Communications	4.53	6.10
Perform Firing Techniques	3.76	3.31	Perform Data Entry Procedures	4.35	6.00
Perform Firing Position Operations	3.52	3.10	Perform Data Management Operations	3.60	4.59
Select A Combat Position	3.09	2.95	Engage Target With PTWS	3.80	3.00
Select Appropriate Weapon System	2.42	2.75	Engage Target With The AWS Turreted Gun	4.40 ^a	4.16 ^a
Perform HIDSS Boresight	2.20	2.48	Perform Aerial Observation	2.96	3.30
Perform HIDSS Operations	2.60	3.04	Identify Major U.S./Allied Equipment and Major Threat Equipment	3.29	3.58
Perform EOTADS Sensor Operations	3.00 ^a	3.39	Operate Aircraft Survivability Equipment	2.70	2.44 ^a

^aBased on ratings from fewer than 10 missions.

Crew Member Tasks	Front Seat Workload Rating	Back Seat Workload Rating
Operate Night Vision Pilotage System	2.60	3.88 ^a

^aBased on ratings from fewer than 10 missions.

Comments regarding lack of external vision in the back seat:

- Task 1042: (Airspace Surveillance) Back seat has no vision.
- Task 1042: Not able to perform airspace surveillance due to lack of night vision.
- Task 1042: B/S has no outside vision
- Task 1042: Can't see in the back when not flying.
- Task 1042 cannot be performed due to lack of night vision in rear seat during scans.
- Task 1500 (Aerial Observation): Can't quickly scan around aircraft (no vision). Would like NVG or equivalent.
- Tasks 1153 (Evasive Maneuvers), 1162 (Actions On Contact), 1442 (HIDSS Operations) and 1448 (EOTADS Sensor Operations): During maneuvering CP unable to acquire TGT with TAS Auto or manual. Since CP is HMD blind, the CP was unable to acquire target with HIDSS.
- Task 1837 (Operate Night Vision Pilotage System): Not available, so abandoned flight to FS.
- I have no visual in the back

Comments regarding the CIK:

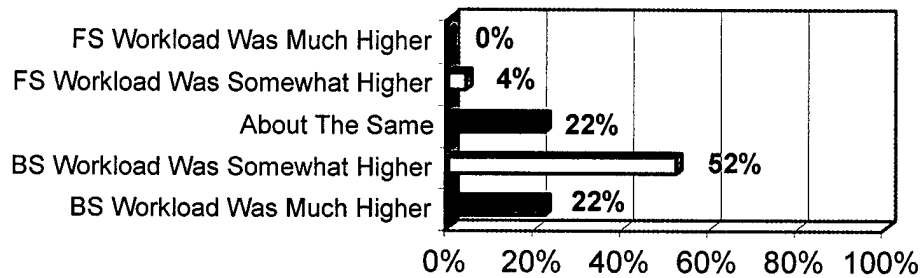
- Tasks 1449 (Digital Communications and 1454 (Data Entry Procedures): CIK very cumbersome. (2 comments)
- Digital communications are totally absorbing.
- Task 1100 (Radio Communications): CIK very cumbersome
- The CIK is not user friendly and too slow.
- Using the CIK and using I2 is cumbersome. The whole digital processing needs work.
- The CIK needs to be more user-friendly.

Comments regarding other cockpit interface problems:

- Task 1410 (TSD Operations) Controls are difficult to operate which causes workload to be higher.
- TAS view last, multi-step must complete before continuing with other functions.
- Data procedures require excessive number of steps and are difficult to work with current controls.
- HIDSS symbology: Reference to aircraft attitude and turn angle difficult to determine from looking off nose or slides. Determining rate of turn impossible. Just guessing at it from movement of heading tape. Predictor a waste of space, pilot must fly terrain.
- 1449 (Digital Communications) and 1455 (Data Management Operations): Vocal reports used to augment diagram because of poor interface.
- Task 1455 (Data Management Operations): Labeling targets cumbersome.

- Tasks 1410 (TSD Operations), 1442 (HIDSS Operations), 1449 (Digital Communications), 1454 (Data Entry Procedures), 1455 (Data Management Operations) and 1837 (Operate Night Vision Pilotage System): System interface is cumbersome requiring excessive time.
- Task 1162 (Actions On Contact) - Only focus was flying the A/C.
- Tasks 1422 (Firing Techniques) and 1426 (Firing Position Operations): Wouldn't allow an engagement.
- When the MPED would direct WP the NAI, I could not see the line on my TSD.
- Had to wait a long time for target ID.
- TSD/TAS labeling due to ATS not Id'ing targets 5K and under. INT not functioning properly.
- Encountered ADA and had to quickly mask without crashing.
- Task 1442 (HIDSS Operations): Not used for other than missile constraints.
- Unable to load and select presets.

Rate Whether Overall Workload was Higher for the Front Seat or Back Seat**?



Pilot comments on why they experienced higher workload in the back seat:

Comments regarding operation of the MEP:

- The MEP operator usually has higher workload.
- MEP operator (has higher workload).
- Running the MEP is higher workload.
- As MEP operator, it requires a lot of attention.
- Back seat (had higher workload) because of working the majority of the MEP in this scenario.
- Current configuration places the MEP operator in the rear seat.
- The back seat was used as the MEP operator.
- More MEP operations (in the back seat).
- Because the back seat has to be able to communicate, ID the target and maintain airspace surveillance. All at the same time.
- The front seater just flies, the back seater was doing all the work.
- The individual not flying classifies and communicates and services while the front seat flew.
- More mission requirement in back seat
- Front seat responsible for obs avoidance, NAV, radio traffic. Rear seat threat location, ID, spot reports.
- It does take a lot of effort to fly point to point, the back seat scanning and reporting ARTY, weapons engagement. (all "inside" work).

**Significant at $\alpha .01$

Comments regarding the TAS:

- Back seat needs NVG or some system to see outside the A/C when the TAS is used.
- TAS manual slew for scanning or viewing difficult.
- P (not on controls) needs vision to improve TAS operations.
- Rear seat should be able to see outside the aircraft even when the TAS is operated.
- Slew hook for TAS manual ops does not allow for any real TGT, ID or development. No azimuth, no target, and no range.
- Front seat primarily responsible for flying, obstacle avoidance, NAV. Rear seat all systems with TAS and NPVs.

Comments regarding labeling function:

- The labeling function is too slow.
- Need new labeling system for TGTS.
- Target labeling in TSD.
- Labels/Windows.
- TAS/Labeling/Windows requires high workload with eyes in almost all times.

Comments regarding radio communications:

- Manual entry of frequencies and grid locations to navigate with.
- Selecting radio requires visual verification (hands on). Radio frequency display position is far from center.
- Location of RFD makes it difficult to see and read. Need ability to see which of our five radios people are transmitting on to aid in situational awareness.

Comments regarding the CIK:

- B/S ops on CIK. The keyboard is cumbersome. I would like it in a normal typing configuration with the numbers in a numerical keypad configuration.
- The CIK is too slow.

Other comments:

- There needs to be another trigger for WPNS engagement.
- The heading tape should remain stationary. It can be confusing if you look down then back up and everything is moving. HSI indicators are hard to see. Both crew stations are looking inside while no one is focusing outside.
- Spot reports, difficult to separate targets destroyed from those not destroyed. Sometimes difficult to separate line and rotated targets.

Pilot comments on why they experienced higher workload in the Front Seat:

- FS only because of difficulty of cross checking dash displays with viewing out the window (HMD) and flying very low and fast.
- ASE display was difficult to view and avoid the terrain from F.S.

NO. OF
COPIES ORGANIZATION

1 ADMINISTRATOR
DEFENSE TECHNICAL INFO CTR
ATTN DTIC OCA
8725 JOHN J KINGMAN RD STE 0944
FT BELVOIR VA 22060-6218

1 DIRECTOR
US ARMY RSCH LABORATORY
ATTN AMSRL CI AI R REC MGMT
2800 POWDER MILL RD
ADELPHI MD 20783-1197

1 DIRECTOR
US ARMY RSCH LABORATORY
ATTN AMSRL CI LL TECH LIB
2800 POWDER MILL RD
ADELPHI MD 20783-1197

1 DIRECTOR
US ARMY RSCH LABORATORY
ATTN AMSRL D D SMITH
2800 POWDER MILL RD
ADELPHI MD 20783-1197

1 DIR FOR PERS TECHNOLOGIES
DPY CHIEF OF STAFF PERS
300 ARMY PENTAGON 2C733
WASHINGTON DC 20310-0300

1 OUSD(A)/DDDR&E(R&A)/E&LS
PENTAGON ROOM 3D129
WASHINGTON DC 20301-3080

1 CODE 1142PS
OFC OF NAVAL RSCH
800 N QUINCY STREET
ARLINGTON VA 22217-5000

1 WALTER REED INST OF RSCH
ATTN SGRD UWI C
COL REDMOND
WASHINGTON DC 20307-5100

1 CDR
US ARMY RSCH INST
ATTN PERI ZT DR E M JOHNSON
5001 EISENHOWER AVENUE
ALEXANDRIA VA 22333-5600

NO. OF
COPIES ORGANIZATION

1 DEF LOGISTICS STUDIES
INFORMATION EXCHANGE
ATTN DIR DLSIE ATSZ DL
BLDG 12500
2401 QUARTERS ROAD
FORT LEE VA 23801-1705

1 HEADQUARTERS USATRADOC
ATTN ATCD SP
FORT MONROE VA 23651

1 CDR
USATRADOC
COMMAND SAFETY OFC
ATTN ATOS PESSAGNO/LYNE
FORT MONROE VA 23651-5000

1 DIRECTOR TDAD DCST
ATTN ATTG C
BLDG 161
FORT MONROE VA 23651-5000

1 HQ USAMRDC
ATTN SGRD PLC
FORT DETRICK MD 21701

1 CDR
USA AEROMEDICAL RSCH LAB
ATTN LIBRARY
FORT RUCKER AL 36362-5292

1 US ARMY SAFETY CTR
ATTN CSSC SE
FORT RUCKER AL 36362

1 CHIEF
ARMY RSCH INST
AVIATION R&D ACTIVITY
ATTN PERI IR
FORT RUCKER AL 36362-5354

1 AIR FORCE FLIGHT DYNAMICS LAB
ATTN AFWAL/FIES/SURVIAC
WRIGHT PATTERSON AFB OH 45433

1 US ARMY NATICK RD&E CTR
ATTN STRNC YBA
NATICK MA 01760-5020

1 US ARMY TROOP SUPPORT CMD
NATICK RD&E CTR
ATTN BEHAVIORAL SCI DIV SSD
NATICK MA 01760-5020

NO. OF
COPIES ORGANIZATION

1 US ARMY TROOP SUPPORT CMD
NATICK RD&E CTR
ATTN TECH LIB (STRNC MIL)
NATICK MA 01760-5040

1 DR RICHARD JOHNSON
HEALTH & PERFORMANCE DIV
US ARIEM
NATICK MA 01760-5007

1 PROGRAM MANAGER RAH-66
ATTN SFAE AV RAH
BLDG 5681 WOOD RD
REDSTONE ARSENAL AL 35898

1 NAVAL SUB MED RSCH LAB
MEDICAL LIB BLDG 148
BOX 900 SUBMARINE BASE
NEW LONDON
GROTON CT 06340

1 USAF ARMSTRONG LAB/CFTO
ATTN DR F W BAUMGARDNER
SUSTAINED OPERATIONS BR
BROOKS AFB TX 78235-5000

1 ARI FIELD UNIT FT KNOX
BLDG 2423 PERI IK
FORT KNOX KY 40121-5620

1 USA TRADOC ANALYSIS CMD
ATTN ATRC WSR D ANGUIANO
WSMR NM 88002-5502

1 STRICOM
12350 RSCH PARKWAY
ORLANDO FL 32826-3276

1 CDR
USA COLD REGIONS TEST CTR
ATTN STECR TS A
APO AP 96508-7850

1 PURDUE UNIVERSITY
SERIALS UNIT
CDM KARDEX
1535 STEWART CTR
WEST LAFAYETTE IN
47907-1535

NO. OF
COPIES ORGANIZATION

1 GOVT PUBLICATIONS LIB
409 WILSON M
UNIVERSITY OF MINNESOTA
MINNEAPOLIS MN 55455

1 DR RICHARD PEW
BBN SYSTEMS &TECH CORP
10 MOULTON STREET
CAMBRIDGE MA 02138

1 DR HARVEY A TAUB
RSCH SECTION PSYCH SECTION
VETERANS ADMIN HOSPITAL
IRVING AVE & UNIVERSITY PLACE
SYRACUSE NY 13210

1 DR ROBERT C SUGARMAN
132 SEABROOK DRIVE
BUFFALO NY 14221

1 DR ANTHONY DEBONS
IDIS UNIV OF PITTSBURGH
PITTSBURGH PA 15260

1 MR R BEGGS
BOEING-HELICOPTER CO
P30-18
PO BOX 16858
PHILADELPHIA PA 19142

1 DR ROBERT KENNEDY
ESSEX CORPORATION STE 227
1040 WOODCOCK ROAD
ORLANDO FL 32803

1 DR NANCY ANDERSON
DEPT OF PSYCHOLOGY
UNIVERSITY OF MARYLAND
COLLEGE PARK MD 20742

1 DR BEN B MORGAN
DEPT OF PSYCHOLOGY
UNIV OF CENTRAL FLORIDA
PO BOX 25000
ORLANDO FL 32816

1 LAWRENCE C PERLMUTER PHD
UNIV OF HEALTH SCIENCES
THE CHICAGO MED SCHOOL
DEPT OF PSYCHOLOGY
3333 GREEN BAY ROAD
NORTH CHICAGO IL 60064

NO. OF
COPIES ORGANIZATION

- 1 GMC N AMER OPERATIONS
PORTFOLIO ENGINEERING CTR
HUMAN FACTORS ENGINEERING
ATTN MR A J ARNOLD
STAFF PROJ ENG
ENGINEERING BLDG
30200 MOUND RD BOX 9010
WARREN MI 48090-9010
- 1 GENERAL DYNAMICS
LAND SYSTEMS DIV LIBRARY
PO BOX 1901
WARREN MI 48090
- 1 DR LLOYD A AVANT
DEPT OF PSYCHOLOGY
IOWA STATE UNIVERSITY
AMES IA 50010
- 1 DR MM AYOUB DIRECTOR
INST FOR ERGONOMICS RSCH
TEXAS TECH UNIVERSITY
LUBBOCK TX 79409
- 1 DELCO DEF SYS OPERATIONS
ATTN RACHEL GONZALES B204
7410 HOLLISTER AVE
GOLETA CA 93117-2583
- 1 MR WALT TRUSZKOWSKI
NASA/GODDARD SPACE
FLIGHT CTR
CODE 588.0
GREENBELT MD 20771
- 1 US ARMY
ATTN AVA GEDDES
MS YA:219-1
MOFFETT FIELD CA 94035-1000
- 1 CDR
US ARMY RSCH INST OF
ENVIRONMNTL MEDICINE
NATICK MA 01760-5007
- 1 HQDA (DAPE ZXO)
ATTN DR FISCHL
WASHINGTON DC 20310-0300

NO. OF
COPIES ORGANIZATION

- 1 HUMAN FACTORS ENG PROGRAM
DEPT OF BIOMEDICAL ENGNG
COLLEGE OF ENGINEERING &
COMPUTER SCIENCE
WRIGHT STATE UNIVERSITY
DAYTON OH 45435
- 1 CDR
USA MEDICAL R&D COMMAND
ATTN SGRD PLC LTC K FRIEDL
FORT DETRICK MD 21701-5012
- 1 PEO ARMORED SYS MODERNIZATION
US ARMY TANK-AUTOMOTIVE CMD
ATTN SFAE ASM S
WARREN MI 48397-5000
- 1 PEO COMMUNICATIONS
ATTN SFAE CM RE
FT MONMOUTH NJ 07703-5000
- 1 PEO AIR DEF
ATTN SFAE AD S
US ARMY MISSILE COMMAND
REDSTONE ARSENAL AL 35898-5750
- 1 PEO STRATEGIC DEF
PO BOX 15280 ATTN DASD ZA
US ARMY STRATEGIC DEF CMD
ARLINGTON VA 22215-0280
- 1 JON TATRO
HUMAN FACTORS SYS DESIGN
BELL HELICOPTER TEXTRON INC
PO BOX 482 MAIL STOP 6
FT WORTH TX 76101
- 1 CHIEF CREW SYS INTEGRATION
SIKORSKY AIRCRAFT M/S S3258
NORTH MAIN STREET
STRATFORD CT 06602
- 1 GENERAL ELECTRIC COMPANY
ARMAMENT SYS DEPT RM 1309
ATTN HF/MANPRINT R MCLANE
LAKESIDE AVENUE
BURLINGTON VT 05401-4985
- 1 JOHN B SHAFER
250 MAIN STREET
OWEGO NY 13827

NO. OF
COPIES ORGANIZATION

1 OASD (FM&P)
WASHINGTON DC 20301-4000

1 COMMANDANT
US ARMY ARMOR SCHOOL
ATTN ATSB CDS
FT KNOX KY 40121-5215

1 CDR
US ARMY AVIATION CTR
ATTN ATZQ CDM S
FT RUCKER AL 36362-5163

1 CDR
US ARMY SIGNAL CTR &
FT GORDON
ATTN ATZH CDM
FT GORDON GA 30905-5090

1 DIRECTOR
US ARMY AEROFLIGHT
DYNAMICS DIR
MAIL STOP 239-9
NASA AMES RSCH CTR
MOFFETT FIELD CA 94035-1000

1 CDR
MARINE CORPS SYSTEMS CMD
ATTN CBGT
QUANTICO VA 22134-5080

1 DIR AMC-FIELD ASSIST IN
SCIENCE & TECHNOLOGY
ATTN AMC-FAST
FT BELVOIR VA 22060-5606

1 CDR
US ARMY FORCES CMD
ATTN FCDJ SA BLDG 600
AMC FAST SCIENCE ADVISER
FT MCPHERSON GA 30330-6000

1 CDR
I CORPS AND FORT LEWIS
AMC FAST SCIENCE ADVISER
ATTN AFZH CSS
FORT LEWIS WA 98433-5000

1 HQ III CORPS & FORT HOOD
OFC OF THE SCIENCE ADVISER
ATTN AFZF CS SA
FORT HOOD TX 76544-5056

NO. OF
COPIES ORGANIZATION

1 CDR
HQ XVIII ABN CORPS & FT BRAGG
OFC OF THE SCI ADV BLDG 1-1621
ATTN AFZA GD FAST
FORT BRAGG NC 28307-5000

1 SOUTHCOM WASHINGTON
FIELD OFC
1919 SOUTH EADS ST STE L09
AMC FAST SCIENCE ADVISER
ARLINGTON VA 22202

1 HQ US SPECIAL OPERATIONS CMD
AMC FAST SCIENCE ADVISER
ATTN SOSD
MACDILL AIR FORCE BASE
TAMPA FL 33608-0442

1 HQ US ARMY EUROPE AND
7TH ARMY
ATTN AEAGX SA
OFC OF THE SCIENCE ADVISER
APO AE 09014

1 CDR
HQ 21ST THEATER ARMY AREA CMD
AMC FAST SCIENCE ADVISER
ATTN AERSA
APO AE 09263

1 CDR
HEADQUARTERS USEUCOM
AMC FAST SCIENCE ADVISER
UNIT 30400 BOX 138
APO AE 09128

1 HQ 7TH ARMY TRAINING CMD
UNIT #28130
AMC FAST SCIENCE ADVISER
ATTN AETT SA
APO AE 09114

1 CDR
HHC SOUTHERN EUROPEAN
TASK FORCE
ATTN AESE SA BLDG 98
AMC FAST SCIENCE ADVISER
APO AE 09630

1 CDR US ARMY PACIFIC
AMC FAST SCIENCE ADVISER
ATTN APSA
FT SHAFTER HI 96858-5L00

NO. OF
COPIES ORGANIZATION

1 AMC FAST SCIENCE ADVISERS
PCS #303 BOX 45 CS-SO
APO AP 96204-0045

1 ENGINEERING PSYCH LAB
DEPT OF BEHAVIORAL
SCIENCES & LEADERSHIP
BLDG 601 ROOM 281
US MILITARY ACADEMY
WEST POINT NY 10996-1784

1 DIR
SANDIA NATL LAB
ENGNRNG MECHANICS DEPT
MS 9042 ATTN J HANDROCK
Y R KAN J LAUFFER
PO BOX 969
LIVERMORE CA 94551-0969

1 DR SEHCHANG HAH
WM J HUGHES TECH CTR FAA
NAS HUMAN FACTORS BR
ACT-530 BLDG 28
ATLANTIC CITY INTNATL
AIRPORT NJ 08405

1 US ARMY RSCH INST
ATTN PERI IK D L FINLEY
2423 MORANDE STREET
FORT KNOX KY 40121-5620

1 NAIC/DXLA
4180 WATSON WAY
WRIGHT PATTERSON AFB OH
45433-5648

1 TACTICAL SHOOTER
ATTN J D TAYLOR
222 MCKEE ST
MANCHESTER CT 06040

10 ARL HRED AVNC FLD ELMT
ATTN AMSRL HR MJ D DURBIN
PO BOX 620716
BLDG 4506 (DCD) RM 107
FT RUCKER AL 36362-5000

1 ARL HRED AMCOM FLD ELMT
ATTN AMSRL HR MI D FRANCIS
BLDG 5464 RM 202
REDSTONE ARSENAL AL
35898-5000

NO. OF
COPIES ORGANIZATION

1 ARL HRED AMCOM FLD ELMT
ATTN AMSRL HR MO T COOK
BLDG 5400 RM C242
REDSTONE ARS AL 35898-7290

1 ARL HRED USAADASCH FLD ELMT
ATTN AMSRL HR ME
K REYNOLDS
ATTN ATSA CD
5800 CARTER ROAD
FORT BLISS TX 79916-3802

1 ARL HRED ARDEC FLD ELMT
ATTN AMSRL HR MG R SPINE
BUILDING 333
PICATINNY ARSENAL NJ
07806-5000

1 ARL HRED ARMC FLD ELMT
ATTN AMSRL HR MH C BURNS
BLDG 1002 ROOM 206B
1ST CAVALRY REGIMENT RD
FT KNOX KY 40121

1 ARL HRED CECOM FLD ELMT
ATTN AMSRL HR ML J MARTIN
MYER CENTER RM 2D311
FT MONMOUTH NJ 07703-5630

1 ARL HRED FT BELVOIR FLD ELMT
ATTN AMSRL HR MK P SCHOOL
10170 BEACH RD
FORT BELVOIR VA 22060-5800

1 ARL HRED FT HOOD FLD ELMT
ATTN AMSRL HR MV HQ USAOTC
E SMOOTZ
91012 STATION AVE ROOM 111
FT HOOD TX 76544-5073

1 ARL HRED FT HUACHUCA
FIELD ELEMENT
ATTN AMSRL HR MY M BARNES
GREELY HALL BLDG 61801 RM 2631
FT HUACHUCA AZ 85613-5000

1 ARL HRED FLW FLD ELMT
ATTN AMSRL HR MZ A DAVISON
3200 ENGINEER LOOP STE 166
FT LEONARD WOOD MO 65473-8929

NO. OF
COPIES ORGANIZATION

- 1 ARL HRED NATICK FLD ELMT
ATTN AMSRL HR MQ M R FLETCHER
NATICK SOLDIER CTR BLDG 3
RM 341 AMSSB RSS E
NATICK MA 01760-5020
- 1 ARL HRED OPTEC FLD ELMT
ATTN AMSRL HR MR H DENNY
ATEC CSTE PM ARL
4501 FORD AVE RM 870
ALEXANDRIA VA 22302-1458
- 1 ARL HRED SC&FG FLD ELMT
ATTN AMSRL HR MS R ANDERS
SIGNAL TOWERS RM 303A
FORT GORDON GA 30905-5233
- 1 ARL HRED STRICOM FLD ELMT
ATTN AMSRL HR MT A GALBAVY
12350 RSCH PARKWAY
FT LEAVENWORTH KS 66027-2326
- 1 ARL HRED TACOM FLD ELMT
ATTN AMSRL HR MU
M SINGAPORE
6501 E 11 MILE RD MAIL STOP 248
WARREN MI 48397-5000
- 1 ARL HRED USAFAS FLD ELMT
ATTN AMSRL HR MF L PIERCE
BLDG 3040 RM 220
FORT SILL OK 73503-5600
- 1 ARL HRED USAIC FLD ELMT
ATTN AMSRL HR MW E REDDEN
BLDG 4 ROOM 332
FT BENNING GA 31905-5400
- 1 ARL HRED USASOC FLD ELMT
ATTN AMSRL HR MN R SPENCER
DCSFDI HF
HQ USASOC BLDG E2929
FORT BRAGG NC 28310-5000
- 1 ARL HRED HFID FLD ELMT
ATTN AMSRL HR MP
D UNGVARSKY
BATTLE CMD BATTLE LAB
415 SHERMAN AVE UNIT 3
FT LEAVENWORTH KS 66027-2326

NO. OF
COPIES ORGANIZATION

- 1 CDR AMC - FAST
JRTC & FORT POLK
ATTN AFZX GT DR J AINSWORTH
CMD SCIENCE ADVISOR G3
FORT POLK LA 71459-5355
- ABERDEEN PROVING GROUND
- 2 DIRECTOR
US ARMY RSCH LABORATORY
ATTN AMSRL CI LP (TECH LIB)
BLDG 305 APG AA
- 1 LIBRARY
ARL BLDG 459
APG-AA
- 1 ARL HRED
ATTN AMSRL HR MB
F PARAGALLO
BLDG 459
APG-AA
- 1 US ATEC
RYAN BLDG
APG-AA
- 1 CDR
CHEMICAL BIOLOGICAL &
DEF CMD
ATTN AMSCB CI
APG-EA
- 1 CDN ARMY LO TO ATEC
ATTN AMSTE CL
RYAN BLDG

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE September 2001		3. REPORT TYPE AND DATES COVERED Final	
4. TITLE AND SUBTITLE Assessment of Crew Workload for the RAH-66 Comanche Force Development Experiment 1				5. FUNDING NUMBERS AMS Code 622716 Project No. AH70	
6. AUTHOR(S) Durbin, D.B. (ARL)					
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Laboratory Human Research & Engineering Directorate Aberdeen Proving Ground, MD 21005-5425				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Research Laboratory Human Research & Engineering Directorate Aberdeen Proving Ground, MD 21005-5425				10. SPONSORING/MONITORING AGENCY REPORT NUMBER ARL-TN-183	
11. SUPPLEMENTARY NOTES					
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.				12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Crew workload was assessed during the RAH-66 Comanche Force Development Experiment (FDE) 1. The purpose was to determine if (a) the pilots experienced tolerable and comparable workload levels when flying the aircraft versus operating the mission equipment package (MEP), and (b) workload levels contribute to a need to "battle roster" Comanche pilots. Workload data were collected via the Bedford Workload Rating Scale and a cockpit controls and displays usability questionnaire. Results of the assessment indicate that (a) workload was tolerable for the pilots, (b) workload was moderately higher for the pilots when they operated the MEP, and (c) there is no compelling need to prescribe battle rostering because pilots experienced only moderate differences in workload when they flew the aircraft versus when they operated the MEP.					
14. SUBJECT TERMS Army aviation crew workload RAH-66 Comanche workload				15. NUMBER OF PAGES 65	
				16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified		20. LIMITATION OF ABSTRACT	