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Human Factors Engineering #3 Crewstation Assessment for the OH-58F Helicopter

by David B. Durbin, Jamison S. Hicks, and Anthony W. Morris

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14. ABSTRACT
An assessment was conducted to identify design characteristics of the OH-58F crewstation that enhanced or degraded pilot performance. Aircrew workload, aircrew situation awareness, the crewstation interface, visual gaze and dwell times (using a head-eye tracker), and the potential for pilot simulator sickness were assessed in an OH-58F simulator. Pilots flew missions based on a battlefield environment simulating southwest Asia. Each successive mission increased in difficulty in order to impose progressively greater workload on the pilots. Pilots reported that workload was manageable for the tasks they performed during the missions. The overall workload ratings provided by the pilots and subject matter experts (SMEs) were lower than the Objective and Threshold workload rating requirements listed in the OH-58F Capability Development Document. The pilots reported that they had moderate levels of situation awareness during the missions. They commented that the crewstation design aided them in conducting navigation, communication and reconnaissance tasks. The pilots recommended that minor design changes be made to the crewstation to enhance usability. The assessment was the third in a series of evaluations to develop and refine the crewstation design. Additional evaluations included human factors modeling, developmental and operational testing.

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1. Introduction

1.1 Purpose and Overview

The U.S. Army Research Laboratory (ARL), Human Research and Engineering Directorate (HRED) conducted a human factors evaluation of the OH-58F Kiowa Warrior Cockpit and Sensor Upgrade Program (KW CASUP) crewstation during 9–20 July 2012 at the Systems Simulation and Development Directorate (SSDD) Apex Laboratory, Redstone Arsenal, AL. The purpose of the evaluation was to identify design characteristics of the crewstation that enhanced or degraded pilot performance. Aircrew workload and situation awareness, the crewstation interface, pilot visual workload, and the potential for pilot simulator sickness were assessed. Additionally, workload was assessed for level of interoperability 2 (LOI 2) tasks that the aircrew performed with an unmanned aircraft system (UAS) during missions. LOI 2 is defined as the "direct receipt of UAS sensor data and metadata". The Human Factors Engineering (HFE) #3 crewstation assessment was the third in a series of crewstation assessments and the first time that LOI 2 with a UAS was evaluated.

The OH-58F crewstation simulator (figures 1 and 2) was used to conduct the evaluation. The human factors evaluation is part of the continuous assessment process to develop and refine the crewstation design. The continuous assessment process includes modeling, simulation, developmental and operational testing.

Pilots received three days of training prior to the beginning of the evaluation. The training was conducted at SSDD and consisted of classroom instruction and hands-on flight training using a desktop simulator and the OH-58F crewstation simulator.

The aircrews flew similar missions during training that they later flew during the record trials. The mission scenarios were based on a battlefield environment simulating southwest Asia. Each successive mission increased in difficulty in order to impose progressively greater workload on the pilots. The aircrews performed route, area, and landing zone/pick-up zone reconnaissance, call-for-fire, and specific Aircrew Training Manual (ATM) tasks with a UAS during missions. Each ATM task has prescribed conditions and standards to which both crewmembers had to perform to ensure mission accomplishment. The pilots rotated seat positions during the assessment.

During the formal evaluation, three sets of aircrews conducted three reconnaissance missions (for a total of nine missions). The missions consisted of flight segments in visual meteorological conditions (VMC), instrument meteorological conditions (IMC), and tactical conditions. The mission scenarios were developed by the Training and Doctrine Command (TRADOC) Capability Manager, Reconnaissance Attack (TCM RA) office, Fort Rucker, AL. The scenarios were developed in accordance with scout aircraft tactics, techniques, and procedures (TTP).

Prior to each mission, the pilots received a briefing about mission goals; at the conclusion of each mission, they completed human factors surveys. Before and after each mission, they completed the Simulator Sickness Questionnaire (SSQ); after each mission, they completed the Bedford Workload Rating Scale (BWRS), and China Lake Situational Awareness (CLSA) rating scale. The pilots completed the Pilot-Crewstation Interface (PCI) questionnaire after they completed all of their missions. During each mission, pilots wore an eye tracker used to assess their visual workload. In addition to the pilot data, subject matter experts (SMEs) provided an independent assessment of aircrew workload, situation awareness, and mission success. After each mission, the SMEs completed an aircrew workload, situation awareness, and mission success survey. After the aircrews completed the mission and surveys, they participated in a mission debriefing and after action review (AAR).

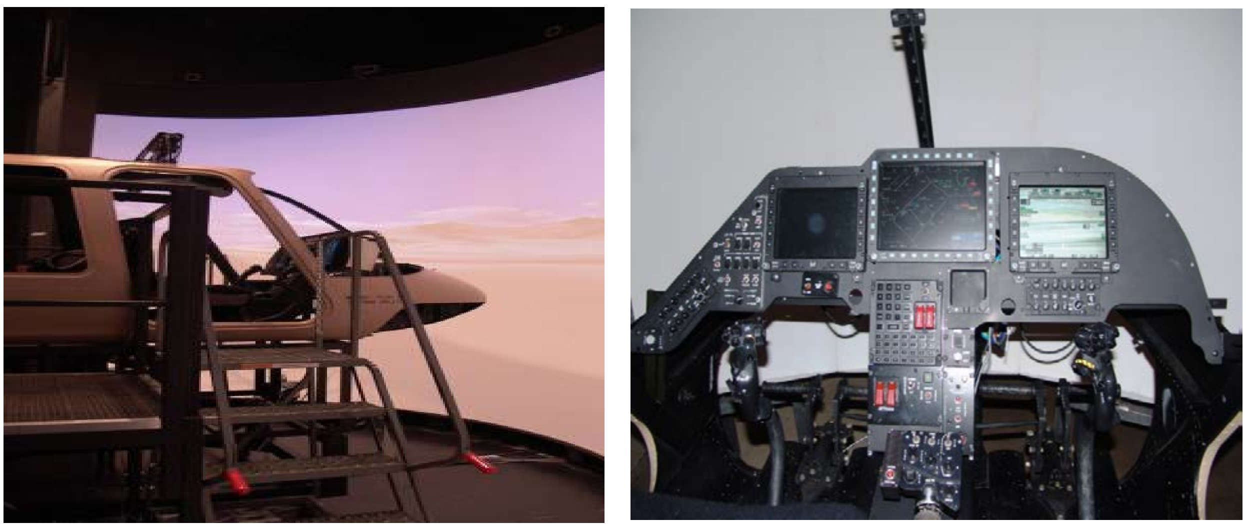

Figure 1. OH-58F crewstation simulator.

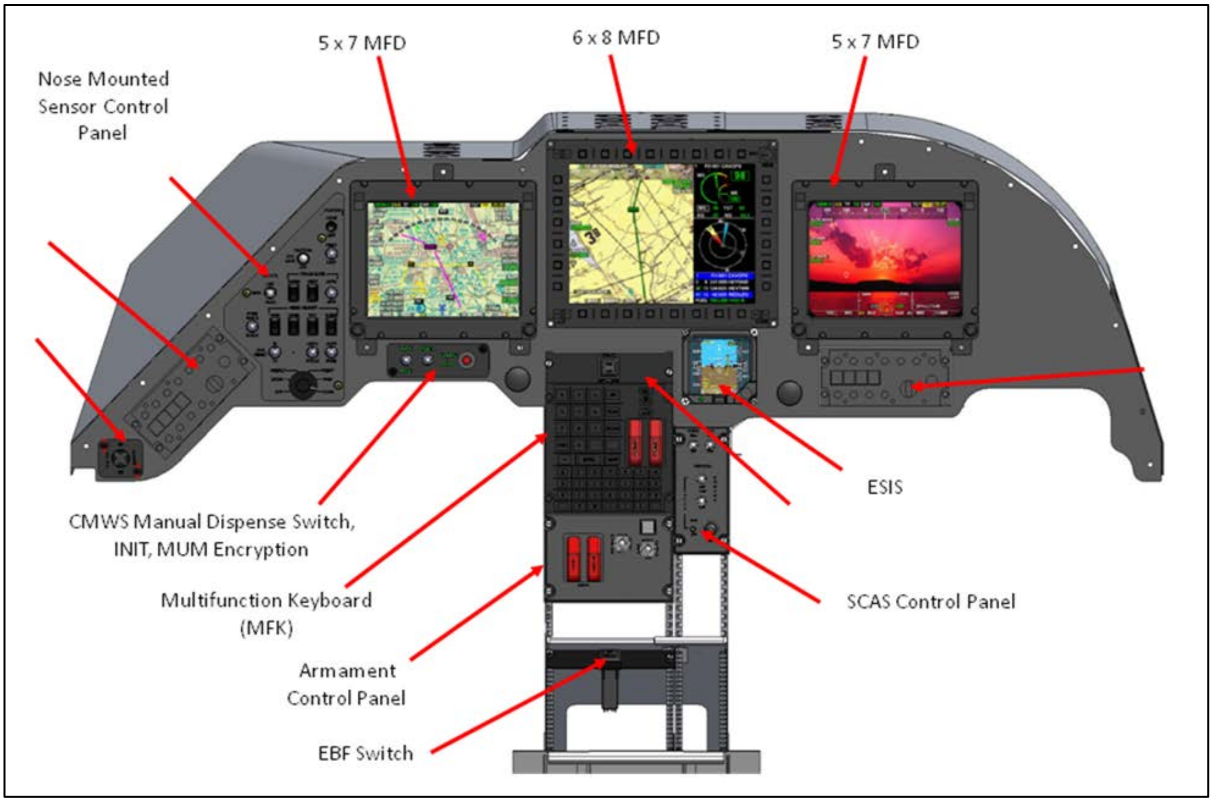

Figure 2. OH-58F instrument panel.

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 excessively high workload while performing flight and mission tasks, the tasks may be performed ineffectively or abandoned. In order to assess whether the pilots are task-overloaded during the mission profiles, the level of workload for each pilot must be evaluated.

1.3 Bedford Workload Rating Scale (BWRS)

The pilots completed the BWRS (appendix A) immediately after each mission to rate the level of workload that they experienced when performing ATM tasks during missions. The ATM tasks (appendix A) were selected by personnel from the TCM RA, ARL HRED, SSDD and the Armed Scout Helicopter Program Managers Office because they were estimated to have the most impact on pilot workload during the missions. SMEs completed the BWRS immediately after each mission to rate overall workload for each pilot. SME workload comments are listed in appendix B.

The BWRS has been used extensively by the military, civil, and commercial aviation communities for pilot workload estimation (Roscoe and 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 scout pilots because they are often required to perform several tasks concurrently. For example, pilots often perform navigation tasks, communicate via multiple radios, monitor aircraft systems, and assist the pilot on the controls with flight tasks (e.g., maintain airspace 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. Integration of the OH-58F crewstation should help ensure that pilots can maintain adequate spare workload capacity while performing flight and mission tasks. The OH-58F has a Capability Development Document (CDD) requirement that aircrew workload not exceed 6.0 (Threshold) and 5.0 (Objective) on the BWRS.

1.4 Visual Workload

An eye tracker was used during the evaluation to assess visual gaze and dwell times for the pilots. The data were collected to help determine how well the design of the crewstation allowed the flying pilot to remain focused outside the aircraft during visual flight rules (VFR) flight and how well the non-flying pilot was able to maintain visual focus outside the aircraft to assist with navigation (e.g., identification of terrain features), local security, terrain flight, etc. Visual gaze and dwell times also help identify if pilots experience excessive visual workload or cognitive capture because they had problems interpreting information presented to them on the crewstation displays.

1.5 Assessment of Crew Situational Awareness (SA)

SA can be defined as the pilot's mental model of the current state of the flight and mission environment. A more formal definition is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future" (Endsley, 1988). It was important to assess SA because it had a direct impact on pilot and system performance. Good SA should increase the probability of good decision-making and performance by aircrews when conducting flight and mission tasks in the OH-58F.

1.6 China Lake Situational Awareness (CLSA) Scale

The CLSA (appendix C) is a unidimensional rating scale for pilots to report their perceived SA. The CLSA uses a five-point scale that requires pilots to rate their knowledge of aircraft energy state, tactical environment and mission, ability to anticipate and accommodate trends, and if they shed tasks during the mission.

1.7 Assessment of the Pilot-Crewstation Interface (PCI)

The PCI directly affects aircrew workload and SA during a mission. A crewstation that is designed to augment the cognitive and physical abilities of crews will minimize workload, enhance SA, and contribute to successful mission performance. The pilots completed a PCI questionnaire (appendix D) to identify any problems with the usability of the controls, displays, or subsystems.

1.8 Assessment of Simulator Sickness

Simulator sickness has been defined as a condition where pilots suffer physiological discomfort in the simulator, but not while flying the actual aircraft (Kennedy et al., 1989). It is generally believed that simulator sickness is caused by a mismatch either between the visual and vestibular sources of information about self-motion, or between the sensory information (e.g., acceleration cues) presented by the simulator and the sensory information presented by the primary aircraft that the pilot operates. When the sensory information presented by the simulator does not match the aircraft, the pilot's nervous system reacts adversely to the sensory mismatch and the pilot begins to experience discomfort. Characteristics of simulator sickness include nausea, dizziness, drowsiness and several other symptoms (Kennedy et al., 1989). It is important to assess simulator sickness because the discomfort felt by pilots can be distracting. Pilot distraction is one of the operational consequences of simulator sickness listed by Crowley (1987). If pilots are distracted by the discomfort they feel during missions, their performance is likely to suffer. Additionally, the discomfort could influence the perceived levels of workload and SA that the pilots experienced during a mission.

1.9 Simulator Sickness Questionnaire (SSQ)

The SSQ was administered to the pilots to estimate the severity of physiological discomfort that they experienced during missions and help assess whether they were being distracted by the discomfort. The SSQ (Kennedy et al., 1993) is a checklist of 16 symptoms. The 16 symptoms are categorized into three subscales. The subscales are Oculomotor (e.g., eyestrain, difficulty focusing, blurred vision), Disorientation (e.g., dizziness, vertigo), and Nausea (e.g., nausea, increased salivation, burping). The three subscales are combined to produce a Total Severity score. The Total Severity score is an indicator of the overall discomfort that the pilots experienced during the mission.

1.10 Subject Matter Experts (SMEs)

Three SMEs typically observed the missions and rated crew workload, crew SA, and mission success. The SMEs provided an independent assessment of the workload and SA levels experienced by the crews. They also helped identify whether problems with crew workload or crew SA contributed to lack of mission success.

The SMEs were TCM RA personnel who had substantial experience conducting armed reconnaissance missions and were familiar with the OH-58F crewstation. They observed each mission from the Battlemaster station where they could monitor crewstation displays and the out-the-window (OTW) view provided to the crew. They also listened to all audio communications between crewmembers and outside sources during the missions.

An additional SME was used during the crewstation assessment to perform the role of Ground Control Station operator. The SME was from TCM Unmanned Aircraft Systems. He controlled the UAS aircraft and payload and conducted sensor scans for the pilots.

1.11 Simulation Environment

SSDD provides modeling and simulation support of weapon systems early in the acquisition process. This is accomplished through several methods, including man-in-the-loop simulators, distributed simulation experimentation, and constructive simulation development in the SSDD Apex Laboratory.

The Advanced Prototype Engineering and Experimentation (APEX) Lab is High-Level Architecture (HLA) and Distributed Interactive Simulation (DIS) compliant, and has the capability to connect to the Army's Battle Labs and other distributed simulation facilities through the Defense Research and Engineering Network (DREN).

The APEX Lab includes a Battlemaster control center that has access to each simulation playing on the network by means of a One Semi-Automated Forces (OneSAF) test bed terminal, data collection devices, headset communications, and video monitoring. All exercises are controlled from the Battlemaster station to ensure that all players are engaged in the exercise and all data collection devices are active. Time coordination and time stamping of video collection devices is achieved through an integrated Global Positioning System (GPS) clock. Audio and video are captured and routed throughout the lab and various conference rooms through a custom video capture and switching system.

The APEX Lab has a complete synthetic environment development team that is able to develop custom, correlated terrain databases that are designed to specifically enhance realism of the immersive environment and support operational scenarios for each event. The Battlefield Highly Immersive Visual Environment (BHIVE) provides this immersiveness with high-fidelity OTW terrain databases and image generators. The BHIVE was developed in support of weapon system evaluation in an HLA/DIS compliant, man-in-the-loop, virtual environment. It was designed with a roll-in/roll-out capability to allow integration of several types of devices into the environment through a standard interface. This provides the flexibility to immerse multiple types of cockpits in a realistic and reusable synthetic world. Six projectors are used to project the OTW view onto an 180° × 60° directional curved dome. The projection system is capable of edge blending for high-definition synthetic environments.

2. Method

2.1 Pilots

Six pilots participated in the crewstation assessment. The pilots were warrant officers and rated in the OH-58D. Three pilots held the rank of CW2 and three pilots held the rank of CW4. They were from the 2-6 CAV (25ID), 7-17 CAV (159 CAB), 1-13th AVN (Directorate of Evaluation and Standardization), 2-17 CAV, and 2-6 CAV. The pilots represented a broad range of experience with their total flight hours ranging from 500–4200 h. The relevant demographic characteristics of the pilots are listed in table 1.

Table 1. Pilot demographics (N = 6).

Summary of Demographic Characteristics	Age (years)	Flight Hours in OH-58D	Total Flight Hours in Army Aircraft
Mean	33.0	2121	2232
Median	32.5	2088	2145
Range	26–42	400–3850	500–4200

2.2 Data Collection

The pilot questionnaires were developed in accordance with published guidelines for proper format and content (O'Brien and Charlton, 1996). A pretest was conducted to refine the questionnaires and to ensure that they could be easily understood and completed by pilots and SMEs.

The pilots completed the workload and SA questionnaires after each mission. They completed the SSQ before and after each mission. The pilots completed the PCI questionnaire after they completed all of their missions. The SMEs completed questionnaires after each mission. Additional data were obtained from the pilots and the SME members during post-mission discussions and the final AAR. Questionnaire results were clarified with information obtained during post-mission discussions and the final AAR.

2.3 Eye Tracker System

Pilot visual gaze and dwell times were collected with an eye tracking system (Model 501) from Applied Science Laboratories (ASL) and a head tracking system (Polaris Spectra) from Northern Digital Incorporated (NDI). These systems were used because they allowed unrestricted head movement during data collection and were compatible with the HGU-56 flight helmet worn by the pilots. This technology allowed the collection of digital data that specified point of gaze with respect to stationary objects within the crewstation. The ASL software allowed data collectors to continuously monitor the eye position of the pilots by crosshairs superimposed over live imagery (figure 3). The software also included a built-in analysis tool that allowed data to be viewed in tabular or graphical format.

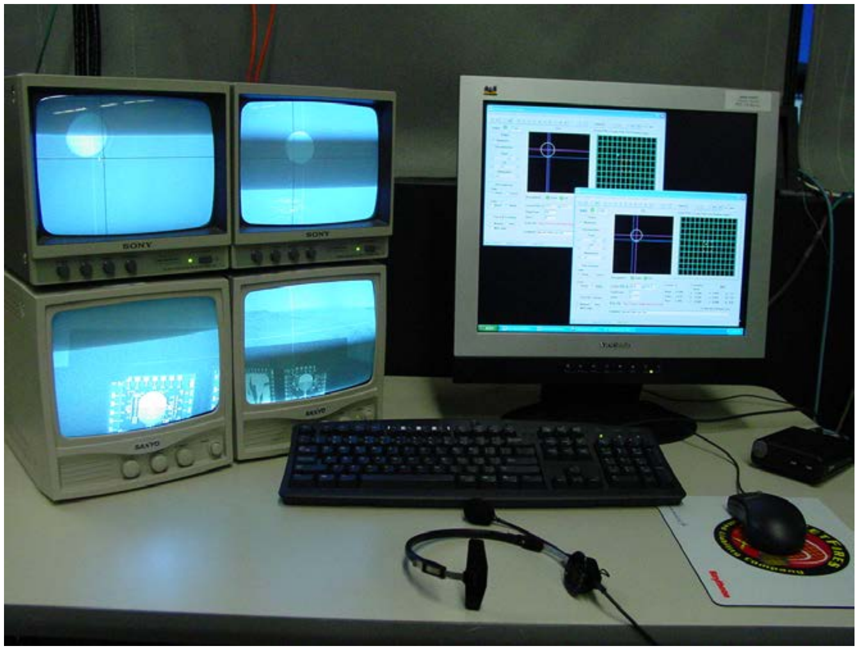

Figure 3. Eye tracker scene camera monitors and control panel interface.

2.4 Data Analysis

Pilot responses to the BWRS, CLSA, SSQ, and PCI questionnaires were analyzed with means and percentages. The eye tracker data were summarized by calculating the total percentage of fixations that occurred for the different areas of interest (AOI). Eight AOIs were created for the pilot and copilot: 5 × 7 multifunctional display (MFD), 6 × 8 MFD, kneeboard (both pilots), OTW, lower console, and outer left instrument panel (copilot). A final category, called "Other," captured eye fixations not focused on a specific AOI. Results of the eye tracker data are listed in figure 4.

2.5 Evaluation Limitations

Limitations included the small sample size of pilots (N=6) who participated in the crewstation simulation assessment, limited amount of training provided to the pilots, and hardware/software limitations. The primary hardware and software limitations are listed below:

- Built-In Test (BIT) functions were not available
- Hands-On Grip (HOG) functional for Joint Variable Message Format (JVMF) free text only
- Video Tape Recorder (VTR) was nonfunctional

- Health Usage Monitoring System (HUMS) was not available
- Display map did not have Controlled Image Base (CIB) and 12.5 software functionality
- Pulse Interval Module (PIM) codes were not available
- Satellite Demand Assigned Multiple Access (DAMA) and frequency hop were nonfunctional
- Video rocker switches were nonfunctional
- Hellfire was functional in lock-on-before-launch (LOBL) mode only
- Certain display font sizes were slightly inaccurate
- Video rocker switches were nonfunctional
- Collective throttle was nonfunctional
- Feature track is the only mode that will allow tracking a building
- Stability Control Augmentation System (SCAS) was nonfunctional
- Circuit breaker panels were nonfunctional and not representative of final design
- Nose-mounted sensor (NMS) Linear Motion Control did not function if the NMS was pointed off the ground

These limitations are common because of funding and time constraints as well as replicating a complex aviation system in a simulator. However, the information and data listed in the Results and Summary sections of this report should be interpreted based on these limitations. Additional data should be collected during future simulations and tests to augment and expand the findings contained in this report.

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3. Results

3.1 Crew Workload

3.1.1 Mean Workload Ratings For Flight and Mission Tasks

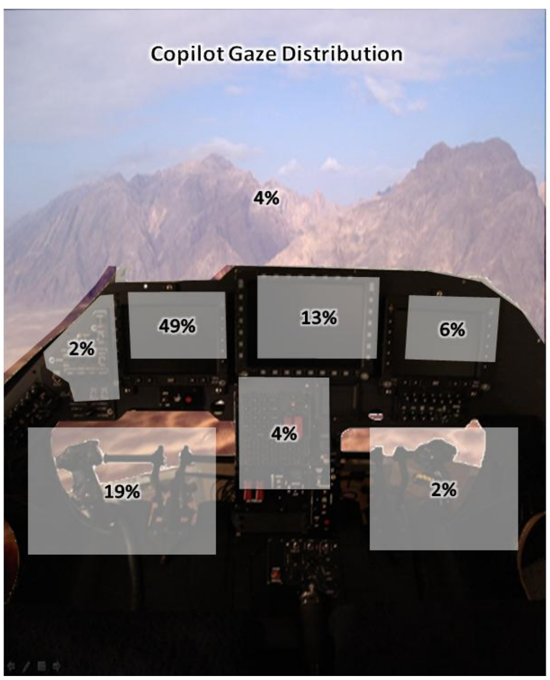
The average mission workload rating was 2.56 for the pilot and 3.44 for the copilot (figure 5). These ratings indicate that the pilots and copilots typically felt that workload was tolerable for all flight and mission tasks they performed during the missions. Additionally, the ratings indicate that the pilots and copilots typically felt they had enough spare workload capacity to perform all desirable additional tasks (within the same time interval) during missions. The average workload ratings for LOI 2 with the UAS were 2.67 for the pilot and 3.00 for the copilot. Based on these ratings and post-mission discussions with the aircrew, the addition of UAS LOI 2 tasks do not appear to significantly increase workload for the pilot and copilot during missions.

The average workload ratings for flight and mission tasks (appendix A) provided by the pilots and copilots were lower than the Objective (5.0) and Threshold (6.0) BWRS workload rating requirements contained in the OH-58F CDD except for the task "Perform an Autorotation."

During one mission, the copilot helped perform an autorotation and provided a workload rating of "5" for the task. He commented that the higher workload he experienced during the autorotation was due to the intensive nature of the task and that no additional tasks could be performed in order to safely land the aircraft.

3.1.2 SME Workload Ratings

SMEs provided an overall Bedford workload rating for each pilot during each mission that they observed. The average SME Bedford workload rating (figure 4) was 3.26 for the pilot and 4.48 for the copilot for all missions. These ratings indicate that the SMEs believed that workload was tolerable for the pilots and copilots with insufficient spare capacity for easy attention to additional tasks for the copilots. The ratings are lower than the Objective (5.0) and Threshold (6.0) BWRS workload rating requirements contained in the OH-58F CDD.



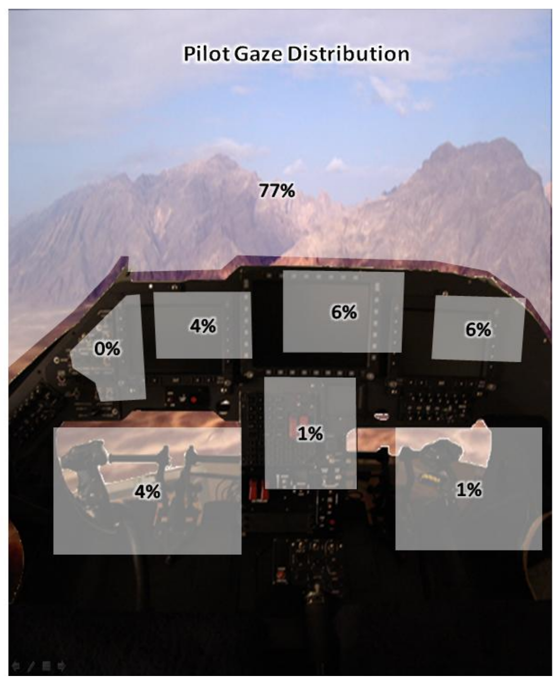


Figure 4. Pilot and copilot visual gaze and dwell times.

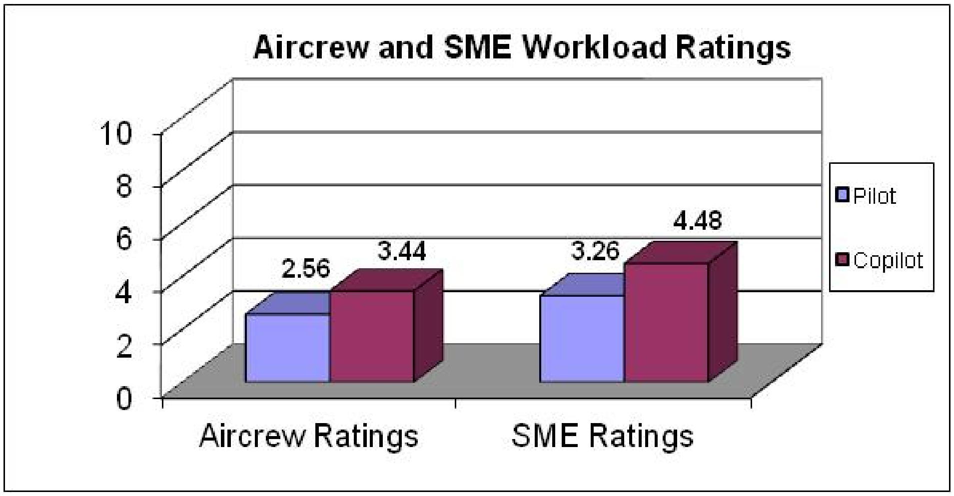


Figure 5. Aircrew and SME workload ratings.

3.1.3 Workload Comparison for HFE #1, HFE #2, and HFE #3 Crewstation Assessments

The average overall aircrew and SME workload ratings for the three crewstation simulation assessments (HFE #1, HFE #2, and HFE #3) are listed below (table 2). These ratings indicate that the pilots, copilots, and SMEs typically felt that workload was tolerable for all flight and mission tasks that were performed during the missions. Additionally, the ratings indicate that the pilots and copilots typically felt they had enough spare workload capacity to perform all desirable additional tasks during missions. The SME workload ratings indicate that they felt that the copilots often had insufficient spare capacity for easy attention to additional tasks. The workload ratings for HFE #1, HFE #2, and HFE #3 were lower than the Objective (5.0) and Threshold (6.0) BWRS workload rating requirements contained in the OH-58F CDD.

Table 2. Average workload ratings for crewstation assessments.

Aircrew and SME Workload Ratings	HFE #1	HFE #2	HFE #3
Aircrew Workload Ratings	Pilot – 3.0 Copilot – 3.17	Pilot – 2.75 Copilot – 3.38	Pilot – 2.56 Copilot – 3.44
SME Workload Ratings	Pilot – 3.88 Copilot – 4.00	Pilot – 3.31 Copilot – 3.46	Pilot – 3.26 Copilot – 4.48
CDD Workload Requirement "Combined mission workload tasks not to exceed Bedford workload rating of 5.0 (Objective) and 6.0 (Threshold)"			

3.1.4 Visual Workload

Figure 5 shows the percentage of time that the pilots were visually focused (during VFR flight) on each AOI during the missions. It is interesting to note that the copilots typically spent only 4% of the time visually focused OTW during missions. The copilot needs to periodically maintain visual focus outside the aircraft to assist with navigation (e.g., identification of terrain and cultural features) and airspace surveillance. The percentage of time that the copilot maintained visual focus outside the aircraft was about the same as it was during the HFE #1 crewstation assessment (table 3). Maintaining visual focus outside the aircraft for only 4% of a typical zone reconnaissance mission is likely too low a percentage of time to adequately assist the pilot with crew tasks such as obstacle avoidance and terrain flight navigation. The low percentage of time that the copilots were visually focused outside the aircraft was mostly due to the workload required to manage information on the crewstation displays, operate the NMS and the lack of in-depth experience that the copilots had with the crewstation interface. It will be important to assess visual gaze during the Limited User Test and Initial Operational Test and Evaluation to determine if copilot workload precludes maintaining adequate visual focus outside the aircraft.

Table 3. Comparison of eye tracker results for OH-58F, AH-64D and ARH simulations.

	AH-64D/UAS Workload Assessment (Block III)		AH-64D Workload Assessment (Block III)		ARH[a] HFE-CAAS[b] Evaluation		OH-58F HFE #1 Evaluation		OH-58F HFE #2 Evaluation		OH-58F HFE #3 Evaluation	
	Flying Pilot (%)	**Non-Flying Pilot (%)**	**Flying Pilot (%)**	**Non-Flying Pilot (%)**	**Flying Pilot (%)**	**Non-Flying Pilot (%)**	**Flying Pilot (%)**	**Non-Flying Pilot (%)**	**Flying Pilot (%)**	**Non-Flying Pilot (%)**	**Flying Pilot (%)**	**Non-Flying Pilot (%)**
Outside	75	4	75	6	75	3	61	7	50	14	77	4
Inside	25	96	25	94	25	97	39	93	50	86	23	96

[a]Armed reconnaissance helicopter. [b]Common Aviation Architecture System.

The pilots typically spent 77% of the time visually focused OTW during VFR flight. The amount of time (77%) that the pilots were visually focused outside the aircraft was higher than in the HFE #1 and HFE #2 crewstation assessments.

3.1.5 Comparison of Eye Tracker Data

Table 3 shows a comparison of OH-58F, AH-64D, and ARH eye tracker data for VFR flight during simulations. While the simulator, missions, and personnel experience levels were different for each simulation evaluation, it is interesting to note that the flying pilot maintained visual gaze and dwell times outside of the crewstation for 50% to 77% of the time and the non-flying pilot for 4% to 14% of the time during missions.

3.2 Crew SA

3.2.1 Pilot and Copilot SA Ratings

The pilots and copilots reported that they typically experienced good SA during missions, were able to maintain knowledge of the aircraft energy state, tactical environment and mission, were able to partially anticipate and accommodate trends, and had minimal task shedding (due to high workload) during the missions. The pilots and copilots typically reported "fairly high" to "very high" levels of SA for the location of their ownship during missions, route information (e.g., phase lines), location of friendly and enemy units, cultural features, and status of the aircraft systems (e.g., fuel consumption). Table 4 compares SA ratings for the HFE #1, HFE #2, and HFE #3 crewstation assessments. For all assessments, the pilots and copilots reported that they typically experienced good SA during missions. The CLSA rating scale is on page 32 for reference.

Table 4. Aircrew SA ratings for crewstation assessments.

HFE #1	**HFE #2**	**HFE #3**
Pilot – 2.55 Copilot – 2.33	Pilot – 2.50 Copilot – 2.75	Pilot – 1.67 Copilot – 2.22

3.2.2 SME SA Ratings

The SMEs provided an independent assessment of SA based on the scale shown in table 5. The mean SME SA rating was 2.85. This indicates that the SMEs believed that the crews typically had adequate levels of SA with some variation between aircrew perception of entities on the battlefield and reality. During several mission segments, some crews or individual crewmembers had reduced SA. The SMEs made several comments that crew fixation on the NMS imagery and maps displayed on the MFDs, lack of experience using a UAS to perform reconnaissance tasks, low experience levels of young pilots, and periods of increased workload reduced overall aircrew SA during several mission segments. Table 6 compares SA ratings for the HFE #1, HFE #2, and HFE #3 crewstation assessments. The ratings indicate that the SMEs believed that the crews typically had adequate levels of SA with some variation between aircrew perception of entities on the battlefield and reality during the three assessments.

Table 5. SME SA rating.

SME SA Ratings

1. Crew was consistently aware of all entities on the battlefield.
2. Crew was aware of the battlefield with minor or insignificant variation between perception and reality.
3. Crew was aware of the battlefield. Variation between reality and perception did not significantly impact mission success.
4. SA needs improvement. Lack of SA had some negative effect on the success of the mission.
5. Lack of SA caused mission failure.

Mean Rating
2.85
(SD = 1.16)

Table 6. SME SA ratings for crewstation assessments.

HFE #1	HFE #2	HFE #3
2.77	2.54	2.85

3.3 SME Mission Success Ratings

At the end of each mission, SMEs rated whether the mission was a success or failure. The criteria that the SME used to rate mission success or failure was whether the aircrew completed the mission requirements and did not get shot down or crash. The SMEs rated all of the missions (100%) as "successful" and "objectives completed" (figure 6).

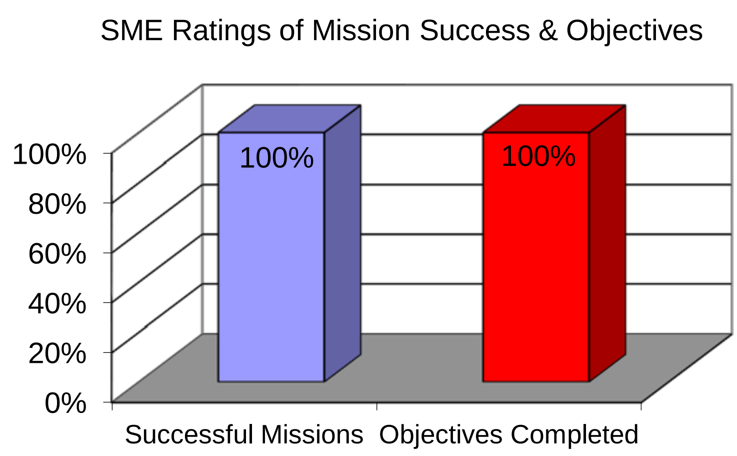


Figure 6. SME ratings of mission success and objectives.

3.4 Pilot-Crewstation Interface (PCI)

The pilots were mostly favorable in their ratings of the crewstation interface (appendix D). They reported they were able to effectively use the MFD pages and functions, quickly navigate through the pages, subpages and overlays on the crewstation displays, easily use the switches on the cyclic and collective and easily use the switches to control the NMS. They also reported that it was easy to detect the Warnings, Cautions, and Advisories on the MFD and entry into operational limits. The pilots reported that the control display system (CDS) 5 software was quicker and easier to use compared to the CDS 4 software. They also reported that the 6 × 8 display enhanced SA and that NMS functionality is an improvement versus the mast-mounted sight (MMS) on the OH-58D Kiowa Warrior. The pilots reported several minor crewstation improvements that should be made to the OH-58F (see appendix E).

3.5 Simulator Sickness

The pilots and copilots reported that they typically experienced very mild simulator sickness symptoms during the evaluation. The overall mean Total Severity (TS) score (post mission) for the pilots and copilots was 7.48 (table 7). The mean TS score for the pilot was 6.23 and the mean TS score for the copilot was 8.73. When flying the aircraft, the pilots were visually immersed in the changing scene outside the aircraft and often transitioned their visual gaze inside the aircraft to monitor information displayed on the MFDs. The copilots primarily maintained their visual gaze inside the aircraft to monitor and input data into their MFDs. All pilots commented that the simulator sickness symptoms were typically very mild. Overall, the simulator did not appear to induce debilitating simulator sickness symptoms and should continue to be a suitable simulation environment for future training and assessments.

Table 7. Simulator SSQ ratings.

Condition	Nausea Subscale	Oculomotor Subscale	Disorientation Subscale	Total Severity Score (Mean)
Premission pilot	1.06	1.68	0	1.25
Premission copilot	1.06	2.53	0	1.66
Post mission pilot	5.30	5.90	4.64	6.23
Post mission copilot	10.60	8.42	1.55	8.73
Post mission combined (pilot and copilot)	7.95	7.16	3.09	7.48

3.5.1 Comparison of OH-58F Simulator SSQ Scores to Other Helicopter Simulators

To assess whether the SSQ ratings provided by the pilots during the HFE assessment were similar or different to ratings obtained in other helicopter simulators, the mean SSQ scores for the OH-58F simulator were compared to the mean SSQ scores for several other helicopter simulators (table 8). The other helicopter simulators were the ARH, OH-58F (HFE #1 and

HFE #2), S-3H, Sikorsky RAH-66 Engineering Development Simulator (EDS), RAH-66 Comanche Portable Cockpit (CPC), the simulator used during the UH-60M from the Early User Demonstration (EUD) and Limited Early User Evaluation (LEUE), AH-64D, CH-46E, and CH-53F. These simulators typically induced very mild to mild simulator sickness symptoms in pilots.

Table 8. Comparison of OH-58F simulator SSQ ratings with other helicopter simulators.

Simulator	Nausea Subscale	Oculomotor Subscale	Disorientation Subscale	Total Severity Score (Mean)
ARH Simulator	18.02	21.48	9.28	20.15
OH-58F Simulation #2	8.86	21.32	18.91	19.23
SH-3H	14.70	20.00	12.40	18.80
OH-58F Simulation #1	16.43	12.21	10.05	15.16
RAH-66 EDS	11.84	14.98	4.54	13.25
CH-53F	7.50	10.50	7.40	10.00
RAH-66 CPC	3.29	12.94	7.89	9.80
UH-60M (LEUE)	6.36	11.81	3.09	9.15
AH-64D – IUAS (RACRS)	9.01	7.58	4.64	8.51
UH-60M (EUD)	13.88	6.89	0	8.50
OH-58F Simulation #3	**7.95**	**7.16**	**3.09**	**7.48**
CH-46E	5.40	7.80	4.50	7.00
AH-64D VUIT-2 (RACRS)	3.18	5.05	4.64	4.98

3.6 Crewstation Design Enhancements

Several design enhancements to the OH-58F crewstation displays have been made via the Crewstation Working Group and crewstation simulation assessment process (see figure 7). These enhancements improved the functionality and presentation of display pages to pilots and overall crewstation interface. Examples of the enhancements are improved color-coding of battlefield graphics, reduced number of button presses to display information on MFDs, refinement of the composite map page, and enhanced presentation of operational limits on the Systems Page. Additionally, the Crewstation Working Group and simulation process has aided in the refinement of TTP for OH-58F operational employment.

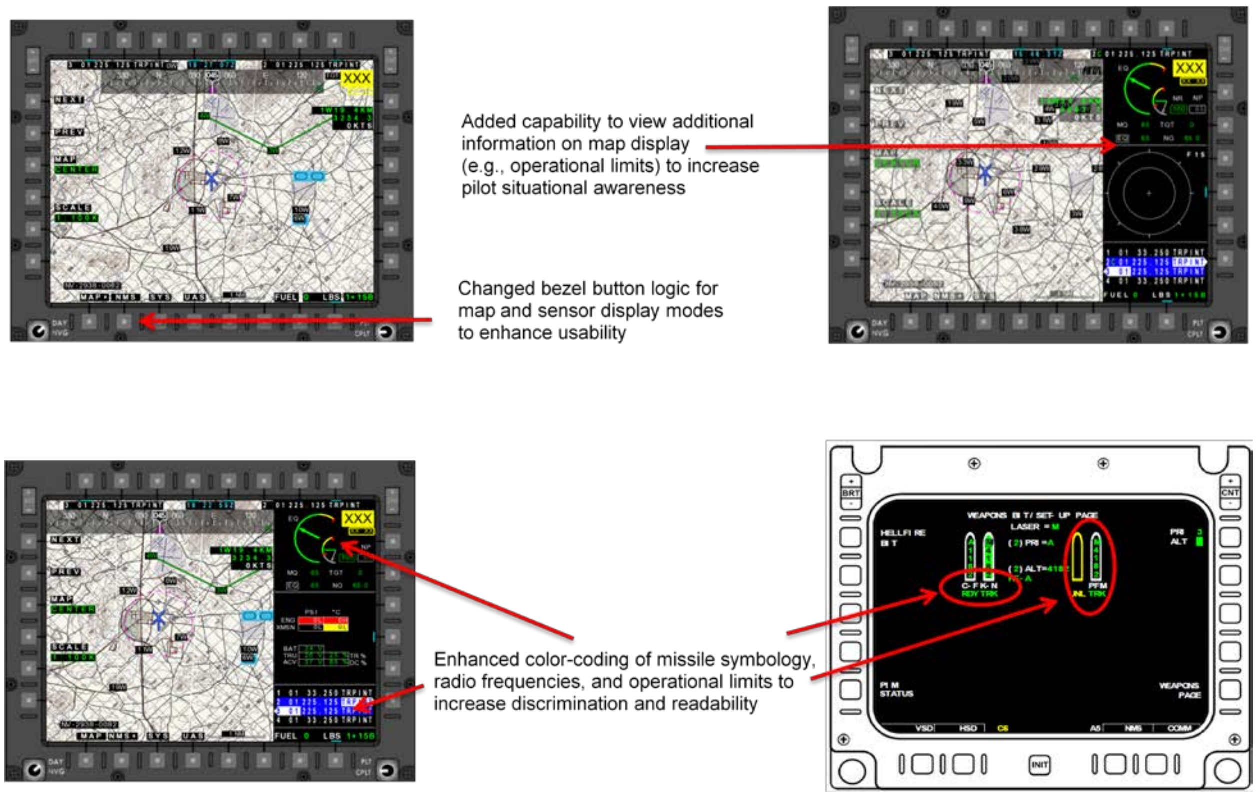


Figure 7. Examples of crewstation design enhancements.

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4. Summary

4.1 Crew Workload

The pilots and copilots reported that workload was manageable for all flight and mission tasks they performed during the missions to include LOI 2 tasks with the UAS. The SMEs reported that workload was manageable for the pilots and copilots. The average mission workload ratings provided by the pilots, copilots, and SMEs were lower than the Objective (5.0) and Threshold (6.0) BWRS workload rating requirements contained in the OH-58F CDD.

4.2 Visual Workload

The copilots typically spent 4% of the time visually focused OTW during VFR flight. The small percentage of time that the copilots were visually focused outside the aircraft was mostly due to the workload required to manage information on the crewstation displays, operate the NMS and the lack of in-depth experience that the copilots had with the crewstation interface. The pilots typically spent 77% of the time visually focused OTW during VFR flight. The amount of time (23%) that the pilots were visually focused inside the aircraft was due to instrument scans, lack of in-depth experience with the crewstation interface, and the "helping behaviors" of the pilots when flying the aircraft. The pilot occasionally helped the copilot manage information on the crewstation displays that kept both of them visually focused inside the crewstation.

4.3 Crew SA

The pilots and copilots reported that they typically experienced good SA during missions, were able to maintain knowledge of the aircraft energy state, tactical environment, and mission, were able to partially anticipate and accommodate trends, and had minimal task shedding (due to high workload) during the missions. They reported that they had fairly high to very high levels of SA of most battlefield elements (e.g., location of their ownship, route information) during the missions. The SMEs reported that the crews typically had adequate levels of SA during missions.

4.4 Pilot-Crewstation Interface (PCI)

The pilots reported they were able to effectively use the MFD pages and functions, quickly navigate through the pages, subpages and overlays on the crewstation displays, easily use the switches on the cyclic and collective, and easily use the switches to control the NMS. They also reported that it was easy to detect the Warnings, Cautions, and Advisories on the MFD and entry into operational limits. The pilots reported that the CDS5 software was quicker and easier to use versus the CDS4 software. They commented that the 6 × 8 display enhanced SA and the NMS functionality is an improvement versus the MMS on the OH-58D Kiowa Warrior.

4.5 Mission Success

All of the missions performed by the aircrews were rated as "successful" by the SMEs who observed each mission.

4.6 Simulator Sickness

The pilots and copilots reported that they typically experienced very mild to mild simulator sickness symptoms during the evaluation. The OH-58F simulator did not induce debilitating simulator sickness symptoms and should continue to be a suitable simulation environment for future assessments and training.

4.7 Simulator Functionality

Simulator functionality was somewhat limited during the HFE #3 assessment. The information and data listed in the Results and Summary sections of this report should be interpreted based on these limitations.

4.8 HFE #1, HFE #2, and HFE #3 Crewstation Assessments

The aircrew workload, SA, and crewstation interface data collected during the HFE #1, HFE #2, and HFE #3 assessments have been helpful in evaluating and refining the crewstation design and refining TTP. These assessments have helped ensure that the aircraft will meet requirements as it progresses toward operational testing and fielding.

5. Recommendations

The following recommendations are made to enhance the overall effectiveness and suitability of the OH-58F crewstation development and assessment process:

- Workload, SA, and crewstation interface data should be collected in the same format (as the crewstation assessments) during operational testing. This will allow direct comparison to assess workload, SA, and the crewstation interface.
- Continue to resolve the PCI issues identified during the HFE simulation assessments.
- Consider using the OH-58F simulator to augment pilot training for the Limited User Test (LUT) and Initial Operational Test and Evaluation.

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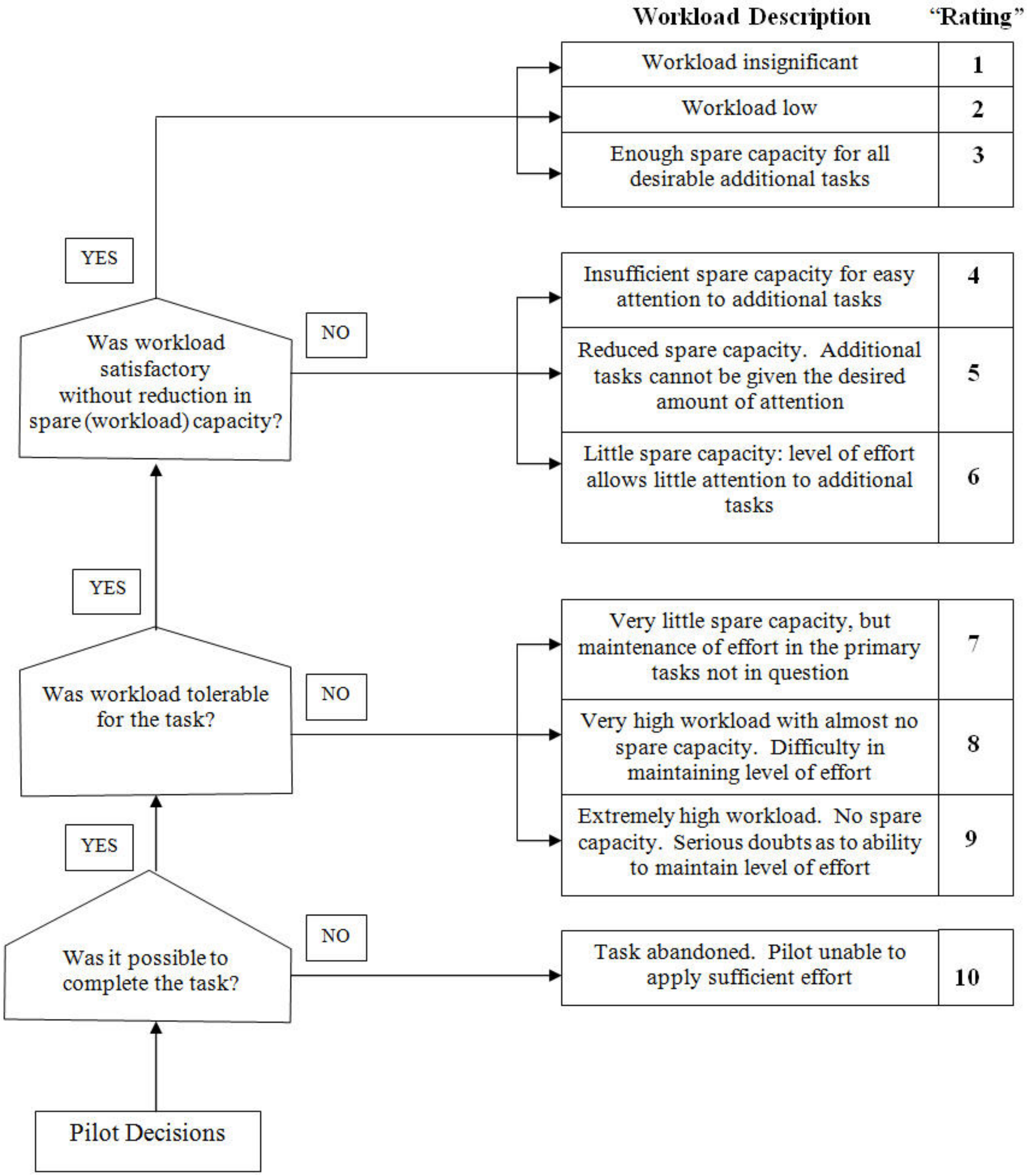
Appendix A. Bedford Workload Rating Scale Scores and Pilot Comments

This appendix appears in its original form, without editorial change.

BEDFORD WORKLOAD RATING SCALE (BWRS)



BEDFORD WORKLOAD RATING SCORES

Task No.	Flight and Mission Tasks	Pilot Workload Rating	Copilot Workload Rating
1026	Maintain Airspace Surveillance	1.11	1.56
1028	Perform Hover Power Check	1.00	1.00
1030	Perform Hover Out-Of-Ground-Effect (OGE) Check	1.33	---
1032	Perform Radio Communication Procedures	1.33	2.56
1038	Perform Hovering Flight	1.86	1.00
1040	Perform Visual Meteorological Conditions (VMC) Takeoff	1.13	1.00
1044	Navigate by Pilotage and Dead Reckoning	1.33	1.25
1046	Perform Electronically Aided Navigation	1.67	2.00
1048	Perform Fuel Management Procedures	1.00	1.11
1052	Perform VMC Flight Maneuvers	1.11	1.00
1058	Perform VMC Approach	1.29	1.00
1066	Perform A Running Landing	1.00	---
1070	Respond to Emergencies	2.38	2.17
1074	Respond to Engine Failure in Cruise Flight	3.40	3.00
1140	Perform Nose Mounted Sensor (NMS) Operations	3.00	3.11
1142	Perform Digital Communications	---	2.44
1155	Negotiate Wire Obstacles	1.00	1.00
1170	Perform Instrument Takeoff	2.25	3.50
1176	Perform Non Precision Approach (GCA)	2.33	---
1178	Perform Precision Approach (GCA)	2.00	---
1180	Perform Emergency GPS Recovery Procedure	1.50	3.00
1082	Perform an Autorotation	2.25	5.00

1182	Perform Unusual Attitude Recovery	2.00	3.00
1188	Operate ASE/transponder	1.17	1.14
1184	Respond to IMC Conditions	2.29	3.17
1194	Perform Refueling / Rearming Operations	1.25	1.50
1404	Perform Electronic Countermeasures / Electronic Counter-Countermeasures	1.00	1.00
1405	Transmit Tactical Reports	2.00	2.67
1407	Perform Terrain Flight Takeoff	2.17	---
1408	Perform Terrain Flight	1.89	1.00
1409	Perform Terrain Flight Approach	1.67	---
1410	Perform Masking and Unmasking	2.00	1.00
1411	Perform Terrain Flight Deceleration	2.00	---
1413	Perform Actions on Contact	2.50	2.71
1416	Perform Weapons Initialization Procedures	1.50	1.63
1422	Perform Firing Techniques	2.13	1.67
1456	Engage Target with .50 Cal	---	---
1458	Engage Target with Hellfire	2.11	2.75
1462	Engage Target with Rockets	2.50	---
1472	Perform Aerial Observation	1.89	2.29
1471	Perform Target Handover	2.50	2.60
1473	Call for Indirect Fire	2.00	2.33
2010	Perform Multi-Aircraft Operations	1.50	2.00
2127	Perform Combat Maneuvering Flight	2.20	1.67
2128	Perform Close Combat Attack	2.00	2.00
2129	Perform Combat Position Operations	1.00	---
2164	Call for Tactical Air Strike	1.50	3.00
-----	Zone Reconnaissance	2.33	2.00
-----	Route Reconnaissance	2.22	2.43
-----	Area Reconnaissance	2.00	2.29
-----	Level 2 UAS	2.67	3.00

-----	Aerial Surveillance	2.56	2.50
-----	Overall Workload for the Mission	2.56	3.44

Pilot Workload Comments:

Comments for flight and mission tasks that were given a workload rating of '5' or higher during missions:

- Tasks 1070 (Respond to Emergencies), 1074 (Respond to Engine Failure in Cruise Flight), and 1182 (Perform Unusual Attitude Recovery) are workload intensive allowing no additional tasks to be performed to insure safe outcome of maneuver.

- Tasks 1070 (Respond to Emergencies), 1074 (Respond to Engine Failure in Cruise Flight), and 1182 (Perform Unusual Attitude Recovery) were experienced in responding to engine failure in cruise flight. In order to establish safe outcome of maneuver complete attention was focused on rotor rpm, airspeed and sequencing of final flight maneuvers. No additional tasks are recommended while accomplishing this task without inviting jeopardy to maneuver outcome. Only recommendation to reducing workload in cruise flight autorotation would be to add symbology around airspeed numbers only when in an autorotation when airspeed falls outside of safe limits (55-80 kts).

- Task 1074 (Respond to Engine Failure in Cruise Flight) as soon as the warnings started, I was focused only on successfully completing the maneuver. I shed all radio calls to my left seater and stayed focused on my landing area, instruments and controls.

- Tasks 1170 (Performing Instrument Take Off) and 1184 (Respond to IMC Conditions) were encountered simultaneously during take-off from a FARP which resulted in unexpected brownout condition. Safe outcome of flight without overtorque to aircraft required one pilot to commit to VSD display while other pilot not on the controls alternated attention to SYS display page (torque setting primarily), outside horizon (to scan for VMC conditions), and the occasional backup of pilot VSD screen. No additional tasks are safely permitted under such an event to ensure successful outcome.

- Tasks 1170 (Performing Instrument Take Off), 1184 (Respond to IMC Conditions) and 1407 (Perform Terrain Flight Takeoff) were experienced in Brown-out takeoff condition. Similar to above, power setting, sequencing of flight maneuvers, and aircraft attitude become primary focus with little ability to focus on additional tasks. Difficulty of task is not affected by software to OH-58.

- Task 1413 (Perform Actions on Contact) when hostile threat is encountered requires significant focus to evade enemy fire and develop situation in a manner to neutralize threat or bypass. New aircraft systems reduce workload on aircrew compared to current OH-58D CDS4 Block 2 software and systems.

- Tasks 1413 (Perform Actions on Contact) when I began taking fire from such a close range, my only focus was suppressing and getting distance between the aircraft and the target. I was able to make a couple of radio calls to the trail aircraft until we were safely away and set up to engage the target.

- Task 1471 (Perform Target Handover) using UAS reduces additional workload capacity as 2 of the 3 screens within cockpit as well as single radio become utilized to designate target to be handed over, confirmation that correct target was handed over, and verbal confirmation of spot and track of target. Redundancy of confirmation however insures PID and minimizes potential for collateral damage and fratricide/non-combatant casualties.

Miscellaneous Workload Comments:

- The left seater in this profile is focused inside 90% of the time operating the systems. Maintain airspace surveillance is not being accomplished. Lack of experience with the NMS and UAS video also contributed to higher workload.

- Overall workload was a '5' mostly due to inexperience.

- While trying to maneuver the aircraft and access the UAS page as well as maneuver the UAS drastically increased the workload on the right seater.

- Due to lack of experience with the NMS workload was high. Lack of situational awareness was experienced because I became so focused on operating the NMS.

Appendix B. Subject Matter Expert Workload Comments

This appendix appears in its original form, without editorial change.

- Mission 1 - CPG had little capacity to perform standard crew tasks due addition of new functions. CPG is a junior flight crew member who would have had difficulty performing normal operations in a CDS4 environment. Right seat was more than capable of making up for the deficiencies of the left seat.

- Mission 1 - Left seat crewmember's experience level with CDS4 contributed to his difficulties in utilizing CDS5 effectively. Left-seater was not familiar enough with CDS5 capabilities in order for him to use it to his advantage during setup as well as during the mission. Unable to use particular facets of the system such as Laser Spot Tracker, EOS, or MUM without being prompted by right-seater. Right seat crewmember's workload was only slightly increased due to left seater's difficulty in completing tasks, but did not affect his ability to conduct operations.

- Mission 1 - Left Seat Crewmember was behind the aircraft and had significant issues multitasking as scenario workload increased. Increased training will help this junior aviator increase proficiency in working left seat mission equipment and radios. Right seat PC directed left seater as workload increased and basic tasks needed additional attention.

- Mission 3 - Crew had sufficient capacity but at times, left-seater had to drop certain tasks such as response to BFT messages and making radio calls.

- Mission 3 - Left Seat Crewmember's task saturation increased the workload for the Right Seater attempting to maintain or increase SA. Left Seat Crewmember sometimes directed trail aircraft to take simple tasks like BFT messages and shed those tasks altogether, and not returning to them even when lower workloads were present. Both crewmembers lost SA at times, however it didn't significantly affect the mission.

- Mission 6 - CPG had NMS control issues (not associated with the SIM) that caused a snowball effect for him in the cockpit. Result being the lack of situational awareness coupled with being two steps behind for the duration of the mission.

- Mission 7 - Right seat workload was increased due to left seat limited experience level. This caused right seat to both fly and monitor left seat workload to ensure tasks were accomplished. Right seat was still able to use system tools (i.e. 6 x 8 map) as needed.

- Mission 7 - I think the overall aviation experience of the left seater caused the overload situation. Right seater's workload was increased with trying to direct the left seater in specific tasks

- Mission 8 - This was a much more experienced crew. Use of the new systems did not affect workload.

- Mission 9 - Additional familiarity with new systems is helping to reduce initial workload observations. The addition of the 6 x 8 screen and MUM capability will undoubtedly increase left-seat workload, but this crew handled it well.

Appendix C. Situation Awareness Ratings and Comments

This appendix appears in its original form, without editorial change.

China Lake Situational Awareness Rating Scale (CLSA)

VERY GOOD 1	• Full knowledge of aircraft energy state, tactical environment and mission • Full ability to anticipate and accommodate trends
GOOD 2	• Full knowledge of aircraft energy state, tactical environment and mission • Partial ability to anticipate and accommodate trends • No task shedding
ADEQUATE 3	• Full knowledge of aircraft energy state, tactical environment and mission • Saturated ability to anticipate and accommodate trends • Some shedding of minor tasks
POOR 4	• Fair knowledge of aircraft energy state, tactical environment and mission • Saturated ability to anticipate and accommodate trends • Shedding of all minor tasks as well as many not essential to flight safety and mission effectiveness
VERY POOR 5	• Minimal knowledge of aircraft energy state, tactical environment and mission • Oversaturated ability to anticipate and accommodate trends • Shedding of all tasks not absolutely essential to flight safety and mission effectiveness

Pilot Mean Rating 1.67 (SD = 0.71)

Copilot Mean Rating 2.22 (SD = 1.09)

Battlefield Elements	Very High Level of Situation Awareness		Fairly High Level of Situation Awareness		Borderline		Fairly Low Level of Situation Awareness		Very Low Level of Situation Awareness	
	Right Seat	**Left Seat**	**Right Seat**	**Left Seat**	**Right Seat**	**Left Seat**	**Right Seat**	**Left Seat**	**Right Seat**	**Left Seat**
Location of Enemy Units	44 %	44 %	44 %	44 %	11 %	11 %	0 %	0 %	0 %	0 %
Location of Friendly Units	66 %	45 %	33 %	55 %	0 %	0 %	0 %	0 %	0 %	0 %
Location of My Aircraft During Missions	66 %	45 %	33 %	55 %	0 %	0 %	0 %	0 %	0 %	0 %
Location of Cultural Features (e.g., bridges)	33 %	25 %	66 %	75 %	0 %	0 %	0 %	0 %	0 %	0 %
Route Information (ACPs, BPs, EAs, RPs, etc.)	33 %	11 %	66 %	88 %	0 %	0 %	0 %	0 %	0 %	0 %
Status of My Aircraft Systems (e.g., fuel	44 %	22 %	55 %	67 %	0 %	11 %	0 %	0 %	0 %	0 %
Location of Other Aircraft During Missions	38 %	33 %	50 %	44 %	13 %	22 %	0%	0 %	0 %	0 %

Pilot Situational Awareness Comments

- Even though we had radio contact with the BlackHawk flight, I didn't notice their BFT icons. I only had them in sight when they were up and out of the LZ. Also, because we coordinated the A-10 flight through trail, my awareness of their position and activity was low.

- Multiple times I lost enemy personnel while working the NMS.

- For other aircraft, I had a general idea where the UAV was operating but I never utilized the feature on the UAS page to find out his exact position because I was usually busy working the NMS. For status of aircraft systems, I placed a higher priority on executing the mission with the NMS, UAV, and radios and mentally placed the aircraft status in the backseat, probably due to the exercise being a simulation. I also am not as comfortable yet only having 1 driving PWR gauge.

- In the second of the three engagements of this flight, I did not understand my aircraft position relative to the 3 fighters and vehicle until we were being fired upon and my left seater pointed at them at 12 o'clock through the windscreen. I may have confused UAV feed with the NMS or vice versa, and up to that point my left seater was the one tracking those targets, I should have prompted him to help me get oriented much sooner.

SME Situational Awareness Comments

- UAS asset was constantly behind the aircraft causing loss of signal feed on a constant basis. NMS usage was not adequate for the mission and the CPG failed to properly perform basic functions that would have enabled better mission success. SA was lost by both the PC and PI on two occasions at key times during the mission. Prompting by the UAS operator was critical to getting the aircraft re-focused on mission objectives.

- Right-seater picked up several left-seat tasks in order to assist left-seater, which reduced pilot SA on multiple occasions - one resulted in the aircraft losing its primary target, another resulted in the aircraft overflying an NAI, causing it to be fired upon by enemy forces. Left seater was almost completely unaware of ownship location due to difficulties with operating the NMS and focusing on UAV targets. Excessive use of the UAS screen (when no feed was available) reduced pilot use of CDS5 maps, also reducing SA. Good use of the elevation banding was critical in preventing Controlled Flight into Terrain (CFIT) when the crew went IIMC.

- In the middle of the mission, the crew was fixated utilizing the sensor in a narrow FOV and lost SA with surrounding and flew directly into an ambush alongside a road that could have been detected. Crew split their flight, sending UAS to SP of RTE Coral and SWT would conduct Air Route Recon from RP to SP. Later in the mission crew was fixated on the acquiring a ZSU 23-4 that had pinged their ASE. Due to Actions on Contact, crew lost SA on ZSU 23-4's location. On attempting to reacquire, SWT paralleled the moving enemy element and eventually turned into the path and moved to within 1km of the enemy location. SWT would have been KIA if engaged by the threat.

- Left-seat pilot had good SA of the battlefield. Right-seater relied more on left-seater than on CDS for SA - did not fully utilize the system for navigation or SA of other entities on the battlefield. Right-seater came inside the cockpit more than once to accomplish left-seat tasks (but not due to task saturation). In doing so, crew temporarily lost positive ID of enemy (due to hostile fire or evasive action) on multiple occasions and had some difficulty re-acquiring with the NMS. Good use of the MUM system for acquiring targets and also transmitting own-ship feed to the ground forces.

- Crew had SA, but task saturation in more than one instance caused left-seater to abandon tasks. Left-seater's difficulty in communication with role players caused right-seater to take over tasks more than once. Right-seater was consistently aware of all entities on the battlefield.

- Due to Left Seat proficiency, Right Seater was brought into the cockpit to direct tasks and lost some SA, especially when brought into the cockpit to help direct tasks needed to be accomplished by the Left Seater

- Crews effectively used standoff with the NMS and CDS5 system tools

- Pilot was focused on being inside watching the CPG much more than would normally be expected. Loss of SA was noted at several times due to this fact, as well as not having ground reference points to keep track of the aircraft location.

- Right seat increased workload resulted in reduced SA. At one point where right seat was unable to identify current position which could have resulted in a fratricide incident - right seat did a good job compensating by using system tools for SA, but it brought him in the cockpit for longer periods than necessary. Left seat limited experience level also reduced SA of friendly and enemy entities. One significant SA event occurred when Close Air Support was called in to drop ordnance on an enemy location. Pilots did not consider UAS location with reference to the CAS inbound run or gun-target line. This mission had many more friendly and enemy entities in contact which required much more SA in order to be effective and avoid getting shot down. The crew was aware of this for the most part and attempted to use additional assets to maintain SA, but at times, the crew was close to sensory overload - this was more due to a single aircraft performing the mission of two during simulation - it may not be realized to this extent in actual flight except for extreme situations.

- Both crewmembers were consistently behind the aircraft and lost SA on numerous occasions. Left seat failed to utilize NMS to full potential and often because of lack of SA were scanning behind the convoy. Left seater also shed tasks (BFT messages) and never returned to them as workload decreased. Important mission information..such as a weather warning. Right seater took control of the 6x8 for map display and never utilized his 5x7 HSD for SA. Left seater was task saturated and became overloaded due to trying to maintain control of the UAS.

- Crew had reduced SA based on increased workload and failure to utilize systems for accurate SA.

- SA of friendly and enemy was no issue, however when calling CAS and artillery, crew did not take UAV location into account. SA during IIMC was improved with use of terrain elevation banding.

- The crew was denied use of their UAS initially, which did not have any significant SA effect until on the objective. Once on the objective, crew struggled with SA of both friendly and enemy forces. An additional UAS was available as an ISR asset, which would have greatly increased SA if it were utilized. One specific SA factor was direction of artillery fires and inbound heading of CAS. Crew did not have the UAS directly tasked to them, so SA of its location was not considered during fire missions. CDS5 has multiple tools available to aid in preventing this situation.

- Based on assigned mission, crew was completely focused on LZ and didn't utilize available UAS assets to increase SA on the objective which would have increased battlefield SA to threats within the objective area. Crew engaged two personnel around the LZ with a Hellfire Missile. Once SA of threat increased, crew occasionally used UAS assets to increase SA.

- Pilot was looking at the 6x8 more than he should be which causes both pilots to be inside and subsequent loss of SA. Pilot tried to perform unmasking procedures with the NMS which actually causes the aircraft to completely unmask.

- Minor SA issues with this crew. Left-seater maximized use of CDS5 new systems. At times, the right-seater would target fixate on the NMS or UAV screens, reducing his SA of the aircraft position. In an actual flight, proprioceptive senses would alert the pilot to these instances.

- Crew coordination was a slight issue when dealing with announcing actions. Pilot became disoriented due to lack of crosstalk with CPG.

- Crews unfamiliar with MUM are not utilizing it as an effective SA tool. Crew came close to international border during mission. This could have been avoided if SA tools were used such as aircraft map or MUM map. Having a third screen is also new to the crew, so maximizing use of all three screens may require additional training until a standard procedure is developed.

- MUM Teaming experience and cockpit MUM proficiency, coupled with MUM being a federated system which causes the crew to be heads down inside the cockpit to transfer grids to the CDS from the MUM system, significantly reduces overall effectiveness of the CDS MUM system as compared to an integrated system which would have all of the BFT/MUM/Targeting information all in one screen.

- Crew focused on following a vehicle and lost SA to the surrounding areas that affected their safety. Loss of visual cues and reference to the ZSU's after initial contact led them to be engaged within 1 km.

Appendix D. Pilot-Crewstation Interface (PCI) Ratings and Comments

This appendix appears in its original form, without editorial change.

PV1. The following table lists the components (e.g., display pages, sub-pages, overlays) of the KW CASUP crewstation. For each component, indicate whether or not you experienced a problem using the component in a quick and efficient manner during the missions. Check 'Yes' if you experienced one or more problems. Check 'No' if you did not experience any problems. Check 'Not Used' if you did not use the component during the simulation.

- Multifunction Displays (MFD)

o Vertical Situation Display	Yes **0%**	No **100%**	
o Horizontal Situation Display	Yes **0%**	No **100%**	
o NMS Operations	Yes **17%**	No **83%**	
o COM Pages	Yes **17%**	No **83%**	
o NAV Pages	Yes **0%**	No **100%**	
o Digital Map	Yes **17%**	No **83%**	
o Engine Instruments	Yes **0%**	No **100%**	
o ASE Pages	Yes **0%**	No **83%**	Not Used **17%**
o Weapons Pages	Yes **0%**	No **0%**	Not Used **100%**
o Managing GPS/Flight Plan	Yes **0%**	No **100%**	
o Mission Page	Yes **0%**	No **100%**	
o Warning, Caution, Advisory Disp.	Yes **0%**	No **100%**	
o 'Direct To'	Yes **0%**	No **100%**	
o ACP Function	Yes **0%**	No **100%**	
o Fuel Management Pages	Yes **0%**	No **100%**	
o Data Function	Yes **0%**	No **0%**	Not Used **100%**
o ACP Function	Yes **0%**	No **100%**	
o UAS Function	Yes **0%**	No **100%**	
o Autopaging	Yes **0%**	No **100%**	

If you answered "Yes" to any of the questions, describe a) the problems you experienced, b) how much the problems degraded your performance, and c) any recommendations you have for improving the design of the components.

Pilot comments:

- Com pages were difficult for me to get a feel for at first but now I feel more comfortable with it.
- Lack of experience with the NMS caused errors in operation. b) Caused task saturation occasionally) It's not a design problem it's an experience issue.
- Digital Map on 6x8 screen does not display compass rose similar to HSD pages on 5x7 screens. Incorporating this feature to the 6x8 HSD will significantly assist crew by displaying relevant heading information and contributing to greater situational awareness. Recommendation for VSD screen in the event of engine out or autorotation at cruise scenario would be to include noticeable symbology (boxed numbers or ascetics) by airspeed number if out of tolerance for safe outcome of emergency procedure.

PV2. How quickly were you able to navigate through the pages, sub-pages and/or overlays for:

Vertical Situation Display (Circle one)

Avg. Rating 1.33	2	3	4	5
Very Quickly	Somewhat Quickly	Borderline	Somewhat Slowly	Very Slowly

Horizontal Situation Display (Circle one)

1	**Avg. Rating 2.17**	3	4	5
Very Quickly	Somewhat Quickly	Borderline	Somewhat Slowly	Very Slowly

Digital Map (Circle one)

1	**Avg. Rating 2.17**	3	4	5
Very Quickly	Somewhat Quickly	Borderline	Somewhat Slowly	Very Slowly

Engine Instruments (Circle one)

1	Avg. Rating 1.67	2	3	4	5
Very Quickly	▲	Somewhat Quickly	Borderline	Somewhat Slowly	Very Slowly

If you answered ‘Somewhat Slowly’, or ‘Very Slowly’ to any of the questions, list the component and why navigation was slow (e.g., ‘navigating the menu system on the digital map was a slow process due to having to page through several screen displays’).

Pilot comments:

- Working the HSD and Map in conjunction with the NMS page and Sight Mode selection knob really does bog down the system. I thought this was a simism and hope it doesn't transfer to the aircraft (simulator issue).

PV3. Please answer the following questions regarding the Nose Mounted Sensor (NMS).

PV3-1. Did you experience any problems using the following NMS switches/controls?

o Sensor Select	Yes **17%**	No **83%**	
o FOV Select	Yes **17%**	No **83%**	
o Laser	Yes **0%**	No **100%**	
o LOS Designate	Yes **0%**	No **0%**	NA **100%**
o Range/Polarity	Yes **0%**	No **83%**	NA **17%**
o Manual Slave	Yes **17%**	No **83%**	
o Point Track	Yes **0%**	No **100%**	

If you answered “Yes” to any of the questions, describe a) the problems you experienced, b) how much the problems degraded your performance, and c) any recommendations you have for improving the design of the NMS switches/controls.

Pilot comments:

- Pressing the Man/Slave button quickly while using the LOS, NMS page and mode select switch bogs down the system pretty regularly (simulator issue).
- Occasionally I would use the wrong switch) caused slight delay in achieving the desired result) practice.

PV4. Did you have difficulty using any of the switches on the collective or cyclic grips?

Collective Grip	Yes **0%**	No **100%**
Cyclic Grip	Yes **0%**	No **100%**

If you answered "Yes" for either flight control, please list which flight control and switch(es), and the problems you experienced (e.g., confused two switches due to similar shape, switch was too hard to reach).

Pilot comments:

- No comments

PV5. Was there any symbology depicted on the following displays/pages that was difficult to quickly and easily understand, cluttered, or otherwise difficult to use?

Vertical Situation Display	Yes **0%**	No **100%**
Horizontal Situation Display	Yes **0%**	No **100%**
ESIS	Yes **0%**	No **100%**
Engine Instruments	Yes **0%**	No **100%**
Digital Map	Yes **0%**	No **100%**
ASE	Yes **0%**	No **100%**
NMS Pages	Yes **17%**	No **83%**
UAS	Yes **17%**	No **83%**

If you answered "Yes" to any of the questions, please describe a) the display/page, b) the symbology that was difficult to understand, c) how the symbology degraded your performance, and d) any recommendations you have for improving the design of the display page and/or symbology.

Pilot comments:

- If possible, could the current radio and freq be a selectable "sticky" on every page? I know some pilots don't mind returning to the commo page to double check what they are on, but if it was a selectable option off of the initial page to turn that on, I would use it to enhance my SA and reduce my workload from paging back to the commo page.

- The NMS and UAS pages were difficult on occasion due to lack of experience.

PV6. How easy was it to detect the following indication on the displays?

Warning/Caution/Advisory (MFD)

Avg. Rating 1.5

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

Entry into Operational Limits

Avg. Rating 1.67

1	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

Low Fuel

Avg. Rating 1.33

	2	3	4	5
Very Easy	Somewhat Easy	Borderline	Somewhat Difficult	Very Difficult

If you answered “Somewhat Difficult”, or “Very Difficult”, list which indication you had difficulty detecting/understanding, why you had difficulty, and any recommendations to make the indication more easily detectable and/or understandable.

Pilot comments:

- No comments.

PV7. Did you have any problems using the overhead panels due to location, inaccurate labeling, etc?

Yes **0%** No **50%** NU **50%**

PV8. Did you have any problems using the following switches and controls on the instrument panel?

CMWS Manual Dispense Switch	Yes **0%**	No **0%**	NU **100%**
SCAS Control Panel	Yes **0%**	No **17%**	NU **83%**

FADEC Switch	Yes **0%**	No **0%**	NU **100%**
MFK	Yes **0%**	No **87%**	NU **13%**
Armament Control Panel	Yes **0%**	No **100%**	
Channel Select Switch	Yes **0%**	No **100%**	
EBI Filter Bypass Switch	Yes **0%**	No **0%**	NU **100%**

If yes, list the switches and/or controls and describe the problem(s)

Pilot comments:

- No comments.

PV9a. Did you have any problems viewing information (symbology, text, etc) on the following displays:

6x8 Display	Yes **33%**	No **67%**
5x7 Display	Yes **0%**	No **100%**
ESIS Display	Yes **0%**	No **100%**

If yes, list the information you had problems viewing:

Pilot comments:

- Cipher text indication (the green "C") is difficult to discern on the white background.
- 6x8 HSD should incorporate moving compass rose such as 5x7 displays feature.

PV9b. Did you have any problems using the bezels, knobs or hot keys on the 6x8 display?

Yes **0%** No **100%**

PV10. Did the LPCAP (digital ICS) restrict cyclic movement in the right seat?

Yes **0%** No **100%**

If yes, describe the how much the LPCAP restricted movement and in which axis:

No comments:

PV11. Rate whether the CDS5 software was much more or less effective (quicker and easier to use) than the CDS4 software you have used on the KW.

1	2	3	4	5
Much More Effective	Somewhat More Effective	About The Same	Somewhat Less Effective	Much Less Effective

Avg. Rating 1.5

If 'Somewhat Less' or 'Much Less Effective', explain why:

Pilot comments:

- No comments.

Appendix E. Top Crewstation Improvements

This appendix appears in its original form, without editorial change.

- Occluded compass rose overlay on the 6x8 map page.
- When the pilot drops a target from the hover BOB UP Switch, a box identifying the target number should be displayed on the current page on the MFD to alert the pilot the target was dropped.
- NMS with high color resolution, laser spot tracking capabilities, visible IR laser and 360 degree field of view.
- Compass rose displayed on all map pages vs. heading tapes
- Once again, maybe making the current radio/freq a selectable "sticky" on each page could reduce workload on the pilot side.
- When you store a target the data should auto fill after you enter the grid. I am not sure if this was a simism or CDS5 specific.

List of Symbols, Abbreviations, and Acronyms

AAR	after action review
AOI	area(s) of interest
APEX	Advanced Prototype Engineering and Experimentation
ARH	armed reconnaissance helicopter
ARL	U.S. Army Research Laboratory
ASL	Applied Science Laboratories
ATM	Aircrew Training Manual
BHIVE	Battlefield Highly Immersive Visual Environment
BIT	Built-in Test
BWRS	Bedford Workload Rating Scale
CAAS	Common Aviation Architecture System
CDD	Capability Development Document
CDS	control display system
CIB	Controlled Image Base
CLSA	China Lake Situational Awareness
CPC	Comanche Portable Cockpit
DAMA	Demand Assigned Multiple Access
DIS	Distributed Interactive Simulation
DREN	Defense Research and Engineering Network
EDS	Engineering Development Simulator
EUD	Early User Demonstration
HFE	Human Factors Engineering
HLA	High-Level Architecture
HOG	Hands-On Grip

HRED	Human Research and Engineering Directorate
HUMS	Health Usage Monitoring System
IMC	instrument meteorological conditions
JVMF	Joint Variable Message Format
KW CASUP	Kiowa Warrior Cockpit and Sensor Upgrade Program
LEUE	Limited Early User Evaluation
LOBL	lock-on-before-launch
LOI 2	level of interoperability 2
LUT	Limited User Test
MFD	multifunctional display
MMS	mast-mounted sight
NDI	Northern Digital Incorporated
NMS	nose-mounted sensor
OneSAF	One Semi-Automated Forces
OTW	out-the-window
PCI	Pilot-Crewstation Interface
PIM	Pulse Interval Module
SA	situational awareness
SCAS	Stability Control Augmentation System
SME	subject matter expert
SSDD	Systems Simulation and Development Directorate
SSQ	Simulator Sickness Questionnaire
TCM RA	TRADOC Capability Manager, Reconnaissance Attack
TRADOC	Training and Doctrine Command
TS	Total Severity
TTP	tactics, techniques, and procedures
UAS	unmanned aircraft system

VFR	visual flight rules
VMC	visual meteorological conditions
VTR	Video Tape Recorder

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