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A Summary of Crew Workload and Situational Awareness Ratings for U.S. Army Aviation Aircraft

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

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14. ABSTRACT
The U.S. Army Research Laboratory Human Research and Engineering Directorate (ARL/HRED) assesses crewstation design for new and upgraded U.S. Army Aviation aircraft during simulations and operational testing. The assessments are conducted to identify and eliminate human factors design problems. ARL/HRED evaluates pilot workload and situational awareness (SA) during simulations and operational testing to assess crewstation design. To date, more than 12,000 pilot workload ratings and 3000 pilot SA ratings have been collected by ARL/HRED for Army aircraft. This report summarizes the Bedford Workload Rating Scale, Situation Awareness Rating Technique, and China Lake Situational Awareness scale ratings collected during simulations and operational testing to assess crewstation design.

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Contents

List of Figures

List of Tables

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1. Assessment of Crew Workload and Situational Awareness

1.1 Overview

Effective aircrew performance is critical to mission success. Crewstations that are designed to augment the cognitive and physical abilities of aircrews help minimize pilot workload, enhance situational awareness (SA), and contribute to successful mission performance. It is vital that crewstations be assessed early and often during development to ensure optimal design.

The U.S. Army Research Laboratory's Human Research and Engineering Directorate (ARL/HRED) assesses crewstation design for new and upgraded Army Aviation aircraft during simulations and operational testing. The assessments are conducted to identify and eliminate human factors design problems. ARL/HRED evaluates pilot workload and SA during simulations and operational testing to assess crewstation design. To date, more than 12,000 pilot workload ratings and 3000 pilot SA ratings have been collected by ARL/HRED for Army aircraft. This report summarizes the Bedford Workload Rating Scale (BWRS), Situation Awareness Rating Technique (SART), and China Lake Situational Awareness (CLSA) scale ratings collected during simulations and operational testing to assess crewstation design.

1.2 Workload

There are several definitions of pilot workload. A useful definition 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 general, workload assessment techniques are used to answer the following questions (Eisen, 1987):

- Does the operator have the capability to perform the required tasks?
- Does the operator have enough spare capacity to take on additional tasks?
- Does the operator have enough spare capacity to cope with emergency situations?
- Can the task or equipment be altered to increase the amount of spare capacity?
- Can the task or equipment be altered to increase/decrease the amount of mental workload?
- How does the workload of a new system compare with the old system?

To assess whether the pilots are task-overloaded during the missions, the level of workload for each pilot must be evaluated.

1.2.1 Bedford Workload Rating Scale

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 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.

After each mission, pilots rate flight and mission tasks using the BWRS scale (figure 1). Roscoe and Ellis (1990) describe the BWRS and explain its use in assessing pilot workload. The pilot starts the decisionmaking process at the bottom left corner of the decision tree, which consists of three questions requiring yes or no answers, in order to proceed to the descriptions of different levels of workload. The descriptors denote increasing levels of workload associated with ratings 1–10. The flight and mission tasks should be well defined and the workload being assessed should be related to the execution of the primary task; any additional tasks (e.g., monitoring communications) must be included as part of spare capacity. Once the pilot settles on a workload rating using the decision tree, the rating is made for the task for the mission or mission segment. A sample task list used by ARL/HRED is shown in table 1 and a full task list is in appendix A. For several aircraft, ARL/HRED wrote the workload requirement that operation of the aircraft must not result in aggregate pilot BWRS task and mission ratings of more than 5.0–6.0. Flight and mission tasks that are rated 5.0 or above are evaluated to determine if crewstation design problems contributed to higher workload ratings.

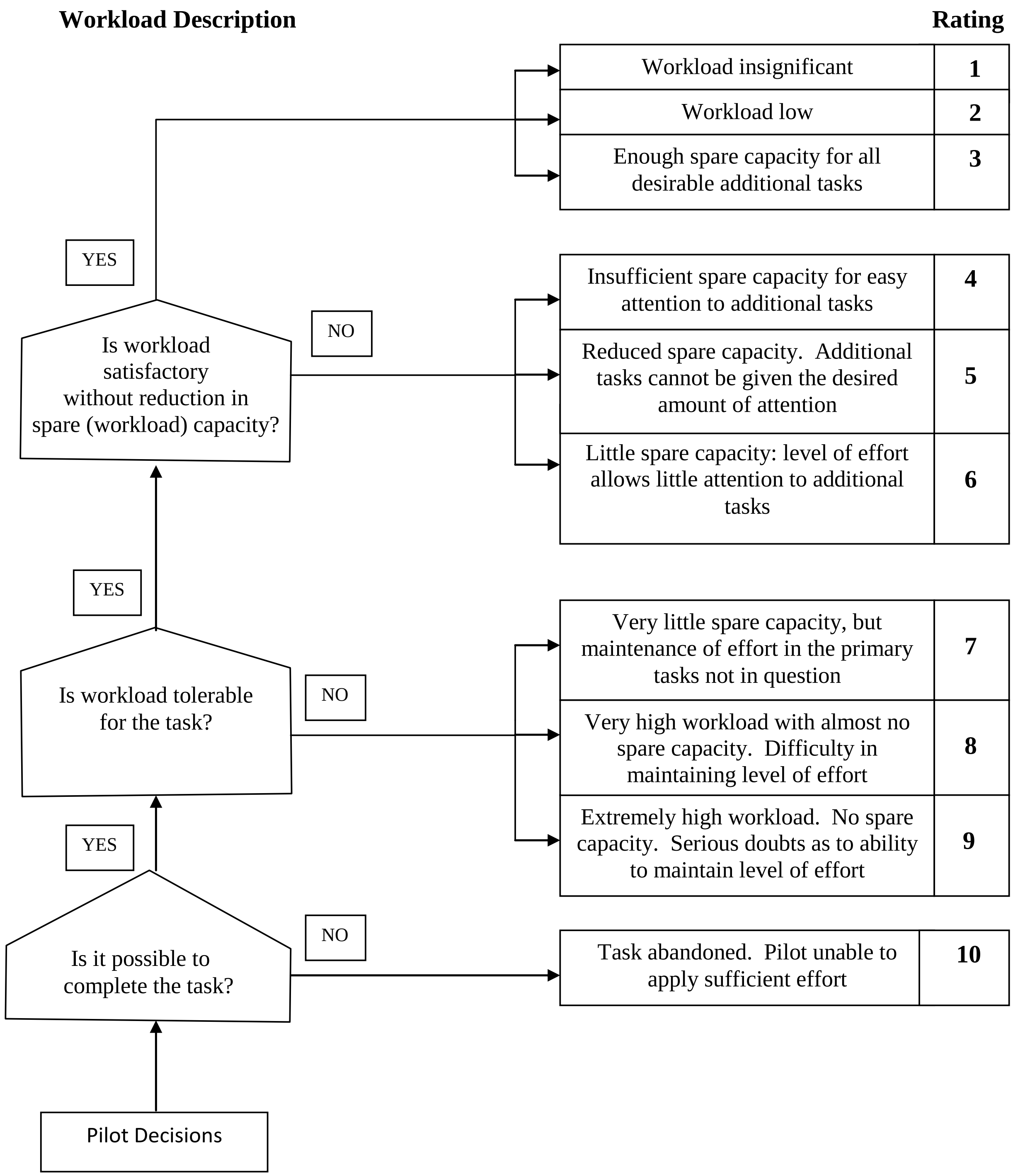

Figure 1. Bedford Workload Rating Scale.

Table 1. Sample flight and mission task list.

Task No.	Flight and Mission Tasks	Workload Rating
1026	Maintain airspace surveillance	
1028	Perform hover power check	
1030	Perform hover out-of-ground-effect check	
1032	Perform radio communication procedures	
1038	Perform hovering flight	

1.3 Situational Awareness

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). The Endsley model of SA in dynamic decisionmaking can be seen in figure 2 (Endsley, 1995). The SA model encompasses three levels of SA. Level 1 includes the perception of elements in the current situation, level 2 is the comprehension of the current situation, and level 3 is the projection of future status. The understanding of how these three levels of SA form an overview of pilot understanding is important. Each mission segment and stimulus may call for different levels of SA. Maintaining a single level of SA would not be appropriate for all scenarios, especially when evaluated with workload. For example, a requirement for level 3 SA in all scenarios would burden pilots with workload requirements to maintain and identify level 3 SA for all variables. Ideally, SA is transferred at different levels among relative variable occurrences, and an overall concept of the mission and aircraft parameters is established that is constantly revised throughout the mission and based on pilot actions. It is important to assess SA because of its potential to directly impact pilot and aircraft performance. Good SA should increase the probability of good decisionmaking and performance by aircrews when conducting flight and mission tasks.

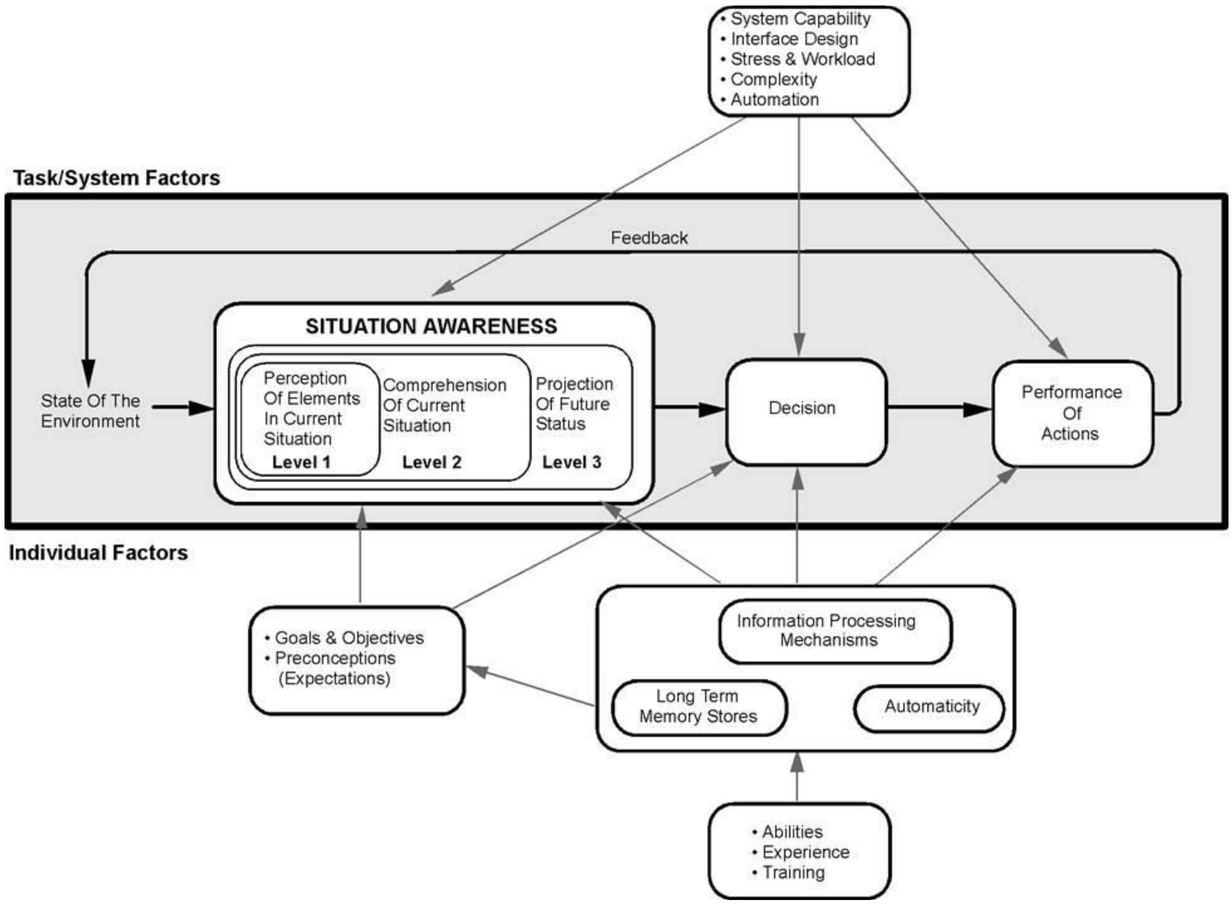

Figure 2. Endsley model of situation awareness in dynamic decisionmaking.

1.4 Situation Awareness Rating Technique and China Lake Situational Awareness Scale

The SART (appendix B) is a multidimensional rating scale for pilots to report their perceived SA. SART uses 10 dimensions (table 2) to measure operator SA: familiarity of the situation, focusing of attention, information quantity, information quality, instability of the situation, concentration of attention, complexity of the situation, variability of the situation, arousal, and spare mental capacity. SART is administered after each mission by ARL/HRED personnel and involves the participant rating each dimension on a seven-point rating scale (1 = low, 7 = high) to gain a subjective measure of SA (Salmon et al., 2006). SART was developed as an evaluation tool for the design of aircrew systems (Taylor, 1989) and assesses three components of SA: understanding, supply, and demand. These components are subcategories that contain the 10 dimensions. Taylor proposed that SA depends on the pilot's understanding (U) (e.g., quality of information they receive) and the difference between the demand (D) on the pilot's resources (e.g., complexity of mission) and the pilot's supply (S) (e.g., ability to concentrate). When D exceeds S, there is a negative effect on U and an overall reduction of SA. The formula $SA = U - (D - S)$ is used to derive the overall SART score. The SART is one of the most thoroughly tested rating scales for estimating SA (Endsley, 2000).

Table 2. SART dimensions.

Situation Awareness Rating Technique (SART)	
Demand	
Instability of situation	Likeliness of situation to change suddenly
Variability of situation	Number of variables that require your attention
Complexity of situation	Degree of complication (number of closely connected parts) of the situation
Supply	
Arousal	Degree to which you are ready for activity; ability to anticipate and keep up with the flow of events
Spare mental capacity	Amount of mental ability available to apply to new tasks
Concentration	Degree to which your thoughts are brought to bear on the situation; degree to which you focused on important elements and events
Division of attention	Ability to divide your attention among several key issues during the mission; ability to concern yourself with many aspects of current and future events simultaneously
Understanding	
Information quantity	Amount of knowledge received and understood
Information quality	Degree of goodness or value of knowledge communicated
Familiarity	Degree of acquaintance with the situation

ARL/HRED personnel also use the CLSA (table 3), which is a five-point SA scale that pilots use to rate their perceived level of SA for the mission or mission segment. The scale relates to general knowledge of aircraft systems, the tactical environment, and the mission objectives as well as the ability to accommodate trends and the level of task shedding due to high workload. The CLSA is considered to have positive attributes of high face validity or "common sense," clear criteria, ease of use, and ease of analysis.

Table 3. CLSA scale.

CLSA Scale Value	Content
Very good – 1	Full knowledge of aircraft energy state, and tactical environment/mission Full ability to anticipate/accommodate trends
Good – 2	Full knowledge of aircraft energy state, tactical environment and mission Partial ability to anticipate/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/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 essential to flight safety and mission effectiveness

1.5 Situation Awareness of Battlefield Elements

Assessing crew SA of battlefield elements (table 4) is important to evaluate their comprehension of the elements (e.g., threat vehicles) during simulation and testing. Pilots provide ratings for each element, and these ratings are used to determine whether the elements are identified and understood throughout the mission.

Table 4. Battlefield elements.

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**
Location of enemy units					
Location of friendly units					
Location of noncombatants (e.g., civilians)					
Location of my aircraft during missions					
Location of other aircraft in my flight					
Location of cultural features (e.g., bridges)					
Route information (e.g., air control points)					
Status of my aircraft systems (e.g., fuel consumption)					

1.6 Additional Metrics

In addition to the BWRS, SART, and CLSA data, other metrics are used to evaluate the overall crew workload and SA during missions. These sources include a Pilot-Crewstation Interface (PCI) survey distributed at the end of all missions, subject matter expert (SME) ratings, and pilot interviews.

1.6.1 PCI Evaluation

PCI evaluations are used to examine the interaction between the pilots and the crewstation interface. The PCI impacts crew workload and SA during a mission. A PCI that is designed to augment the cognitive and physical abilities of crews will minimize workload, enhance SA, and contribute to successful mission performance. To assess the PCI, the pilots report any problems that contributed to high workload and low SA at the end of each mission. They also complete a lengthy questionnaire (appendix C) at the end of their final mission. The questionnaire addresses usability characteristics of the PCI (e.g., software interface, control reach, and button presses).

1.6.2 Subject Matter Experts

SMEs observe the missions and rate pilot workload and SA, mission success, and levels of crew coordination (appendix D) that they observe during the missions. A SME is typically an experienced pilot that has in-depth knowledge of the aircraft and crewstation being assessed. The ratings provided by the SME are compared with the corresponding pilot ratings to identify any significant anomalies in perceived levels of workload or SA while interacting with the crewstation.

1.6.3 Pilot Interviews

Pilots are formally interviewed about their performance during after-action reviews in which the mission events and goal outcomes are discussed. Pilots are also interviewed informally by ARL/HRED researchers throughout the test process to gain insights into procedures and to capture any additional comments or perceptions of workload and SA experienced during the missions. Pilots also complete a form providing recommendations for improvements to the crewstation. Recommended design improvements made by the pilots are addressed in future design analyses and incorporated into software and hardware modifications (within funding constraints).

2. Crewstation Assessment During Simulation and Operational Testing

2.1 Crewstation Assessment Methodology

ARL/HRED developed a methodology to assess crewstation design. The methodology includes: anthropometric modeling; human factors evaluation during simulation and operational testing to assess pilot workload, SA, crew coordination, PCI, and anthropometric accommodation; and use of a head and eye tracker to assess visual gaze and dwell times. This methodology has been used to help develop all modernized U.S. Army Aviation systems including the AH-64D/E Apache, UH-60M Blackhawk, CH-47F Chinook, OH-58F Kiowa, and UH-72A Lakota. The methodology was also used to develop aircraft that are no longer being developed by the Army, including the C-27J Spartan, RAH-66 Comanche, and Armed Reconnaissance Helicopter (ARH). Data collected using this methodology are analyzed and used to construct a comprehensive profile of the PCI characteristics and impact on crew workload and SA. Additional information and summary results about each of the steps in the methodology can be found in a report (Hicks and Durbin, 2013) that explains the crewstation assessment process.

2.2 Simulation and Operational Testing

The simulators used by ARL/HRED for crewstation design assessments are engineering simulators. The engineering simulators represent the intended production design and provide a platform for developing and assessing crewstation design, evaluating pilot performance, and assessing crew workload, SA, and crew coordination. Pilots with broad levels of experience (e.g., 500–4000 flight hours) typically participate in the simulation events. This wide range of experience provides ARL/HRED researchers a broad perspective on the design of each crewstation. Pilots use the simulators to conduct operationally relevant missions and tasks (e.g., zone reconnaissance, call for fire, troop transport). The simulators are also used to help pilots develop tactics, techniques and procedures and provide limited training for pilots prior to operational testing in the aircraft. Results of the assessments are provided by ARL/HRED to the aircraft program managers, Training and Doctrine Command Capability Managers, Army Test and Evaluation Command, Aviation and Missile Research, Development and Engineering Center, and defense contractors.

Simulators used by ARL/HRED include the OH-58F Kiowa, AH-64D Apache Longbow Risk and Cost Reduction Simulator (RACRS), UH-60M Blackhawk Helicopter Engineering and Analysis Cockpit (BHEAC) – Battlefield Highly Immersive Virtual Environment 1 (BHIVE 1) and Systems Integration Laboratory (SIL) simulators, CH-47F Chinook Helicopter Engineering and Analysis Cockpit (CHEAC) – BHIVE 2 simulator, ARH simulator – BHIVE 2, and the RAH-66 Comanche Engineering Development Simulator (EDS) and Comanche Portable Cockpit (CPC). The simulators contained the hardware and software that emulated the controls, flight characteristics, out-the-window display, and functionality of the aircraft. The simulator crewstations replicated the corresponding crewstation in the actual aircraft, allowing each pilot to perform realistic flight and mission tasks. Table 5 lists the aircraft, associated simulator, and assessment or operational test that was conducted.

Operational tests are conducted to verify design requirements and ensure crewstation designs are ready for fielding. ARL/HRED helps conduct operational tests and typically collects the same data as was collected during the simulations. This provides a progressive assessment of pilot performance and crewstation design. Results from the operational test are compared with the simulations to ensure improvements have been made to the crewstation design and to identify any new human factors design problems.

Table 5. U.S. Army aircraft, associated simulator, and assessment or test.

Aircraft	Simulator	Assessment/Test
AH-64D	RACRS	Unmanned Aircraft System (UAS) Teaming for Integrated and Federated Systems
AH-64E	—	Limited User Test (LUT) and Initial Operational Test (IOT)
ARH	BHIVE 2	Common Aviation Architecture System (CAAS) Assessment LUT
CH-47F	BHIVE 2	CAAS Assessment Horizontal Situation Display-Hover (HSDH) 2-D HUD Improvements Air Soldier System 3-D Conformal Symbology
C-27J	—	Multi-Service Operational Test (MOT)
OH-58F	BHIVE 2	Human Factors Engineering (HFE) #1, 2, 3 Design Assessment
RAH-66	CPC, EDS	Force Development Test and Experimentation (FDT&E) 1
UH-60L	BHIVE 1, BHEAC, SIL	Air Soldier System Multi-Modal Cueing Pre-MS B Air Soldier System 3-D Conformal Symbology
UH-60M	BHIVE 1, BHEAC, SIL	Early User Demonstration (EUD) Limited Early User Evaluation (LEUE) LUT Required Navigation Performance/Area Navigation (RNP/RNAV) EUD Tactical Airspace Integration (TAIS) 1 & 2 Mission Information Management (MIM) 1 & 2

Examples of simulators that ARL/HRED uses to assess pilot workload and SA include the OH-58F simulator (figure 3) and the AH-64D Apache simulator (figure 4).

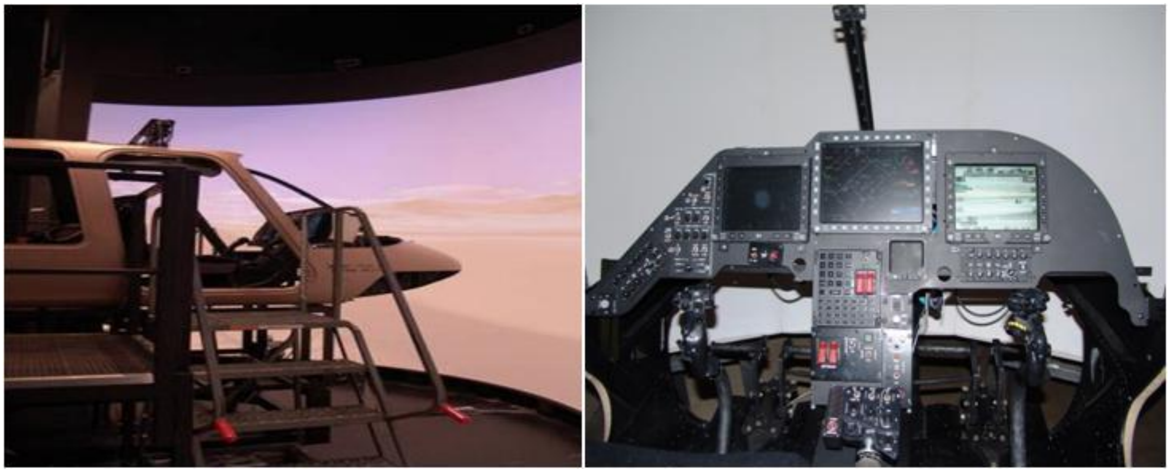

Figure 3. OH-58F crewstation simulator.

Figure 4. AH-64D Apache Longbow crewstation simulator.

2.3 Visual Workload

To help assess pilot workload, SA, and overall crewstation design, pilots wear an eye tracker to record visual gaze and dwell times during missions conducted in the simulators equipped with head trackers. Recording visual gaze and dwell times can identify improvements that need to be made to crewstation design by identifying mission or task segments that require high visual workload. For example, if pilots spend an excessive amount of time viewing the crewstation displays, this can indicate that the displays contain information that requires too many steps (e.g. button pushes, interpretation) to retrieve. Head and eye tracker data are used in combination with BWRS and SA data to help determine high-workload tasks. The inclusion of head and eye tracker data provides objective performance data that can augment the subjective data collected from the crew workload and SA ratings. When pilots spend an excessive amount of time "heads down" or inside the cockpit, their workload ratings are often higher. Situational awareness ratings during excessive heads-down time are usually task-dependent. In some cases, higher workload may actually result in higher SA if a pilot is engaging in tasks that would increase SA of a particular event such as locating enemies or identifying terrain features. Figure 5 shows an example of eye tracker data collected from a copilot-gunner during an AH-64D simulation. ARL/HRED compiled a summary of Army Aviation eye tracker data (Hicks et al., 2012) that documented data collection methodology and results.

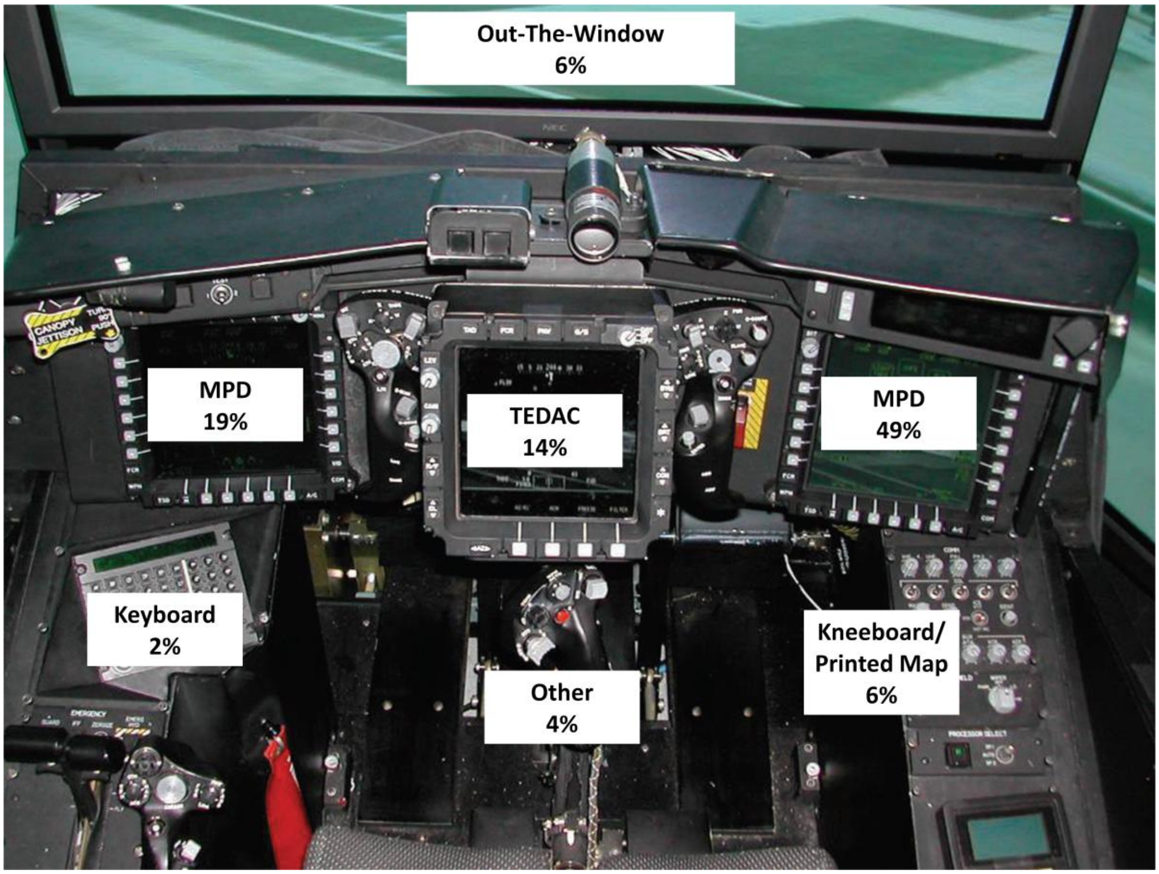

Figure 5. Eye tracker data collected from AH-64D Apache.

3. Workload and SA Ratings

3.1 Bedford Workload Rating Scale Ratings

The pilots completed the BWRS (appendix A) immediately after each mission to rate the level of workload that they experience when performing flight and mission tasks. The ratings are compared against the workload rating requirements for the aircraft (as applicable) to determine if the crewstation design is imposing excessive workload on the pilots. Table 6 shows a summary of overall workload averages collected during the simulations and operational tests. The ratings indicate that the pilots and copilots typically experienced moderate overall workload with either no reduction in spare workload capacity or insufficient to reduced spare workload capacity during the simulations and tests. A rating of 4 or higher on the BWRS indicates that the pilots and copilots had a reduction in spare workload capacity to perform tasks. The one exception was the ARH-70 LUT. Copilots experienced high workload during the LUT because the crewstation display menu structure was nonintuitive and time-consuming to navigate, and the aircraft day TV and Forward-Looking Infrared (FLIR) sensor was difficult to control. In the case of the 3-D conformal tests for CH-47F and UH-60L/M, higher workload ratings were due to the crews performing challenging tasks such as takeoffs and landings in brown-out conditions using new symbology designs.

Table 6. Overall workload averages.

Bedford Workload Ratings - Overall Workload Averages		
System/Test	**Copilot**	**Pilot**
AH-64D – Federated (UAS)	3.30	2.60
AH-64D – Integrated (UAS)	2.60	2.90
AH-64E IOT	2.50	2.50
AH-64E LUT	4.22	3.22
ARH – CAAS	3.71	3.94
ARH LUT	7.39	4.11
CH-47F – CAAS	2.66	2.70
CH-47F – HSDH	2.41	3.36
CH-47F – 2-D HUD	3.31	3.81
CH-47F – 3-D Conformal	3.70	4.10
C-27J MOT	2.17	2.13
OH-58F – HFE #2	3.17	3.00
OH-58F – HFE #3	3.44	2.56
RAH-66 – FDTE 1	3.08	2.90
UH-60M – LEUE	3.33	2.98

Table 6. Overall workload averages (continued).

Bedford Workload Ratings - Overall Workload Averages		
System/Test	**Copilot**	**Pilot**
UH-60M – LUT	2.80	2.58
UH-60M – EUD	2.71	2.16
UH-60M – TAIS 1	1.87	2.42
UH-60M – TAIS 2	2.93	2.66
UH-60M – MIM 1	2.22	2.39
UH-60M – MMI 2	2.35	2.20
UH-60L – Multi-Modal Cues	2.93	3.38
UH-60L – 3-D Conformal	4.27	4.92

3.2 SART and CLSA Ratings

The pilots completed the SART or CLSA immediately after each mission to rate the level of SA they experienced while performing the mission. They also rated their level (high-low) of SA of battlefield elements (e.g., location of enemy units). These data provide ARL researchers information on how well the pilots perceived the simulation environment and potential threats. The battlefield elements situation awareness questionnaire is completed in conjunction with the SART or CLSA questionnaire after each mission. Table 7 shows a summary of overall SART and CLSA score averages collected during the simulations and operational tests. The data indicate that the pilots typically experienced moderate to above moderate levels of SA. The one exception was the ARH CAAS. The pilot and copilot SA ratings indicate that they experienced lower levels of SA due to the workload required to navigate the display menu structure and difficulty controlling the aircraft day TV and FLIR. The CLSA data for the UH-60L and CH-47F were obtained using an inverse scale where higher ratings were indicative of better SA as opposed to the traditional CLSA scale. CLSA ratings would have ranged between 1 and 2 for the UH-60L and CH-47F if they had been obtained with the traditional scale. SA ratings for the AH-64E IOT, ARH LUT, and C-27J MOT were not available for inclusion in the table.

Table 7. Overall SART and CLSA averages.

Situation Awareness Rating Technique - Overall Averages		
System/Test	**Copilot**	**Pilot**
AH-64D – Federated (UAS)	19.00	21.30
AH-64D – Integrated (UAS)	18.40	23.20
ARH – CAAS	17.67	17.22
CH-47F – CAAS	23.83	20.13
RAH-66 – FDTE 1	21.86	22.40
UH-60M – LEUE	26.42	25.25
UH-60M – LUT	28.28	28.22
UH-60M – TAIS 1	33.78	18.66
UH-60M – TAIS 2	17.66	20.60
UH-60L – Multi-Modal Cues	29.33	19.95
China Lake Situational Awareness Scale - Overall Averages		
System/Test	**Co-Pilot**	**Pilot**
AH-64E LUT	1.94	1.74
OH-58F – HFE #2	2.75	2.50
OH-58F – HFE #3	2.22	1.67
UH-60L – Multi-Modal Cues	3.94	3.75
UH-60L – 3-D Conformal	3.74	3.67
CH-47F – 3-D Conformal	3.91	3.74

4. Summary

The method that ARL/HRED uses to assess the human factors characteristics of U.S. Army Aviation helicopter crewstations has been successful in evaluating crew workload and SA, and eliminating human factors design problems. To date, more than 500 crewstation design improvements have been made to resolve the human factors problems and enhance crew performance. Examples include software improvements to crewstation displays such as enhanced functionality and presentation of display pages to pilots, improved color-coding of battlefield graphics, reduced number of button presses to display information, enhanced readability of display map pages, and improved presentation of aircraft operational limits. Hardware improvements include: modifications to crewstation seats, consoles, and glare shields to improve visual access and physical reach to displays and controls; improved functionality of flight helmets and helmet-mounted displays; and optimized crewstation switch location and function. These improvements are documented in ARL technical reports and Army Aviation programmatic and technical documents.

The benefits to using the crewstation assessment method to assess crew workload, SA, and crewstation design are (1) iterative crewstation evaluations drive continuous incremental improvements, (2) improvements are identified in near real time, which aids rapid modification, (3) identifies crewstation design that needs further improvement, (4) issues documented for one aircraft often apply to new or updated aircraft, which helps with early identification of issues for these aircraft, and (5) results feed the assessments used by acquisition officials to determine whether to manufacture and field Army Aviation aircraft.

ARL/HRED will continue to assess crew workload and SA and thereby improve crewstation design to meet the demands of the next generation of Army aircraft.

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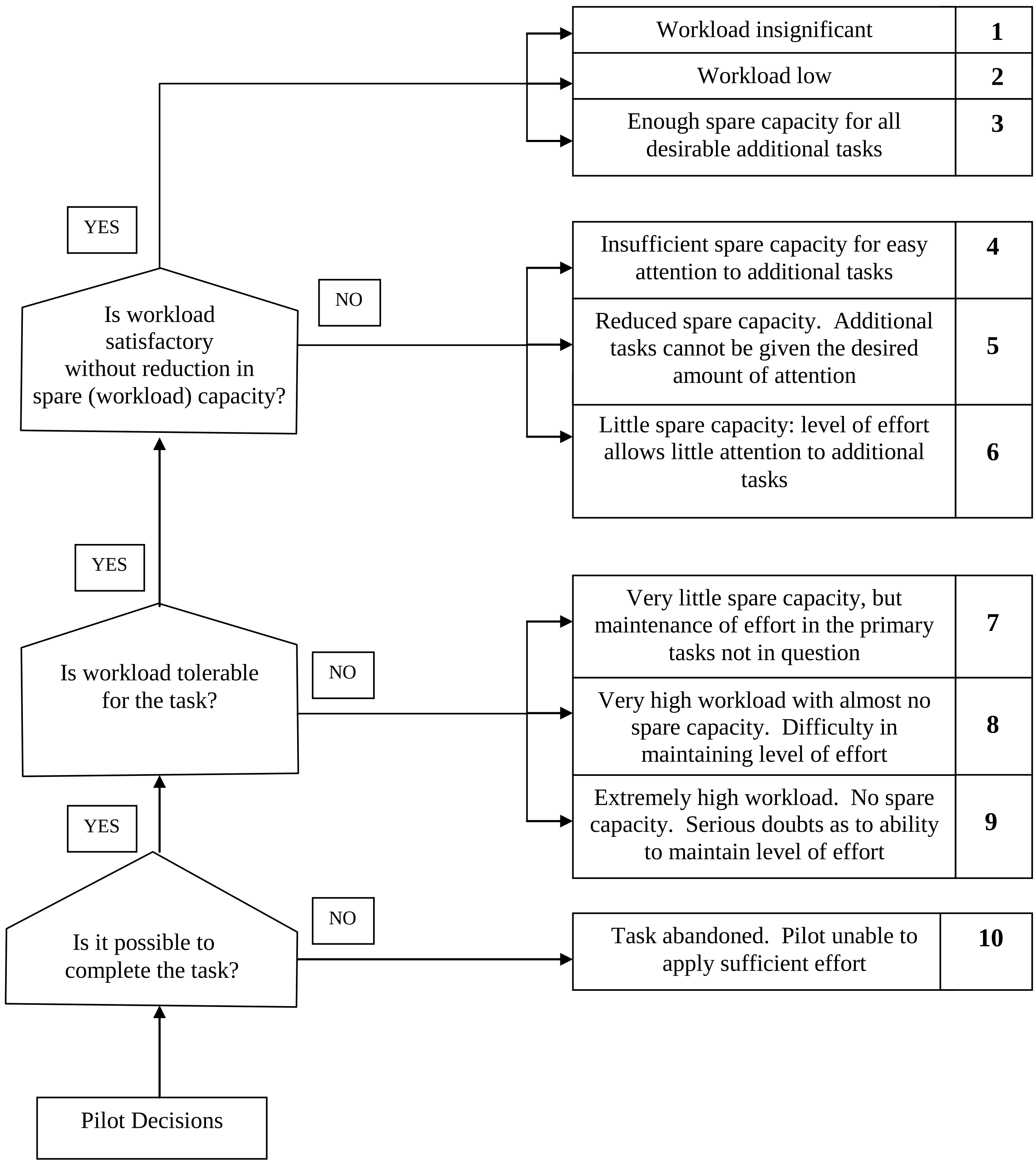
Appendix A. Bedford Workload Rating Scale and Questionnaire

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

Workload

Rate the workload for the Flight and Mission Tasks you performed (on the 2nd page) using the workload scale below. Place the workload rating in the blank next to <u>each</u> Flight and Mission Task.

Workload Description **"Rating"**



Pilot Workload

Rate the workload for the Flight and Mission Tasks you performed during the mission that you just completed. Use the scale provided on the last page of this questionnaire. Place the workload rating in the blank next to each Flight and Mission Task. If you did not perform a task during the mission that you just completed, place an X in the non-applicable (NA) column.

Task No.	Flight and Mission Tasks	Workload Rating	NA
1026	Maintain Airspace Surveillance		
1028	Perform Hover Power Check		
1030	Perform Hover Out-Of-Ground-Effect (OGE) Check		
1032	Perform Radio Communication Procedures		
1038	Perform Hovering Flight		
1040	Perform Visual Meteorological Conditions (VMC) Takeoff		
1044	Navigate by Pilotage and Dead Reckoning		
1046	Perform Electronically Aided Navigation		
1048	Perform Fuel Management Procedures		
1052	Perform VMC Flight Maneuvers		
1058	Perform VMC Approach		
----	Level of Interoperability (LOI) 2 with UAS		
1066	Perform A Running Landing		
1070	Respond to Emergencies		
1074	Respond to Engine Failure in Cruise Flight		
1140	Perform Nose Mounted Sensor (NMS) Operations		
1142	Perform Digital Communications		
1155	Negotiate Wire Obstacles		
1170	Perform Instrument Takeoff		
1176	Perform Non Precision Approach (GCA)		
1178	Perform Precision Approach (GCA)		
1180	Perform Emergency GPS Recovery Procedure		
1082	Perform an Autorotation		
1182	Perform Unusual Attitude Recovery		
1188	Operate ASE/transponder		
1184	Respond to IMC Conditions		
1194	Perform Refueling /Rearming Operations		
1404	Perform Electronic Countermeasures Electronic\Counter-Countermeasures		
1405	Transmit Tactical Reports		
1407	Perform Terrain Flight Takeoff		
1408	Perform Terrain Flight		
1409	Perform Terrain Flight Approach		
1410	Perform Masking and Unmasking		
1411	Perform Terrain Flight Deceleration		

Task No.	Flight and Mission Tasks	Workload Rating	NA
1413	Perform Actions on Contact		
1416	Perform Weapons Initialization Procedures		
1422	Perform Firing Techniques		
1456	Engage Target with .50 Cal		
1458	Engage Target with Hellfire		
1462	Engage Target with Rockets		
1472	Perform Aerial Observation		
1471	Perform Target Handover		
1472	Aerial Observation		
1473	Call for Indirect Fire		
2010	Perform Multi-Aircraft Operations		
2127	Perform Combat Maneuvering Flight		
2128	Perform Close Combat Attack		
2129	Perform Combat Position Operations		
2164	Call for Tactical Air Strike		
-----	Zone Reconnaissance		
-----	Route Reconnaissance		
-----	Area Reconnaissance		
-----	Aerial Surveillance		
-----	Overall Workload for the Mission		

If you gave a workload rating of '5' or higher for any task, explain why the workload was high for the task.

____

____

____

Appendix B. SART and CLSA Rating Scales

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

Situation Awareness is defined as "timely knowledge of what is happening as you perform your right or left seat tasks during the mission."

Situation Awareness Rating Technique (SART)	
DEMAND	
Instability of Situation	Likeliness of situation to change suddenly
Variability of Situation	Number of variables which require your attention
Complexity of Situation	Degree of complication (number of closely connected parts) of the situation
SUPPLY	
Arousal	Degree to which you are ready for activity
Spare Mental Capacity	Amount of mental ability available to apply to new tasks
Concentration	Degree to which your thoughts are brought to bear on the situation
Division of Attention	Amount of division of your attention in the situation
UNDERSTANDING	
Information Quantity	Amount of knowledge received and understood
Information Quality	Degree of goodness or value of knowledge communicated
Familiarity	Degree of acquaintance with the situation

Rate the level of each component of situation awareness that you had when you performed 'flying pilot' tasks in the right seat **–or–** 'non-flying' pilot tasks in the left seat during the mission that you just completed. Circle the appropriate number for each component of situation awareness (e.g., complexity of situation).

DEMAND

Instability of situation:	Low	1---------2---------3---------4---------5---------6---------7	High
Variability of situation:	Low	1---------2---------3---------4---------5---------6---------7	High
Complexity of situation:	Low	1---------2---------3---------4---------5---------6---------7	High

---

SUPPLY

Arousal:	Low	1---------2---------3---------4---------5---------6---------7	High
Spare mental capacity:	Low	1---------2---------3---------4---------5---------6---------7	High
Concentration:	Low	1---------2---------3---------4---------5---------6---------7	High
Division of attention:	Low	1---------2---------3---------4---------5---------6---------7	High

---

UNDERSTANDING

Information quantity:	Low	1---------2---------3---------4---------5---------6---------7	High
Information quality:	Low	1---------2---------3---------4---------5---------6---------7	High
Familiarity:	Low	1---------2---------3---------4---------5---------6---------7	High

Battlefield Elements

Rate the level of situation awareness you had for each battlefield element during the mission? (Place an X in the appropriate column for each battlefield element).

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**
Location of Enemy Units					
Location of Friendly Units					
Location of Non-Combatants (e.g., Civilians)					
Location of My Aircraft During Missions					
Location of Other Aircraft In My Flight					
Location of Cultural Features (e.g., bridges)					
Route Information (ACPs, BPs, EAs, RPs, etc.)					
Status of My Aircraft Systems (e.g., fuel consumption)					

Describe any instances when you had low situation awareness during the mission:

____

____

China Lake Situational Awareness Scale

CLSA SCALE VALUE	CONTENT
Very Good – 1	• Full knowledge of A/C energy state/tactical environment/mission. • Full ability to anticipate/accommodate trends.
Good – 2	• Full knowledge of A/C energy state/tactical environment/mission. • Partial ability to anticipate/accommodate trends; • No task shedding
Adequate – 3	• Full knowledge of A/C energy state/tactical environment/mission. • Saturated ability to anticipate/accommodate trends; • Some shedding of minor tasks
Poor – 4	• Fair knowledge of A/C energy state/tactical environment/mission. • Saturated ability to anticipate/accommodate trends; • Shedding of all minor tasks as well as many not essential to flight safety/mission effectiveness
Very Poor – 5	• Minimal knowledge of A/C energy state/tactical environment/mission. • Oversaturated ability to anticipate/accommodate trends; • Shedding of all tasks not essential to flight safety/mission effectiveness

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Appendix C. PCI Questionnaire Example

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

PV1. The following table lists the components of a CAAS crewstation. For each component, indicate whether or not you experienced a problem using the component in a quick and efficient manner during the mission you just completed. 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 mission you just completed.

- Multifunction Displays (MFD)
  - Vertical Situation Display (VSD) Yes _____ No _____ Not Used___
  - VSD Hover (VSDH) Yes _____ No _____ Not Used___
  - Horizontal Situation Display (HSD) Yes _____ No _____ Not Used___
  - HSD Hover (HSDH) Yes _____ No _____ Not Used___
  - EOS Yes _____ No _____ Not Used___
  - Digital Map Display (DMS) Yes _____ No _____ Not Used___
  - Warning, Caution, Advisory Display (WCA) Yes _____ No _____ Not Used___
    - Engine Instrument Caution Advisory System (EICAS) Yes _____ No _____ Not Used___
- Control Display Unit (CDU)
    - Initializing CDU Yes _____ No _____ Not Used___
    - Managing GPS / Flight Plan Yes _____ No _____ Not Used___
    - Managing COM, NAV, IFF (CNI) Yes _____ No _____ Not Used___

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 recommendation you have for improving the design of the various functional components.

____

____

____

PV3. Please answer the following questions regarding the Multifunction Control Unit (MFCU):

PV3-1. Did the functionality of the directional control and switches on the MFCU perform the actions you expected?

Yes _____ No _____ Not Used ______

PV3-2. Was the sensitivity of the directional control appropriate?

Yes _____ No _____ Not Used ______

PV3-3. Did you experience abnormal hand discomfort while using the MFCU?

Yes _____ No _____ Not Used ______

PV3-4. Did you have adequate space in the cockpit to use the MFCU?

Yes _____ No _____ Not Used ______

If you experienced any problems with the MFCU, please describe the problems in as much detail as you can and make recommendations to correct the problems.

____

____

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

Collective Grip	Yes _______	No ________
Cyclic Grip	Yes _______	No ________

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 too hard to reach).

____

____

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 (VSD)	Yes ______	No ______
VSD Hover (VSDH)	Yes ______	No ______
Horizontal Situation Display (HSD)	Yes ______	No ______
HSD Hover (HSDH)	Yes ______	No ______
EICAS	Yes ______	No ______
Digital Map System (DMS)	Yes ______	No ______

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 may have degraded your performance, and d) any recommendations you have for improving the design of the various functional components.

____

____

PV6. How would you rate your ability to detect the following occurrences based on the characteristics of the flight displays?

Caution/Advisory (MFD)

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

Warning (Master Warning Panel)

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

Entry Into Operational Limits

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

Low Fuel (MFD)

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

If you answered “Somewhat Difficult”, or “Very Difficult”, please indicate which annunciation you had difficulty detecting, why you may have had difficulty detecting it, and any recommendations to make the annunciation more easily detectable.

____

____

PV7. Based on the missions you’ve conducted this week, what are the top enhancements that should be made to the crewstation to improve pilot performance?

____

____

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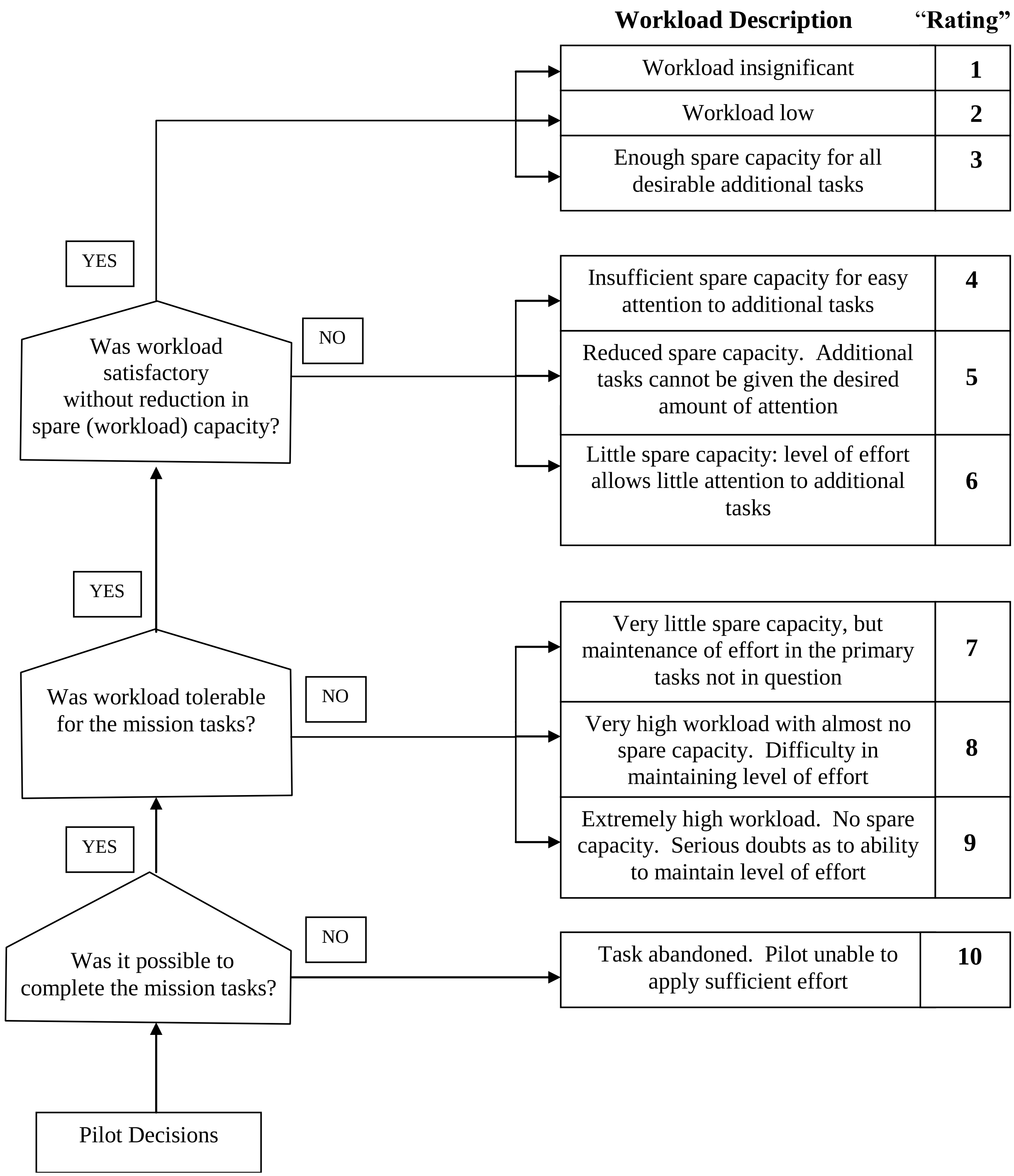
Appendix D. SME Questionnaire

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

<u>Workload</u>

TSCWL1. Using the workload scale below, rate the overall workload for the crewmembers that you observed (during this mission) on the following page.



TSCWL1. Place the workload rating in the blank next to each crewmember using the rating scale on the previous page (continued).

Crewmembers	Overall Workload Rating For This Mission
Left Seat	
Right Seat	

If you assigned a workload rating of '6' or higher for either crewmember, explain why:

____
____

TSCWL2. Which crewmember was the 'flying pilot' for most of the mission?

Left seat _____ Right seat _____

TSCWL3. What percentage of the time was the crewmember (left seat or right seat in question above) the 'flying pilot' during the mission?

_______%

TSCWL4. Rate the effectiveness of aircrew coordination as defined by the USAAVNC Aircrew Coordination ETP and TC 1-210.

1	2	3	4	5
Excellent	Good	Average	Needs Improvement	Unacceptable

Situation Awareness

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

Describe any problems that aircrews had with situation awareness.

____

____

List of Symbols, Abbreviations, and Acronyms

ARH	Armed Reconnaissance Helicopter
ARL	U.S. Army Research Laboratory
BHEAC	Blackhawk Helicopter Engineering and Analysis Cockpit
BHIVE	Battlefield Highly Immersive Virtual Environment
BWRS	Bedford Workload Rating Scale
CAAS	Common Aviation Architecture System
CHEAC	Cargo Helicopter – Engineering Analysis Cockpit
CPC	Comanche Portable Cockpit
EDS	Engineering Development Simulator
EUD	Early User Demonstration
FDT&E	Force Development Test and Evaluation
FLIR	Forward-Looking Infrared
HFE	Human Factors Engineering
HRED	Human Research and Engineering Directorate
IOT	Initial Operational Test
LEUE	Limited Early User Evaluation
LUT	Limited User Test
MIM	Mission Information Management
MOT	Multi-Service Operational Test
PCI	Pilot-Crewstation Interface
RACRS	Risk and Cost Reduction System
RNAV	Area Navigation
RNP	Required Navigation Performance
SA	situation awareness
SART	Situation Awareness Rating Technique
SIL	System Integration Laboratory

SME	subject matter expert
TAIS	Tactical Airspace Integration System
UAS	Unmanned Aircraft System

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