

## Lessons Learned from the UH-60M Early User Demonstrations

**Daniel Kern**  
Utility Helicopters Project Management Office  
Redstone Arsenal, AL  
daniel.kern@uh.redstone.army.mil

**Joshua Kennedy**  
ARL – Human Research & Engineering Directorate  
Fort Rucker, AL  
jkennedy@arl.army.mil

**Jimmy Moore**  
Science Applications International Corporation  
Huntsville, AL  
moorej@saic.com

### ABSTRACT

The Utility Helicopters Project Management Office (UH-PMO) tailored the acquisition strategy for the UH-60M BLACK HAWK through the establishment of Crew Station Working Group meetings and Early User Demonstrations to support the developmental test portion of the System Development program phase. This process provided the opportunity to influence the design of the cockpit early in the acquisition cycle and allowed significant user input to the acquisition process.

A reconfigurable cockpit was designed to allow a variety of cockpit hardware and software configurations to be considered within an operationally relevant scenario. The cockpit was placed in the Battlefield Highly Immersive Virtual Environment (BHIVE). This allowed pilots and human factors experts to experiment with cockpit layout designs and perform cockpit and pilot performance evaluations based on situational awareness studies in a realistic operational environment. Tactical vignettes were developed using Modular Semi-Automated Forces (ModSAF) to provide the pilots with simulated missions representing several operational scenarios.

The displays, cockpit and synthetic environment were modified appropriately during successive simulation events based on pilot and subject matter expert feedback to determine the optimum configuration for the UH-60M cockpit.

Data collection methods were implemented to provide verification and validation of the simulation study results. The team employed a head and eye tracker system to gather quantitative data on elements within the pilot's field of regard. The team designed a time-stamped audio and video capture system to correlate the head/eye tracker data back to the recorded events and implemented a Distributed Interactive Simulation Protocol Data Unit capture system to correlate the head/eye tracker data back to relevant events within the operational scenario.

The use of this approach and the collaborative environment allowed the study team to rapidly define and execute a meaningful exercise that provided relevant, immediate and valuable results. *The capability to provide early user involvement and feedback early in the design process was crucial to identifying and resolving key cockpit configuration issues for the UH-PMO.*

### ABOUT THE AUTHORS

**Daniel Kern** is the UH-60M Test Integrated Process Team lead for the Utility Helicopters Project Management Office. He has more than 13 years in supporting aviation Test and Evaluation programs for the Department of the Army. He holds a B.S. in Aerospace Engineering from Oklahoma State University.

**Joshua Kennedy** is an engineering psychologist with the Fort Rucker field element of the Army Research Lab's Human Research & Engineering Directorate. He is the Human Factors/MANPRINT lead on the UH-60M program. Mr. Kennedy holds a B.S. in Engineering Psychology from the United States Military Academy. He is a former Army officer and rated Army Aviator, with flight and command experience in multiple aviation units.

**Jimmy Moore** is manager of the Synthetic Environments Section of the Experiments and Analysis Division of SAIC. He has more than 10 years of experience in Modeling and Simulation and is the contractor lead for the Advanced Prototyping and Experimentation (APEX) Lab UH-60M Simulation programs. Mr. Moore holds a Bachelor of Science degree in Mechanical Engineering from the University of Alabama in Huntsville.

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### UH-60M PROGRAM DESCRIPTION

The UH-60 BLACK HAWK Modernization Program was established to meet the new requirements for supporting the objective force. This includes increased lift, range, reliability, maintainability, survivability and digitized capability for the future battlefield. The program is also designed to address the challenges of the aging fleet, such as decreasing operational readiness and increasing operating, support and maintenance costs (Robinson, Lake, Bergantz and Bolton, 2001).

The UH-60M, manufactured by Sikorsky Aircraft Corporation (SAC), is based on the UH-60L Lot 21 configuration with additional improvements to airframe, electrical system, main rotor blades, flight control computer, and cockpit/avionics. Airframe improvements include refurbishment or replacement of cabin components, and refurbishment of tail cone, stabilator, vertical pylon, airframe tuning devices, troop seats, and crew seats.

The UH-60M cockpit and avionics improvements represent the most significant changes to the BLACK HAWK configuration (see Figure 1). The modernization program will produce a fully digital “glass” cockpit that is designed to enhance battlefield situational awareness (SA) and decrease pilot workload. The cockpit has undergone the transformation from analog to digital through the integration of four Rockwell Collins Multi-Function Displays (MFDs). These MFDs increase tactical and flight SA by displaying selectable pages for the primary flight instruments, navigation system, dynamic digital map, communications, and Engine Instrument Caution Advisory System (EICAS). Additionally, the Canadian Marconi Flight Management System (FMS) was integrated to provide an improved user interface for control of all voice, navigation and digital communications, as well as

enhanced fault management and system status reporting (Robinson and Hamilton, 2003).

The new cockpit also has improved navigation systems as well as an improved data modem running the Joint Variable Message Format (JVMF) software that provides an interface to the tactical internet. The cockpit also has an improved flight control system, which is enhanced with the ability to be coupled through the Flight Director / Digital Control Panel (FD/DCP). This system enables an autopilot feature for “hands off” flight. The cockpit also adds a multifunction slew controller (MFSC) for each pilot. This device gives the pilot/co-pilot a cursor control for MFD page navigation. This will provide standard computer mouse functionality for navigation, selection, and interaction with the various pages. This has direct applicability with the digital map, allowing pilots to interactively select icons, modify routes and send spot reports via JVMF without leaning forward to select bezel buttons on the MFD displays. The MFSC has future potential use on the HH-60M MEDEVAC for controlling the Forward Looking InfraRed (FLIR), which is used for nighttime operations as well as search and rescue efforts.



**Figure 1.** Artist Rendering of the UH-60M Cockpit (image courtesy of Sikorsky Aircraft Corporation)

## **PROBLEM DEFINITION**

The UH-60 BLACK HAWK modernization program had significant challenges to overcome in order to ensure that the development of the UH-60M cockpit met the needs of the user. The primary task was to develop a process that could provide a structured framework for the development of the cockpit. The Utility Helicopters Project Management Office (UH-PMO) identified the crew station development team, developed a method for requirements traceability and established a collaborative and flexible engineering environment that enabled meaningful data collection for Human Factors Engineering (HFE) valuation.

Once the critical design team was put in place, the next hurdle was to demonstrate the new acquisition concept to the team and get them to take ownership of the process. An initial capabilities demonstration was conducted as a proof of principle of the technology and confirmation of the approach. This initial demonstration was dubbed Early User Demonstration (EUD) #1.

Another critical area was how to manage the meeting process and the dynamics of the group to ensure that the technology could be harnessed appropriately. This not only involved how the meetings were established and run, but also how action items and new requirements were traced and staffed both inside and outside the group.

Finally, the primary technical challenge of the process was how to develop a simulation environment flexible enough to support both rapid reconfigurability and tactical hardware to accommodate a wide variety of cockpit layout and hardware configurations. The cockpit environment needed to be reconfigurable enough to anticipate the evolving issues and requirements, but high enough fidelity to provide a tactically relevant simulation for scenario driven events.

## **THE UH-60M ACQUISITION PROCESS**

The Simulation Support Plan for the UH-60M served as the backbone for the Modeling and Simulation (M&S) Strategy implemented by the UH-PMO. It defines the M&S Mission Statement as follows:

“The UH-PMO will provide a constructive environment to identify opportunities for M&S across the spectrum of program functions and allow the contractor to recommend the best M&S tools to support analysis as a means to verify requirements. The UH-PMO will encourage the contractor to implement a Simulation Test and Evaluation Program and share in potential program cost savings. The Government/contractor team will prudently apply M&S to selectively and decisively satisfy performance requirements in the areas of Reliability Analysis, Vulnerability and Survivability, and engineering design changes that impact the system’s operational performance envelope. The UH-PMO will aggressively invest in M&S technology that has been identified to satisfy our requirements and show a solid return of performance for future modifications of the UH-60 platform” (Edwards, Lumb and Lake, 2000).

The digitization of the UH-60M cockpit was a significant leap forward in technology for the BLACK HAWK program, and thus represented a significant amount of risk. To mitigate this risk, and to ensure user involvement, the UH-PMO inserted EUDs into the acquisition strategy. The EUD process was implemented as a series of progressive M&S events supporting the engineering design and the developmental test portion of the acquisition process. The UH-60M planned Integration and Qualification Test Schedule is shown in Figure 2. To minimize risk, a series of Pilot-Vehicle Interface (PVI) engineering trade studies were conducted to allow users to provide feedback on changes made to the baseline configuration by the cockpit design team. This process ensured that the design of the cockpit improved mission performance and safety.

## **EUD-CSWG-SME Strategy**

The M&S strategy evolved into a tiered approach to system development and design. This approach utilized three levels of events that focused the team on particular aspects of the cockpit design, the Subject Matter Expert (SME) meeting, the Crew Station Working Group (CSWG) meeting, and the EUD. Each event, from SME to CSWG to EUD, increased in scope, breadth, complexity, participant involvement and community visibility.

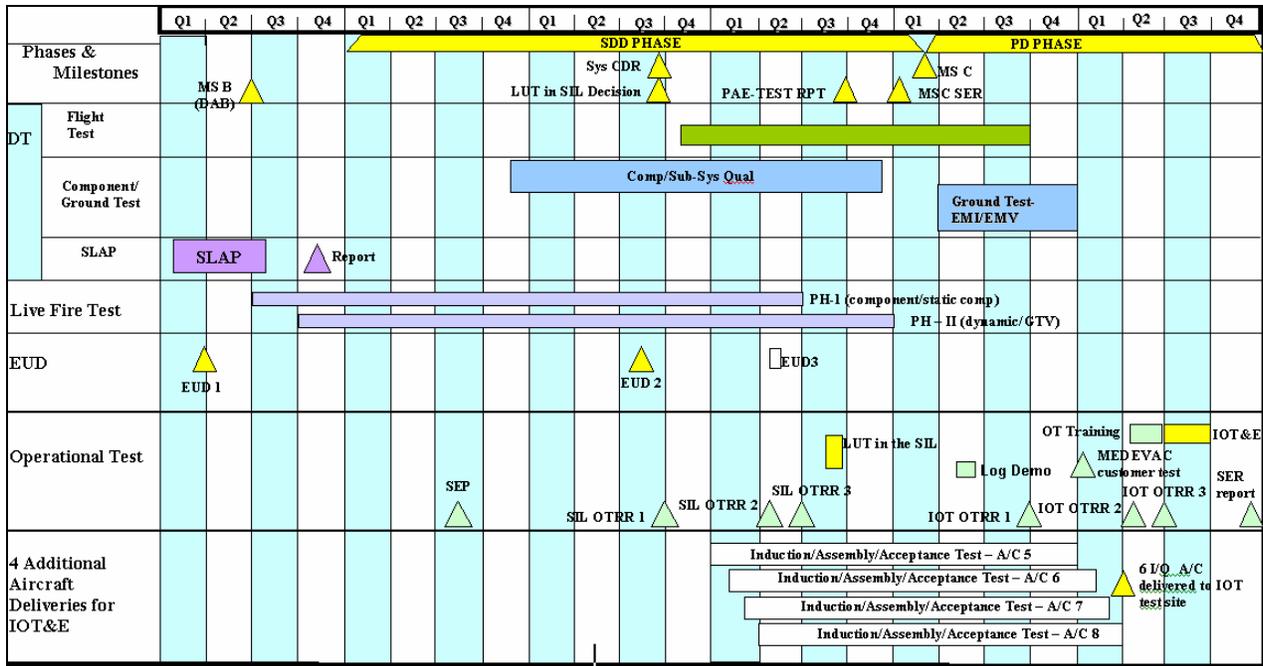


Figure 2. UH-60M Integration/Qualification Test Schedule

The first tier was the SME meeting. The SMEs were informal, internal, one- to two-day, technical meetings that concentrated on fine details within the cockpit. These meetings took place as needed and focused on the functionality and design of a specific sub-component of the overall PVI. Participation in these events was limited to individuals who have in-depth technical knowledge of the subsystem being discussed and typically did not involve extensive use of the reconfigurable cockpit. Simulation was typically limited to vendor demonstrations or simulations of the component under scrutiny.

The next tier was the CSWG meeting. This meeting gathered the full CSWG team for a three- to four-day event that was more formal than the SME meeting. The CSWG meetings looked at the functionality of specific components (i.e. PFD, EICAS, digital map, JVMF, etc.) and the PVI associated with these components. The reconfigurable cockpit was used in this venue to demonstrate different design alternatives and generate new ideas within the cockpit environment. This often required the rapid modification of the functionality or look of individual components so that the design could be evaluated immediately in the reconfigurable cockpit to assess the validity of the design change. The capability to provide immediate feedback was highly beneficial in ensuring that all CSWG members understood the

impact of their decisions. This also ensured concurrence from all associated parties on cockpit design modifications. The CSWG meeting was where the flexibility of the reconfigurable cockpit paid great dividends.

The last tier in the simulation strategy was the EUD, which was a scenario driven event. EUDs looked at the PVI system as a whole by allowing operational line pilots to operate the simulator in an immersive environment while flying operationally and tactically relevant scenarios. These were formal events that had a wide variety of participants from all of the participating groups. These events allowed the CSWG to brief the cockpit design changes to the larger UH-60M community and give the pilots the opportunity to fly the cockpit as a single integrated system. This provided a “snap shot” of the cockpit configuration at various points in the dynamic design process. Furthermore, it provided the opportunity to gain valuable insight into the overall design, functionality, and usability of the cockpit. HFE experts assessed the PVI, SA, and workload associated with the design to ensure that the CSWG process improved the overall design.

## Process Management

The EUD process used the COTS CORE tool to track and evaluate design decisions based on a component level hierarchy of the baseline UH-60M configuration. For the dynamic process to succeed, it was essential to maintain an integrated database that provided traceability between requirements and system elements. This tool allowed the team to communicate and coordinate more effectively by maintaining design changes and resulting action items that could be easily traced and managed.

## THE PARTICIPANTS

Participation from the cockpit design team, the user community and the UH-PMO was essential to the success of this type of acquisition process. The team was solidified during the preparation and execution of the first EUD held in January of 2001. This proof-of-principle event brought together the UH-PMO, SAC, and user representatives from the US Army Aviation Center Director of Combat Development (USAAVN-DCD) in Ft. Rucker to demonstrate the viability of using the reconfigurable simulated cockpit to conduct cockpit design events. Once the team members were established, the wider UH-60 community began to participate in the events and realize the valuable feedback that is generated at these meetings. Participation by a core group of pilots and CSWG members throughout the EUD process was a primary factor in the success of the program.

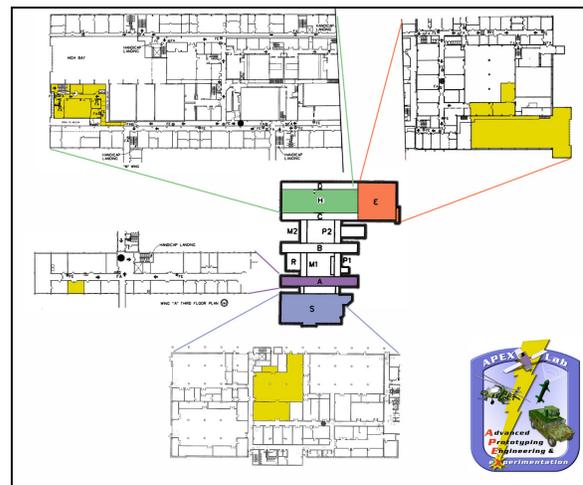
Other government offices that regularly participated in the EUD-CSWG-SME activities included:

- United States Army Aviation Center Directorate of Combat Developments (USAAVNC-DCD) - Combat Aircraft Branch
- UH-60M Product Manager's Office
- Aviation and Missile Research, Development and Engineering Center (AMRDEC) - Systems Simulations & Development Directorate (SS&DD)
- Aviation and Missile Command Software Engineering Directorate (AMCOM-SED)
- Aviation Technical Test Center (ATTC)
- Army Research Lab – Human Research and Engineering Directorate (ARL-HRED)
- Army Evaluation Command (AEC)
- Operational Test Command (OTC)
- Aviation and Missile Command Aviation Engineering Directorate (AMCOM-AED)

## THE ADVANCED PROTOTYPING ENGINEERING AND EXPERIMENTATION LABORATORY

The Advanced Prototyping, Engineering and eXperimentation (APEX) Laboratories offered the appropriate virtual prototyping capability for the EUD process. The APEX Labs are part of the SS&DD family of simulation and analysis facilities, which support AMCOM. The Aviation branch of SS&DD manages various simulation events in the APEX Labs for numerous Program Executive Office Aviation customers.

The mission of these laboratories is to provide M&S support of weapons system design early in the acquisition process. This is accomplished through several means including man-in-the-loop simulators, distributed simulation experimentation, and constructive simulation development. The APEX Labs are High-Level Architecture (HLA) and Distributed Interactive Simulations (DIS) compliant, and have the capability to connect to the Army's battle labs and other distributed simulation facilities through the Defense Research and Engineering Network. This capability enables geographically disperse simulations to be linked in a single distributed experiment architecture. Figure 3 depicts the layout of the APEX laboratories.



**Figure 3.** The APEX Labs Layout

The lab infrastructure is designed to support experimentation through a wide range of technologies. The lab includes a Battlemaster or exercise control station that has access to each simulation playing on the network by means of a Modular Semi-Automated Forces (ModSAF)

terminal, data collection devices, headset communications, and video monitoring. All exercises are conducted from the Battlemaster station to ensure that all players are engaged in the exercise and all data collection devices are active. The Battlemaster station provided the exercise controller and SMEs (see Figure 4) with all of the information needed to coordinate the scenario driven events and data collection devices required for the EUD events.



**Figure 4.** APEX Battlemaster Station

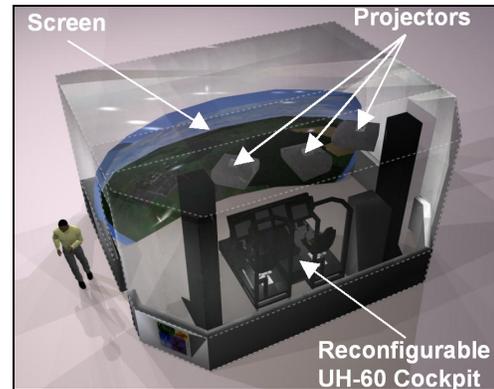
The APEX facility has a complete synthetic environments development team that was able to develop custom, correlated terrain databases that were designed to specifically enhance the realism of the immersive environment and support the operational scenarios for each event.

#### **The Battlefield Highly Immersive Virtual Environment**

Another significant component of the APEX Lab utilized in this process was the Battlefield Highly Immersive Virtual Environment (BHIVE). 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 several types of devices to be integrated into the environment through a standard interface. This provides the flexibility to immerse multiple types of cockpits in a realistic and reusable synthetic world.

The BHIVE is an enclosed environment that is comprised of a projection system, 3D surround sound audio, and a plug and play interface for integration of various engineering analysis devices including the UH-60 / AH-64 A reconfigurable cockpit, AH-1W

and Z Cobra cockpits, RAH-66 Comanche cockpit, and a Tube-launched Optically-tracked Wire-guided (TOW) missile simulator mounted on a HMMWV chassis. The projection system consists of a fixed base bi-directional curved screen with three soft-edge blended projectors and an image generation system. The BHIVE also includes a controller station, a video switching rack and reconfigurable video cameras. The BHIVE allowed the pilots and HFE experts to experiment with cockpit layout designs and perform initial SA and workload assessment studies.



**Figure 5.** BHIVE EUD Configuration

#### **The Reconfigurable UH-60 Cockpit**

The implementation of the M&S strategy for the cockpit design process centered on the design of the reconfigurable cockpit. An overarching concern regarding the UH-60M engineering and analysis cockpit was balancing reconfigurability with fidelity. The cockpit had to be reconfigurable enough to make design changes quickly, yet be realistic enough so that the pilots could provide the necessary feedback to the UH-PMO, SAC, HFE experts, and cockpit design engineers.

The reconfigurable UH-60 cockpit was designed to provide maximum utility and usability throughout the EUD process. The cockpit utilizes flat panel liquid crystal displays and touch screen technology to replicate man-machine hardware interfaces for the MFDs, FMS, and other control surfaces within the cockpit. This allowed for rapid software prototyping of the look, feel, and function of each cockpit component. The cockpit also had integrated 1553 and ARINC 429 busses, providing capability to integrate actual tactical hardware.

## The Reconfigurable UH-60 Cockpit Software

The software configuration for the EUD program evolved throughout the program. The Flight model used for replicating the six-degree-of-freedom (6-DOF) flight dynamics of the aircraft was based on the FlightLab Commercial Off-The-Shelf (COTS) software. The initial module implemented in FlightLab was the UH-60L model supplied by the vendor, Advanced Rotorcraft Technologies (ART). The team then migrated the software from this initial drop to the Aviation Combined Arms Tactical Trainer UH-60 L flight model, which is currently undergoing accreditation. The AMCOM-AED provided the development environment for modification of the flight model where necessary and also provided the engineering expertise to verify flight model characteristics.

The avionics software was developed using the GLStudio COTS product. This software provided a robust and user-friendly interface for MFD page prototyping. The pages were developed based on input from Army aviators, crew station engineers and test pilots from SAC, HFE experts from the Army and SAC, and other participants in the CWSG process. The Primary Flight Display (PFD) page is shown in Figure 6.



Figure 6. Primary Flight Display Page

### PROGRAM EVENTS

#### Early User Demonstration #1 January 8-11, 2001

The purpose of EUD #1 was to allow pilots, cockpit design engineers, and representatives of the UH-PMO to identify user issues and design solutions based on

the current configuration; define the UH-60M cockpit and display candidate baseline configuration; provide an opportunity to define the metrics necessary to measure SA resulting from information presented to the pilot; establish Measures of Effectiveness / Performance (MOE/P) for future SA design and analysis activities; provide lessons learned for EUD2; and to facilitate initial HFE evaluation of candidate instrument panel configurations (Edwards and Nikonchuk, 2001). This event also served as a technology demonstration to prove that the concept of a highly reconfigurable simulator would provide an adequate level of fidelity for engineering and HFE analysis. This event provided the opportunity to test the viability of a two- versus four-MFD cockpit layout, which served as an additional data point for the ongoing trade study that was considering this issue. The results of EUD #1 supported the UH-PMO decision to provide a four-MFD design.

#### Crew Station Working Group #1 September 5-7, 2001

CSWG #1 was held at the Litton facility in Woodland Hills, CA. This event kicked off the formal Crew Station Working Group, providing a formalized charter and introducing many of the concepts that separate the UH-60M cockpit from its predecessors. These included an introduction to the digital map, the slew controller technologies, the four-MFD configuration, the FD/DCP and reversionary panel. It also gave the first demonstration of many of the MFD pages including PFD, EICAS, and navigation pages.

#### Crew Station Working Group #2 January 7-11, 2002

CSWG #2 was held in the APEX Lab and, with pilot input, concentrated on base-lining the initial design of the PFD and EICAS pages. Additionally, a tactical MFD, supplied by Litton, was integrated into the reconfigurable cockpit through an ARINC 429 interface to give the pilots the opportunity to compare and contrast the Litton PFD design versus the existing simulated PFD baseline to generate new ideas and develop a feel for what the issues associated with each design were. The resulting configuration of the PFD represented the best of each of these candidates.

#### Crew Station Working Group #3 April 1-5, 2002

CSWG #3 focused more on the PFD pages, implementing all of the changes that came out of CSWG #2, as well as raising issues with the center

console design, demonstration of the digital map, and the functionality of the FMS. The Litton digital map software was integrated into the reconfigurable cockpit to allow the pilots to have a first look at the digital map in a fully immersed tactical environment.

**Subject Matter Expert Meeting #1  
July 16-18, 2002**

This was the first official SME meeting, although these were already happening as sidebar meetings at other events both within the EUD process and at other opportune times. This meeting focused on a review of the MFD page layout, the FMS functionality, and discussions about the implementation of the JVMF functionality.

**Crew Station Working Group #4  
December 10-12, 2002**

CSWG #4 served as a rebaselining event to bring new CSWG team members up to speed on the process and the progress to date. New team members included Rockwell Collins, Canadian Marconi, and Harris, who were all subcontractors to SAC for avionics hardware and software. The event also demonstrated the digital map interface via the MFSC, integrated the FD/DCP, and included discussions on the Aircraft Survivability Equipment (ASE) and Wx-500 Storm Scope pages. This event facilitated discussion of the FMS page layout using the new FMS faceplate design and allowed pilots to interface with functional PFD and EICAS pages in a tactical environment. This event also introduced the Head/Eye Tracker instrument capabilities and provided the guidance necessary to develop the test plan for EUD #2.

**Subject Matter Expert Meeting #2  
April 3-4, 2003**

SME #2 represented a significant design milestone for the APEX cockpit design team. During this event, the team was able to develop and display five functioning ASE page options on the existing MFD cockpit displays. These pages were developed from designs that were literally scratched on the back of a Taco Bell napkin, then presented in an animated PowerPoint presentation to the SME group, then rapidly prototyped and demonstrated in the reconfigurable cockpit based on the output of the SME discussions. The design that came out of the SME meeting was not any of the five original options that were presented, but a fusion of the best of several of the ideas. In addition to the ASE page design the SME group also prototyped options for Wx-500 Storm Scope implementation in the new cockpit.

**Early User Demonstration #2  
May 12-16, 2003**

EUD #2 was conducted prior to and in support of the UH-60M system design and development Critical Design Review (CDR). This event was designed to ensure that the HFE criteria were correctly addressed and to identify design or operational deficiencies that may degrade the system's intended performance. Through an HFE evaluation of workload, SA, and PVI, this event allowed the user community to assess the avionics system Preliminary Design Review (PDR) design of the UH-60M crew station.

This demonstration included the addition of a Fokker control loading system for the flying pilot. This system provided realistic forced feedback for the sticks and pedals as well as a seat shaker for improved realism and immersion in the virtual environment. This demonstration also investigated the use of the JVMF messaging, the use of the integrated digital map, the use of the MFSC, and was the first demonstration of the FD/DCP in an integrated cockpit environment.

The most significant result of EUD #2 was that it demonstrated that the future UH-60M cockpit design is capable of performing today's air assault mission. The CSWG concluded that even though considerable work remains, the cockpit design was on a good path.

EUD #2 represented a major leap forward in technology integration and was a major success for the CSWG-SME-EUD process. Thus, this latest demonstration will be discussed in further detail to highlight the gains it brought to the UH-60M acquisition process and to provide insight into the test development procedures.

**EUD #2 TEST DEVELOPMENT**

**Test Purpose**

The primary purpose of EUD #2 was to conduct a HFE evaluation of the UH-60M crew station. Technology improvements in aircraft capability and the display of information in modern "glass cockpits" has resulted in increased aircrew monitoring, workload, crew coordination, and decision making responsibilities. EUD #2 was an engineering event that provided valuable data as part of the system developmental test program, with the objective of conducting risk mitigation in the overall crew station design process. The primary areas of evaluation, in accordance with the UH-60M System Evaluation

Plan, were the PVI, cockpit workload, SA and crew coordination (Kennedy and Bordett, 2003). This event afforded the opportunity to gain feedback from multiple users to assess and improve the crew station well before formal developmental testing on the actual aircraft.

### Test Design

Two sets of aircrew (four pilots) flew a series of scenarios, each lasting approximately sixty minutes. Operational scenarios were developed by the UH-60M User Representative (USAAVNC-DCD) and integrated into the BHIVE using a combination of the Aviation Mission Planning System (AMPS) and ModSAF to provide the pilots with simulated missions representing a variety of operational scenarios. The scenarios developed for EUD #2 included a long-range surveillance detachment insertion, air movement and air assault missions. These scenarios were augmented by several events not briefed to the aircrews that further stressed and stimulated the pilots and forced their attention into the cockpit. These included adverse weather conditions, emergency procedures, unplanned navigation routing, and changes of mission. A total of six missions were flown over the course of three days, with each pilot flying one scenario per day. Crew mixes were changed daily to help gain new insights on possible cockpit changes and crew coordination.

### Data Collection

#### HFE Questionnaires and Debriefing

The primary data collection was performed through a series of questionnaires issued pre- and post-flight for pilots to rate the PVI, their perceived workload, and SA. The HFE evaluation of the PVI was rated by crewmember evaluation of the design through targeted questionnaires that gathered data in several areas. The questionnaires were completed while still in the simulator allowing immediate feedback to the HFE experts. Simulator sickness questionnaires were administered pre- and post-flight to assess any possible problems with simulator sickness affecting performance. The PVI questionnaires were targeted to gather data in multiple aspects of the crew station. Pre-flight questionnaires were administered to gather data on each pilot's flying experience, and limited anthropometric measurements were taken.

In addition to the questionnaires, HFE experts were able to view the pilot's actions during each exercise from behind the cockpit. Two other UH-60 SMEs from USAAVNC-DCD independently evaluated crew

workload, SA, crew coordination, and mission success from the Battlemaster station. After each scenario, the SMEs, pilots, and HFE evaluation team performed a mission debriefing in an adjacent conference room.

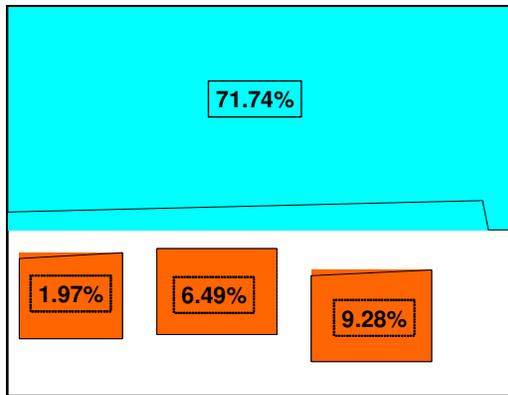
#### Head/Eye Tracker

While the data from the questionnaires was systematically gathered by widely accepted HFE methodologies, it was still subjective in nature. Complementary objective data was collected through a head/eye tracking system from Polhemus. Their VisionTrak head mounted eye tracking system is a fully integrated solution for eye and target tracking. This system collected pupil size, eye movement, and eye point-of-regard. It correlated the raw eye position to the precise position in the scene and collected data in real time from human subjects while allowing complete freedom of head movement. The image being viewed by the subject was identified by crosshairs and instantaneously superimposed over live imagery (see Figure 7). Built-in analysis software allowed data to be viewed in tabular or graphical format, to include velocity, acceleration, and gazing information.



**Figure 7.** Eye Tracker FOV and Data Capture Viewing Planes

This system allowed APEX engineers to quickly establish viewing planes that were used to capture specific data regarding critical areas of the cockpit for rapid data reduction. Additionally, the APEX team was able to experiment with an eye tracking system that was integrated into the pilot's existing helmet to add more realism and immersion for the pilot test subject. A composite of the visual gaze data for the pilot that was collected throughout EUD #2 is shown in Figure 8.



**Figure 8.** Composite of Visual Gaze Data

The beauty of the eye tracking system was that it allowed the material developers an objective means of assessing visual gaze, and by extension, mental workload. The Army Aviation community as a whole has concerns about the effect of ‘glass cockpits’ on pilot workload and SA. The eye tracker is an inexpensive, objective means of assessing whether pilots are ‘cognitively captured’ by the new digital displays in this cockpit.

#### Audio/Video

Participant comments, concerns and actions were recorded at each event through video taped simulation runs and after action discussions. This video capture was time stamped and cataloged for each run to give the participants a permanent record of the events and feedback for each set of crews in each scenario. This video was distributed to participants for post exercise analysis and documentation. Figure 9 is a screen capture of the quad screen view of the video collected during EUD #2. This video shows the video from the pilot camera in the upper left; the video from the over the shoulder camera in the upper right; the left side inboard MFD on the lower left (showing the digital map); and the pilot outboard MFD (showing the PFD) on the lower right. The quad view could be modified as required to display any of the other cameras or video inputs that the exercise controller deemed necessary for data collection.



**Figure 9.** Quad View of EUD2 Experiment

#### Distributed Interactive Simulation (DIS)

Utilizing a DIS Logger system, each of the events were captured via DIS data packets that can be replayed over the DIS network to look at various aspects of the simulation to include, vehicle attitude, orientation, speed, and location at any given time during the exercise. This was a useful tool to help exercise coordinators debug simulation anomalies or provide after action reviews of simulation performance parameters.

#### LESSONS LEARNED

There were many lessons learned throughout this process that can be applied to other similar programs. The overarching lesson learned was that the reconfigurability of the cockpit and flexibility of the immersive environment as well as cooperation and coordination between the CSWG members are both essential to the success of the design process.

Due to the reconfigurable nature of the cockpit simulator as well as the evolving design of the cockpit itself, it is imperative that adequate training be given to the pilot test subjects prior to scenario record runs. This will avoid a great deal of frustration on the part of the pilots if they are familiar with and have had proper training on all of the new system components. The SMEs conducting independent assessments reported that pilot workload, SA, and crew coordination improved over the course of the demonstration indicating that the crew were “self training” during the event. This phenomenon should be avoided in future tests to ensure consistent data collection across all trials.

The use of this approach and the collaborative environment allowed the study team to rapidly define and execute a meaningful exercise that provides

relevant and valuable results. The capability to get user involvement and feedback in the design process was crucial to identifying and resolving key cockpit configuration issues for early in the UH-60M acquisition phase. In addition, the CSWG-SME-EUD process became such a valuable HFE tool, that all crew station design decisions were deferred to the CSWG for final recommendation to the UH-PMO.

Pilot workload for most aircraft and mission tasks was acceptable, the primary exception being the digital messaging task performed via the FMS and MFDs. That task reflected the highest workload rating and had some negative impacts on aircrew performance. This task also had some negative effects on SA as it forced a more 'eyes in' condition for the non-flying pilot to perform the task during the mission. Overall, pilots felt workload was similar to the UH-60A/L cockpit.

SA was much improved in this digital cockpit, and pilots felt their SA was improved versus the UH-60A/L cockpit. The combination of a digital map, steering cues and embedded GPS devices in the aircraft greatly enhanced SA and made the navigation task much easier to perform. This drastically impacted crew coordination by providing a "complete navigation picture" to the flying pilot. Historically, navigation has been handled by the non-flying pilot and communicated to the pilot through cross-cockpit crew coordination. The capabilities of the new digital cockpit made this unnecessary. Therefore, a significant shift in crew coordination techniques is anticipated for the UH-60M platform.

## **PATH FORWARD**

### **Additional UH-60M Development**

The UH-PMO has expressed interest in continuing the CSWG and SME meeting process as risk reduction for the next milestone, EUD #3 or Limited User Test (LUT) in the Software Integration Lab (SIL). These meetings will address open issues still unresolved from EUD #2 as well as emerging requirements as they are identified. Current issues include: Aircraft Survivability Equipment; Integrated Heads Up Display (IHUD) integration, new cyclic and collective grip evaluation, FLIR integration, digital map and JVMF messaging. The technology now exists in sufficient fidelity to provide a prototyping capability for future Pre-Planned Product Improvement (P3I) studies.

### **The Limited User Test in the Software Integration Laboratory**

The LUT is a formal test event that will be executed by OTC. EUD #1 and #2 were engineering events that provided input to the developmental test program and provided risk reduction and user input for design of the digital cockpit. These events also provided lessons learned for conducting a formal operational test in a simulated environment. The LUT is that formal operational test. It will provide the initial testing of the hardware and software in support of the UH-60M test and evaluation program. The LUT is currently being planned for 2<sup>nd</sup> Qtr FY04. This event will differ from the previous EUD and CSWG events in that it will be conducted in the AMRDEC Software Engineering Directorate BLACK HAWK SIL. The SIL will integrate actual tactical flight components and software to give the user a preview of the cockpit as designed before first flight.

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