

A Parabolic Flight Study of the Mobile Information System

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ABSTRACT

Focus on sustained lunar operations and human exploration of Mars has become the National Aeronautical Space Administration's (NASA) goal for the 21st century. NASA's objective is to provide crewmembers with a "hands-free" environment to promote more efficient operations in microgravity and reduced planetary gravity missions. A prototype integrated Mobile Information SysTem (MIST) was evaluated in a simulated microgravity environment while supporting the Langley Research Center (LaRC) Electron Beam Freeform Fabrication (EBF³) experiment. Two LaRC crewmembers wore the MIST during half of the parabolic flights as the experimental group. The other half of the parabolic flights served as a baseline group without the MIST being worn. Post-flight questionnaires, interviews, video/audio analysis, and field observations were used as evaluation measures. Results indicate mobility and compactness of a display are important in experimental procedures and other tasks. Using the MIST facilitated team communications and dynamics capturing more information about the experiment under these flight conditions.

INTRODUCTION

Recently, NASA's focus has turned to manned long-duration and exploration missions. On these journeys, crewmembers will be required to execute thousands of procedures to maintain life-support systems, checkout space suits, conduct science experiments, perform medical exams, etc. To support the many complex tasks crewmembers undertake in microgravity and reduced gravity, NASA is interested in providing crewmembers a hands-free work environment to promote more efficient operations. The overarching objective is to allow crewmembers to use both of their hands for tasks related to their mission versus holding a manual or controlling a display. The use of advanced, hands-free tools will undoubtedly make the crewmembers' task easier, but it can also add to overall task complexity if not properly

designed [1]. NASA's Johnson Space Center's (JSC) Usability Testing and Analysis Facility (UTAF) has been evaluating commercially available technologies in a multiphase process that can support a hands-free work environment, as well as define requirements and objectives for such hands-free technologies.

BACKGROUND

The primary technology needed to support a hands-free environment is head-mounted display technology. A Head-Up Display (HUD) is a natural fit for this need. HUD can be defined as a display where information is superimposed on the outside world, but not blocking, the field of view (FOV) of the user (i.e. aircraft windshield or helmet visor) [3, 4, 5].

Many human-computer interface (HCI) researchers have focused solely on traditional display issues. Although some work has been done in the area of cockpit HUDs, additional research is required in order to produce concrete guidelines for the design of optimal, near-eye HUDs for hands-free tasks. It is also important to provide NASA with requirements for such advanced technologies for future implementation. These issues are of critical importance for the safety and productivity of future space missions. Thus, the first step was to identify commercial products that meet the need to provide crewmembers a near-eye visual display for procedures and additional reference material. A heuristic evaluation had been conducted on eight viable commercial-off-the-shelf (COTS) HUDs for the down-select process to three HUDs for Phase 1 of the evaluation study.

In Phase 1, evaluation of the three COTS HUDs focused on maintenance procedures for the International Space Station (ISS) [2]. The objective was to evaluate these HUD integrated systems using a medium fidelity ISS-like mockup and ISS-like maintenance procedures. Maintenance tasks provide a wide variety of evaluation scenarios as well as capitalizing on the HUD's advantages. Results indicated a conflict between display

size, visual surround, and stability. Although some participants preferred a larger and crisper display area for presentation of the procedures, a clear need surfaced for being able to see the visual surround (of the work environment) with the eye that was reading the text instructions. That is, being aware of the world view as well as the HUD view was unmistakably important [6].

For Phase 2, the best HUD from Phase 1 evaluation was compared with two other electronic displays: the conventional laptop, and an e-book, again using maintenance procedures. The laptop and e-book were rated more positively than the HUD on several attributes, but device performance was differentiated for only the more comprehensive of the two maintenance procedures, filter inspection; the HUD use resulting in slightly longer task completion times [7].

In Phase 3, an evaluation of an enhanced HUD system was conducted aboard NASA's C-9 aircraft during brief exposures to microgravity in parabolic flights. This was in conjunction with the operations of a Langley Research Center (LaRC) fabrication experiment. It was an opportunity to test the MIST hardware and software in a real world/microgravity operational environment. The enhanced HUD system is the result of the incorporation of lessons learned from earlier phases of our work. Due to the complexity of flying on microgravity flights no other electronic display device except the MIST prototype was tested with the informational content. Results from these flights are discussed in this paper.

EVALUATION METHODOLOGY

The methodology for this evaluation consisted of video/ audio capture for analysis of operator performance, daily post-flight questionnaires, daily onboard flight observations, and daily post-flight debriefing interviews with LaRC test Operators 3 and 4. During the Electron Beam Freeform Fabrication (EBF³) C-9 flights, Operator 3 and Operator 4 evaluated the enhanced supportability hardware in conjunction with evaluations by an onboard UTAF representative, Operator 5.

The general objectives planned four days on the C-9 aircraft. The LaRC EBF³ team's proposed investigation was to focus on the various effects and controlling parameters of a microgravity environment on the EBF³ process for use in space manufacturing, and to examine the physics behind the results.

The focus of the JSC/UTAF evaluation was the operability and functionality of the enhanced HUD system and its components. This represented an opportunity to conduct a real world checkout of the HUD system hardware while supporting the LaRC research protocol.

PARTICIPANTS –The project involved team members from the Habitability Design Center (HDC), and the UTAF. Personnel acting as the participants for assessing the use of HUDs in performing operational procedures

were from the LaRC flight crew (civil servants). JSC personnel from the UTAF and HDC supported the LaRC personnel with enhanced HUD systems for two of four Operators.

The project team included four individuals to serve as two evaluators/observers and two operations personnel (Operators 1-4). For the preparation and checkout of the HUD support system vests during pre-flight, the designated UTAF/HDC crew for a given flight was identified as Operator 5. Table 1 lists the responsibilities of each team member during the evaluation.

Table 1. Project Team Members Responsibilities

Team Member	Responsibility
Operator 1 (LaRC)	Commanding the EBF ³ process control computer
Operator 2 (LaRC)	Experiment's scribe, maintain flight checklist, operate internal camera from laptop
Operator 3 (LaRC)	MIST test participant, EBF ³ process observer and voice note experiment recorder
Operator 4 (LaRC)	MIST test participant, EBF ³ experiment video operator and monitor pumping station operator
Operator 5 (UTAF/HDC)	Assisting LaRC flight crew in donning/doffing MIST vest, checkout and validation of all MIST hardware and software, act as flight observer for evaluation.

Each LaRC observer wore a MIST support vest that was pre-packed and pre-wired with equipment before the flight and placed in soft flight bags. During the 20 to 25-minute flight out to the parabolic flight test zone, the designated UTAF crew person for a given flight, Operator 5, was responsible for assisting with the donning and doffing of each MIST support vest, its checkout and validation (Figure 1).

The LaRC participants received a minimal amount of training on the MIST hardware before the evaluation due to time constraints. Only a few minor issues arose during the evaluation which was quickly corrected by the Operators.

During the monitoring procedures of the LaRC EBF³ process, the LaRC flight crew evaluated the functionality of the system, operability of the hardware, and usability of the HUDs in microgravity while they were conducting planned activities. Afterward, the crew was debriefed about the operations and functionality of the HUD system components.



Figure 1. UTAF evaluator assisting LaRC crewmember with donning MIST support vest.

HANDS-FREE SYSTEM DESCRIPTIONS - For each LaRC observer, the MIST consisted of the following:

- HUD Headgear Equipment
- HUDs
- Miniature Cameras
- Microphones

MIST Support Vest Equipment

- Miniature Laptops
- Bodypack Transmitters
- Camera Control Units (CCU)
- Lithium Ion Battery for CCU
- Mouse or Touchpad
- Various Interconnection Cables

UTAF Support Equipment

- Audio Receivers
- Digital Video Recorders (DVR)
- Digital Video Cameras
- Full MIST Backup System

The MIST headgear used for the evaluation has a head-borne mass of approximately 0.23 kg (0.5 lb) which included the headband, microphone, miniature camera, and HUD. The HUD display tested had a screen resolution of 640 x 480 supporting real-time color S-video with display dimensions of 18.87 x 11.96 mm (0.74 x 0.47 in). One adjustment knob on the side on the HUD was available to the participant from bring the HUD up/down (y-plane) or forward/backward (z-plane). The HUD itself has a flexible arm for fine adjustments (x-plane). Adjustments for the microphone were minimal with up/down and left/right. The miniature camera was not adjustable once in place. View from the camera was a point-of-view from the participant perspective. All the interconnecting cables were Velcro to the headband and continued onto the support vest.

The MIST vest supported all of the other equipment used in the mobile system. Material used for the vest was neoprene for its elasticity, ability to form to the human body, and its thermal protective properties of the systems hardware. Basic vest design was based on scuba diving clothing with a zipper in the back. Human fitting was approximated to the basic dimensions of the

test participants. Body-borne mass of the vest was approximately 2.38 kg (5.26 lb) which included a miniature laptop computer with battery, wireless body pack transmitter with battery, the miniature camera control unit, one lithium ion battery for the CCU, and a mouse. All the interconnection cables from the headgear and vest were threaded into loops and Velcro strips on the support vest with connection to the support equipment nestled into strategically placed pockets on the front. Due to the nature of microgravity flight, all of the support equipment in the vest was positioned in front so the participant could lean back against the aircraft during the high-g maneuvers.

TEST ENVIRONMENT - This study was conducted aboard NASA's C-9 aircraft in which experiments are conducted during brief periods of microgravity achieved with parabolic profiles that traverse approximately two miles of altitude during each parabola. The McDonnell-Douglas DC-9B aircraft is a two engine turboprop aircraft with a cargo bay test area approximately 45 feet long, 104 inches wide, and 80 inches high. A typical mission is two to three hours long and consists of 40 to 50 parabolas. Each parabola is approximately 40 to 50 seconds in total length with 20 to 25 seconds in 0-G and 20 to 25 seconds in a 2-G environment. This makes up one parabolic cycle. Typically, parabolas are flown in sets of ten with short breaks between maneuvers to reconfigure test equipment. The EBF³ hardware and HUD support equipment were positioned at the forward location just aft of the cockpit in the C-9 as shown in Figure 2.



Figure 2. LaRC EBF³ processor. Note Operator 3 (right) wearing MIST. Photo taken from cockpit door.

TEST PROCEDURES - In the test plan, on alternating batches of 10 parabolas, Operator 3 and Operator 4 were to use enhanced HUDs that have microphones and small video cameras attached. These support hardware would enable both operators to follow their "planned actions" lists independent of callouts by Operator 2. The microphones supported digital voice recordings of observations by Operator 3 and Operator 4. On every other batch of 10 parabolas, the operators planned to