Human Engineering of Space Vehicle Displays and Controls

Panel Chair Name and Panel Co-Chair Name

OVERVIEW

Proper attention to the integration of the human needs in the vehicle displays and controls design process creates a safe and productive environment for crew. Although this integration is critical for all phases of flight, for crew interfaces that are used during dynamic phases (e.g., ascent and entry), the integration is particularly important because of demanding environmental conditions. This panel addresses the process of how human engineering involvement ensures that human-system integration occurs early in the design and development process and continues throughout the lifecycle of a vehicle. This process includes the development of requirements and quantitative metrics to measure design success, research on fundamental design questions, human-in-the-loop evaluations, and iterative design. Processes and results from research on displays and controls; the creation and validation of usability, workload, and consistency metrics; and the design and evaluation of crew interfaces for NASA's Crew Exploration Vehicle are used as case studies.

RESEARCH TO APPLICATION

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Too often, research reports end up on a shelf, without impact to real projects. When performed correctly, applied research can be invaluable for advancing design in real-world development projects. Research results can be used as the basis for requirements and standards, and can provide design direction and prototypes for displays and controls development. For example, research on label alignment and orientation can yield standards for software and hardware label design; research comparing various types of cursor control mechanisms can be used to aid decisions about custom cursor control device design for extreme environments; research on vibration and gloved operations can drive design requirements for performance in spaceflight environments.

The key to successfully applying research to real-world efforts is to carefully structure the experimental question and protocol to address issues needing resolution on the development side of the house. Experimental conditions should include components of design options in question; test scenarios should be defined to represent target conditions; software and hardware used in the evaluation should be designed to closely emulate or at least approximate the real-world environment. Sometimes it is necessary to relax experimental constraints ever so slightly in order to bring some fidelity into a laboratory test protocol. Despite the fact that some experimental control may be lost, this may be preferable to results that are “out of touch” and make no concrete contribution. Careful design with an eye toward application will result in an experimental task that has face validity with respect to the actual environment, and research that is able to offer specific guidance for the design environment in question.

This presentation will highlight some of the Space Human Factors Engineering research performed as part of NASA’s Human Research Program, and will show how results from applied research have been successfully implemented in real-world projects.

ORION HARDWARE DEVELOPMENT: APPLYING HUMAN ENGINEERING TO DESIGN

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Human Engineering (HE) plays an integral role in the design and advancement of Orion hardware. Through requirements generation and interpretation, application of human factors principles, focused systematic analyses (e.g., population analysis and human modeling) and Human-in-the-Loop (HITL) evaluations, HE ensures safe, usable designs. On the Orion Program, HE personnel are part of the engineering design teams, making sure that human factors principles are applied starting the earliest stages of design. By applying human factors principles early, Orion HE is able to identify needed design improvements before cost and schedule are impacted. Because Orion HE is integrated into the design teams, human factors analyses are conducted in parallel with design engineers drafting design solutions and feedback is incorporated before the hardware CAD models are finalized. Once hardware is ready for prototyping, HE continues to aid the design teams by leading HITL evaluations, determining appropriate system inclusion, collecting quantitative and qualitative metrics of integrated task performance, and providing recommendations for design improvements. Two examples of HE design impacts are determining the cursor control device (CCD) design and placement and improvements to the Orion seat and cabin egress operations. HE identified the use environment and task demands of the CCD through task analysis, identified appropriate control types, iteratively tested functional controls in a HITL evaluation collecting usability and workload data. Due to HE involvement in the design of the egress operations, several design and integration issues were identified early through analyses and HITL evaluations. For example, evaluations found that impact attenuation struts impeding egress and human contact with hardware affecting dynamic flight operations, allowing design modifications to be made during the early phases. The HE participatory approach and lessons learned from the design and evaluation of Orion hardware could be applied to future space vehicles to increase human-interface integration.

HUMAN INTERACTION WITHIN THE "GLASS COCKPIT": HUMAN ENGINEERING OF ORION DISPLAY FORMATS

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A "glass cockpit" – in which crew members interact almost exclusively with software rather than hardware – can result in a lighter vehicle, more crew automated assistance, and centralized commanding. The design of a glass cockpit, however, introduces numerous human factors challenges because text, graphics, and icons need to convey a complex and vast array of information and crew actions in an often limited display real estate. Good design is particularly critical for displays used during dynamic phases of flight because crew members must be able to access and interpret critical information and controls in a timely manner under challenging environmental and cognitive conditions. The development of displays for NASA's Orion Crew Exploration Vehicle (CEV) provides a case study for how a human-centered approach, display standards, and usability evaluations can address some of the challenges of a glass cockpit. Throughout the design process, human engineers worked within an interdisciplinary team of individuals with unique expertise and provided human factors guidelines and helped develop prototypes with increasing fidelity. Usability evaluations were conducted with nine displays. These included electronic procedures, caution and warning, and subsystem displays. In total, 36 participants from NASA's Crew office participated in the evaluations. Each session included an overview of the displays, static evaluations, procedure-based interactive evaluations, and post-session interviews and questionnaires. Participant comments and observed errors were recorded. The evaluations revealed over 75 separate issues associated with the design of the displays that had not previously been identified by the design team. In two cases, the evaluations revealed the need for full redesigns and reevaluations. The standardized process allowed for evaluations to be conducted and recommendations returned to design teams within a few days. The suggested approach and lessons learned from the design and evaluation of CEV displays could be applied to future space vehicles to decrease potential human-interface errors.

QUANTIFYING AND FINDING CRITERIA FOR USABILITY, WORKLOAD AND CONSISTENCY

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At NASA, the Human-Systems Integration Requirements (HSIR) contains all the requirements that drive the human-system interaction of the design. These requirements are useful to the extent to which the used concepts are defined operationally and their levels of measurement and the decision making about them is well defined. That is, verifiable requirements call for metrics that can quantify concepts such as usability. However, it is a challenge to find measures that can provide criteria for these concepts, either because there are no generally accepted measurements or because they are not applicable as they are to the space domain. There are many metrics that are used in the usability realm. Nevertheless, not all of them can be used in requirement and verification definitions due to the difficulty of choosing a criterion. For example, to define a criterion that could be used for task completion time, one needs to define a reference. Should this be an expert's task completion time, or a time that is estimated based on task analysis? Similarly, workload can be measured using objective and subjective measures. Objective measures are sometimes intrusive to be appropriate in a dynamic flight evaluation. However, subjective scales can be used and crew are familiar with them, although it is a challenge to define the appropriate level of workload on a subjective scale. Intra- and inter-system consistency is another area that needs quantifiable metrics. There are no existing scales, and the current approach to its measurement is based on heuristic evaluation rather than structured approaches that could lead to a criterion for verification. This presentation will cover research leading to verifiable requirements in the areas of usability, workload, and consistency.