

Human Factors Engineering Requirements for the International Space Station – Successes & Challenges

Advanced technology coupled with the desire to explore space has resulted in increasingly longer human space missions. Indeed, any exploration mission outside of Earth's neighborhood, in other words, beyond the moon, will necessarily be several months or even years. The International Space Station (ISS) serves as an important advancement toward executing a successful human space mission that is longer than a standard trip around the world or to the moon. The ISS, which is a permanently occupied microgravity research facility orbiting the earth, will support missions four to six months in duration.

The ISS poses unique challenges to National Aeronautics and Space Administration (NASA) in the area of Human Factors Engineering (HFE). First, mission duration is always a critical issue for human factors because small design flaws or stressors on the user can accumulate over time to cause more serious performance failures. In addition, user preparedness to respond as well as fluctuations in vigilance and psychological issues of morale and team interaction all increase in importance as mission duration increases. Secondly, the ISS is not only a research facility but also a home; therefore it must be designed to support very different crew operations. Human factors design guidelines and issues vary with the type of activity being performed. Thirdly, modules, systems and equipment for the ISS are being manufactured all over the world and assembly in space requires diligent and detailed planning, training and integration. Finally, this effort is the product of an international partnership among the United States, Russia, Europe, Japan, Canada and other nations and HFE standards vary across nations and cultures.

In planning for the ISS, the NASA developed an agency-wide set of human factors standards for the first time in a space exploration program. The Man-Systems Integration Standard (MSIS), NASA-STD-3000, a multi-volume set of guidelines for human-centered design in microgravity, was developed with the cooperation of human factors experts from various NASA centers, industry, academia, and other government agencies. The MSIS covers a range of topics including anthropometry, control and displays, human restraint and mobility requirements for zero-gravity environments, maintainability, and safety. This standard was the basis for the ISS Flight Crew Integration Standard, SSP 50005, which is a requirements document specific to the ISS Program. Elevating human factors to the status of a "system" with its own set of unique requirements was a real advancement for habitability and human factors as a discipline at NASA. However, NASA's first experience with human factors requirements in a Program did identify some challenges.

One of the main challenges is maintaining a balance between specifying contractually binding requirements which must be verifiable and ensuring that the intent of the requirement is accurately manifested in the design. Intuitively, it seems that these two objectives are compatible; however, that is not always the case. For example, one

good HFE design principle is to use the perceptual principle of *grouping by proximity* for the design of labels and controls to enable accurate association between a control and its label. To facilitate perception and comprehension, a related design consideration is to reduce clutter in favor of order--that is, for a series of controls, labels should be placed relative to each associated control in a common manner. To make such a design goal verifiable and objectively demonstrable, it was necessary to define parameters within which the design requirement is met. Thus, a requirement was generated to place a label within 2 inches of the interface. This specification does not appear to be problematic until the designer encounters hardware that does not have surface area within the immediate surroundings of its interface. In an attempt to apply the actual letter of the requirement rather than meet the intent of the requirement, the designers constructed a dedicated surface area, mounted to a rod, such that it could support a label in the area within 2 inches of the interface. This inadequate design implementation is a consequence of the occasional conflict that is created when the intent of a requirement is lost during modification to verifiable and objectively demonstrable language.

There is no question that it is indeed necessary to the extent possible to provide HFE design requirements that are measurable and verifiable. However, there is a need to ensure that the intent is maintained, and that inadequate designs that meet requirements but don't promote human-system performance are avoided.

In order to address this challenge, the ISS program formed a human factors team analogous to any major engineering subsystem. This team develops and maintains the human factors requirements regarding end-to-end architecture design and performance, hardware and software design requirements, and test and verification requirements. It is also responsible for providing program integration across all of the larger scale elements, smaller scale hardware, and international partners. As part of this integration effort, the human factors team promotes a balanced approach between commonality and case-by-case assessment; it is this effort that is addressing the challenge of requirements verifiability and intent. The team promotes commonality by systematically determining consensus among its members and other HFE personnel on requirement intent and documenting that consensus to be generically applicable to all hardware. However, the team also employs a case-by-case strategy by dedicating qualified HFE personnel to each major and minor piece of the ISS to evaluate specific issues of requirements application and design in the interest of quality HFE. Dedicated human engineering assessments are performed to address and resolve issues and concerns. These studies include human factors and habitability assessments, computer modeling analyses, lighting evaluations, and compiling human factors lessons learned from previous space and analog missions.

Regardless of the challenges, the adoption of human factors requirements represented a major cultural change for NASA. Prior to ISS – e.g., when preparing equipment, software, and procedures for the Space Shuttle – individual crew involvement was the major, if not sole, source of usability and human factors input. Since most activities performed in space were performed by only

one crewmember, and the crew would consist of 4 – 8 people who would receive two years of training for a two to three week mission, this intense tailoring of hardware and software to specific users was feasible. However, with ISS, there has been a paradigm shift with longer missions where hardware will be staying onboard throughout its life cycle, and the missions and crews have different capabilities, preferences and training needs. Thus, it has been crucial to systematically provide both HFE requirements and a team of HFE experts to oversee the implementation of these requirements for an effective experience onboard ISS. This integrated approach helped facilitate standardization of software and hardware user interfaces, and procedures in a very complex system with numerous payloads and onboard subsystems. This is not to say that other programs such as the Shuttle program do not have important human factors considerations. However, as illustrated earlier, the ISS missions and short duration Shuttle missions are different for human factors. Additionally, the fact that ISS is manufactured across the world and according to different schedules increases the need to ensure that strict interpretation of verifiable requirements does not result in a poor design.

The next challenge for the HFE community is to revisit the MSIS and critically question each requirement's wording whether it focused too much on giving a specific design solution, or conveying the intent of the design principle involved. This activity will provide us better-defined and more effective requirements that will complement the effective HFE oversight activity established for working with specific programs such as ISS or any other future vehicles.