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Human Factors and Ergonomics Society

Policy Statement on

Human Space Flight & Exploration Programs

HFES Policy Statement:
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Introduction

Mission performance and system safety are highly dependent on human performance, especially when unforeseen events or inevitable system failures are involved. A robust domestic space exploration program is also dependent on the avoidance of catastrophic failures and accidents (e.g., the Challenger and Columbia accidents) given the public, political, and international attention. Therefore, there is a substantial need for all space actors (NASA as well as commercial space entities) to optimize the safety and performance of flight crews, mission controllers, and ground and support personnel throughout the design, engineering, and operation of space systems.

The practice of human factors engineering is based on scientifically derived data on how people perceive, think, move, and act, particularly when interacting with technology. The way in which any technology is designed significantly affects the performance of the people who interact with it. The user interface of the technology can make human performance much more efficient and human error significantly less likely when it is designed to be compatible with human capabilities. High levels of human performance in operating the system can be achieved when the system is easy to use, guards against typical human frailties and errors (i.e., error tolerance and error resistance), and helps people to rapidly understand key information about what is happening in the moment. Conversely, if the technology displays are difficult to perceive or understand, significant effort is required to piece together needed information in order to stay abreast of a complicated and dynamic situation and the likelihood of human error increases greatly. **In most complex systems (e.g., aviation and space), between 60 and 80% of major catastrophic accidents have underlying human error problems that are induced by a failure of the system design to consider human factors principles[1; 2].**

The safe operation of space vehicles and conduct of crewed missions requires that human factors science and practices be incorporated in the design, testing, certification, and operation of associated systems. While NASA has historically maintained an active human factors program for the design and development of its systems, future space flights will be conducted by a variety of commercial entities that may lack the same expertise or processes. For example, the NTSB found that "proper safeguards to prevent human error were not in place" [3] following the fatal 2014 Virgin Galactic SpaceShipTwo accident. The NTSB showed that the importance of directly considering, *during the design of the system*, the types of human errors that might occur during system operations. In this case, incorporating design features that would have prevented the accidental premature activation of the vehicle's feathering system would have prevented the accident. A failure to consider human factors science in system design can result in both loss of lives and costly mission failures. NTSB Chairman Hart stated "The big picture: Commercial spaceflight stands on the verge of becoming a reality….But the success of commercial space travel depends on the safety of commercial space travel, at the level of every operator and every crew."[4]

Further, as human spaceflight programs and exploration priorities evolve, new challenges will be encountered. These include:

a) Interacting with artificial intelligence and more autonomous software systems;

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b) Delays in communications with Earth (e.g., as much as 20 minutes from Mars) which can negatively affect crew health and wellbeing due to delays in needed assistance from Earth, and leading to the need for greater crew independence and agile decision making;
c) The opportunity for more unforeseen events in new, unexplored environments that may stress crew resilience; and
d) Considerable increases in psychological, physiological, psychosocial, and environmental-interface challenges in long duration space flight [5].

In addition, commercial and government space operations are evolving from simple transportation events to sustained living and working in space, with proposals for extended operations in Low Earth Orbit (LEO), the lunar environment, and eventually Mars. Thus, the successful conduct of space missions will require even more attention to human factors engineering and human performance in the design of the technologies, training, and operational procedures, given the increased need for resilience in support of robust performance in routine and challenging conditions.

Recommendations

For all NASA and Commercial Space Programs:

1) ***HSI Processes and Standards*** - NASA should require the application of human-system integration (HSI) processes and standards in all system development programs, including the procurement of systems and services from commercial space companies, that involve human operators and/or maintainers, and in the flight certification of all vehicles that contain human occupants, including the latest version of the Space Flight Human-System Standard (NASA-STD-3001) and the Human Integration Design Handbook (NASA/SP-2010-3407/Rev 1). This includes those featuring AI and autonomous systems which pose special human-interaction considerations. The conception, design, development, test, operation, and sustainment of all complex systems used or maintained by people requires the application of human factors principles and design criteria, and the coordination of human factors activities with other systems engineering, design, management, and logistics disciplines, as described in HSI standards and guidelines. While NASA typically may require compliance with this standard in direct procurement systems, commercial spacecraft and service leases from commercial enterprises may not have adequate consideration of these important system design issues. These processes are critical for reducing system-induced human error.

2) ***Human Readiness Levels -*** All programs supporting the development, acquisition, or procurement of services involving crewed space vehicles and habitats should be required to report to NASA on the Human Readiness Level (HRL) of their systems on an annual basis (HFES/ANSI Standard 400) [6]. HRLs provide a useful correlate to Technology Readiness Levels (TRLs). HRLs communicate to NASA management the degree to which programs have addressed human-system integration during system development and testing. The HRL should be reported for each major component of the system (e.g., vehicle operations, habitability and life support, maintainer support, remote control stations, mission control stations). The HRL should be used to identify deficiencies and areas where additional attention to human-system integration is warranted, to reduce risks to program schedules and human safety and effectiveness.

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3) ***Safety Reporting System*** – Companies developing systems for operations in space should be required to maintain an active safety management and confidential safety reporting system for employees, consistent with the standards and recommended practices contained in Annex 19 to the Convention on International Civil Aviation (61 Stat. 1180). The potential for integrating with NASA's Aviation Safety Reporting System (ASRS) or forming a system based on ASRS should be considered. This is important for avoiding problems such as declines in safety culture that were significant contributors to the Challenger and Columbia accidents.[7-9]

4) ***Personnel -*** Qualified HSI professionals, including those with expertise in human factors, (from government and/or private space operators) should be assigned responsibility for the conduct or oversight of the following human-system integration activities related to crewed spaceflight and human operators, mission controllers, system maintenance personnel, and occupants:
    a) Developing user-centered systems requirements, to include support of human perceptual, cognitive, and physical tasks and performance, including mission, function, task, cognitive and workload analyses;
    b) Adapting and applying human factors design criteria to the equipment and software that people interface with, to ensure that system's users and maintainers will be satisfactorily accommodated;
    c) Conducting probabilistic risk assessments, failure modes and effects analyses, and fault detection, isolation, and recovery management and process activities;
    d) Conducting system test and evaluation activities associated with assessing the impact of the system design on human situation awareness, workload, task performance, error, and physical well-being, and recommending design changes to minimize negative impacts and improve outcomes;
    e) Verifying compliance with system requirements for supporting human performance;
    f) Documenting HSI plans, activities, and results, and developing and submitting relevant deliverable data; and,
    g) Coordination with other HSI domain practitioners, the HSI program manager, and systems engineering management and processes.

    Qualified HSI professionals are defined as having bachelors or graduate level degrees in human factors engineering, psychology, human-systems integration, safety, physiology, or a related degree field. These experts should have degrees that include education in the physical, physiological, perceptual, cognitive, and/or organizational considerations that affect human systems performance, and the application of this knowledge to the design of technologies, organizations and systems.

5) ***Conduct Research to Develop Best Practices and Standards:*** NASA should be directed to conduct increased levels of research (through its Centers, academic institutions, contractors, or some mixture of all three) on new and emerging technologies and issues that may affect the safe performance of new space missions. Current research on these topics has been minimal to date. This research could be supplemented with input from or supported by independent evaluation by the National Academy of Science, Engineering and Medicine's Board on Human Systems Integration (BOHSI) to ensure the appropriate translation of outcomes into best practices and standards. This activity should be appropriately funded so that HRL-related outcomes can be mapped to the TRL levels of space systems development timelines, as

recommended by the ANSI/HFES Std-400, in order to reduce program, mission and safety risks. Increased research focus should specifically include:

a) Human interaction with autonomous software systems;
b) Team performance on long-distance space missions;
c) Fitness for duty qualifications; and,
d) Human-system integration across systems-of-systems for long duration space missions.

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About the Human Factors and Ergonomics Society (HFES) With more than 3,000 members, HFES is the world's largest nonprofit association for human factors and ergonomics professionals. HFES members include psychologists, engineers and other professionals who have a common interest in working to develop safe, effective, and practical human use of technology, particularly in challenging settings. Members of HFES play a leading role in the development of guidelines and standards and are active in national and international standards organizations, such as ASTM, ANSI, NEMA, and ISO.