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SENSORIMOTOR DISPLAYS AND CONTROLS TO ENHANCE SAFETY OF HUMAN/MACHINE COOPERATION DURING LUNAR LANDING: PROJECT REVIEW

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ABSTRACT

Landing on the moon or another planetary body requires the selection and identification of an appropriate location that is level and free of hazards, along with a stable controlled descent to the surface. During crewed landings astronauts normally interact with automated systems, based upon terrain maps and sensor updates, to perform tasks such as manual re-designation of the landing point, adjustment of the automatic descent trajectory or direct manual control. However, various sensorimotor challenges may interfere with the astronauts' responses. These include the astronauts' first exposure to partial gravity following microgravity adaptation, unique vehicle motions, and dust blowback from the descent engine thruster.

The nature of the anticipated sensorimotor challenges was studied using a combination of modeling and experimental techniques. A quantitative, physiologically-based model of orientation perception was simulated with lunar landing motions to identify the potential for pilot spatial disorientation during landing. The findings were partially validated in a human subject experiment in the NASA Ames Vertical Motion Simulator (VMS), where subjects reported their perceptions of vehicle orientation during lunar landing-like motions. The VMS experiment was extended utilizing the US Army Aeromedical Research Laboratory's UH-60 helicopter simulator with modified dust blowback characteristics to more closely resemble lunar conditions as inferred from Apollo landing videos. The dust blowback resulted in subjects' misperceiving the vehicle orientation and velocity during the final stages of landing as compared to when they viewed instrument display information. To study how pilot perception of vehicle orientation is affected by altered gravity as will be experienced on space exploration missions, we have used hyper-gravity as our altered gravity test-bed. We have performed an experiment at the NASTAR Center using the ATFS-400 long-radius centrifuge to create a hyper-gravity environment. In the experiment, subjects reported their perceptions to dynamic roll tilt experienced at 1, 1.5, or 2 G's. Roll tilt angle was significantly overestimated in hyper-gravity, with more overestimation at larger angles and higher G-levels. Overestimation was seen both during dynamic roll rotations and during static roll tilts. The experimental data will allow us to develop a model for orientation perception in altered gravity, which will provide predictions for hypo-gravity conditions such as on the moon or Mars.

Advanced display countermeasures were developed and tested in Draper Laboratory's fixed-based lunar landing simulator. In particular, we developed an "achievability contour" display which provides the pilot information on where on the lunar surface it is feasible to land with the remaining amount of fuel and the current vehicle state (altitude, horizontal velocity, etc.). In a highly fuel constrained vehicle, such as a planetary landing vehicle, this type of display provides the astronaut with essential information for landing point selection. In testing this advanced display concept improved pilot situational awareness and confidence in landing point selection. In addition, a primary flight display was developed and used for testing. The displays were further tested at NASA JSC in the tilt-translation sled (TTS). Subjects performed either a "critical tracking task" or "hover task" with and without our advanced display concepts. The display information improved piloting performance in each of the motion paradigms that were tested, emphasizing the importance of the display information in challenging visual and vestibular environments. In conclusion, we have identified the nature of the anticipated sensorimotor challenges associated with piloted lunar landing and developed advanced display countermeasures to improve safety and performance.

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