

DEVELOPING AN EARTH-FIXED VISUAL REFERENCE TO AID STABILITY, READAPTATION, AND EGRESS AFTER A WATER LANDING

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Water landings present the worst possible sensory conditions for crews trying to orient and stabilize themselves immediately after long-duration spaceflight. Of the three sensory feedback systems involved in maintaining stability (i.e., proprioceptive, vestibular, and visual), none will provide reliable orientation information under the current water landing scenarios. Although the visual system is likely not affected by the disuse and adaptation to microgravity that affect the proprioceptive and vestibular systems, the visual environment within an enclosed space that is subject to wave-induced rocking will prevent the crewmember from using vision to determine which direction is up. This is true whether enclosed in the capsule or in a room on the recovery ship. The result is an increased risk of fall-related injury. In a prior study, 70% (21 of 30) of nonimpaired subjects reported that the presence of an Earth-fixed horizontal line helped them stabilize when their visually enclosed environment was exposed to wave motion. In addition to aiding stability, an Earth-fixed visual reference also can assist in the readaptation process. Sensory readaptation occurs when the three sensory systems are synchronized with one another and aligned with Earth's gravity. The earlier an Earth-fixed visual reference can be introduced the sooner the readaptation process can begin. The goal of this project is to identify the optimal features of a device that visually presents gravitational reference cues to support egress, stability and readaptation.

Progress on this study was halted by COVID restrictions, but approval to continue was recently granted. The aims are to: a) enhance our existing capsule sensory-condition simulator to include instrumented handholds, a compliant support surface and galvanic vestibular stimulation (GVS) and b) develop and test multiple presentation methods of an Earth-fixed visual reference.

The capsule sensory-condition simulator is a three-sided enclosure atop a six degree-of-freedom motion platform. A sum-of-sines equation is used to drive the motion platform, producing the simulated wave motion. The equation was derived using the frequency range present in inertial measurement unit (IMU) data collected during open-water Orion mock-up testing. The enclosure creates a visual environment similar to what will be experienced inside the capsule or in an interior exam room on a recovery ship where the walls move in relation to the standing surface. Nonimpaired subjects were used in a previous study, but to more accurately represent the condition that crewmembers encounter upon landing, we will apply GVS to disrupt normal vestibular function and have the subjects stand on a compliant surface to attenuate proprioceptive feedback. These changes will have a significant impact a subject's ability to remain standing without also providing them with a handhold. We will use an instrumented handhold to measure the forces imparted to it. With instructions to minimize the use of the handhold, these data will serve as a primary dependent variable. Greater force applied to the handhold will correspond to greater instability.

Although it has become common to refer to the proposed countermeasure as an "artificial horizon," the phrase "Earth-fixed visual reference" is used here because a vertical line, or some other visual reference, may be equally effective at producing the desired results, and may be easier to implement. To define the characteristics of the visual reference that best improves stability, we will compare horizontal, vertical, multiline and "starfield" visual references. The horizontal line used in our previous study was projected onto the moving walls of the simulator from a stationary source positioned outside of the enclosure. This is obviously not possible in the real-world conditions where this countermeasure will be used, so we will also address methods of providing an Earth-fixed visual reference from within the enclosure. These methods range from the presence of a simple plumb line secured to the ceiling to more complex LED arrays and use of both passive and electronic gimbals. The information obtained during this investigation should lead to greater stability, safer egress, and more rapid readaptation for water landings.