NASA RESEARCH AND TECHNOLOGY STUDIES (RATS) 2012: EVALUATION OF HUMAN AND ROBOTIC SYSTEMS FOR EXPLORATION OF NEAR-EARTH ASTEROIDS. Andrew F. J. Abercromby[1], S. P. Chappell[1], H. L. Litaker[2], and M. L. Gernhardt[3], [1] Wyle Science, Technology, and Engineering, Wyle/HAC/37C, NASA Johnson Space Center, Houston, TX 77058, USA, (andrew.abercromby-1@nasa.gov), [2] Lockheed-Martin Corporation, 2625 Bay Area Blvd, Houston, TX 77058, [3] National Aeronautics and Space Administration, NASA Johnson Space Center, Houston, TX 77058, USA.

Introduction: Fundamental to the development of NASA's Capability Driven Framework [1] is identifying the exploration systems that are required for the range of destinations being considered and finding safe, affordable, and effective ways to develop and operate those systems. Design reference missions (DRMs) currently being considered by NASA for human exploration of near-Earth asteroids (NEAs) include stays in the proximity of the target NEA of between 14 and 56 days during which time the Earth-NEA transit vehicle, Deep Space Habitat (DSH), and multi-purpose crew vehicle (MPCV, used for crew launch and re-entry) would remain between 500 meters and 2 km away from the NEA to minimize the possibility of collision. Exploration and sampling of the NEA surface would be conducted by crewmembers leaving the DSH in extravehicular activity (EVA) suits with appropriately sized EVA jetpacks to enable brief sorties to the NEA surface and/or by using a Multi-Mission Space Exploration Vehicle (MMSEV), which is a small pressurized spacecraft with rapid EVA capability enabling multi-day exploration sorties away from the DSH [2,3].

Methods: The RATS 2012 test focused on optimizing utilization of a four-person crew, DSH, MMSEV, EVA jetpacks, and Mission Control Center operating with 50 seconds each-way communication latency, during exploration within an immersive virtual-reality physics-based simulation of the NEA Itokawa (Fig. 1). High-resolution imagery from the Japanese Space Agency's (JAXA) Hayabusa mission was integrated into the simulation and models of three-dimensional boulders of representative sizes, shapes, and distributions were added at specific locations based on inputs from a scientist with expert knowledge of Itokawa. Traverse plans were prepared based on the Hayabusa imagery and using assumptions for sampling and instrument deployment methods and durations based on data from complementary testing in reduced gravity environments [4]. Traverses were planned to include variation in terrain, illumination, and centripetal acceleration within each traverse while maintaining consistency among test conditions.

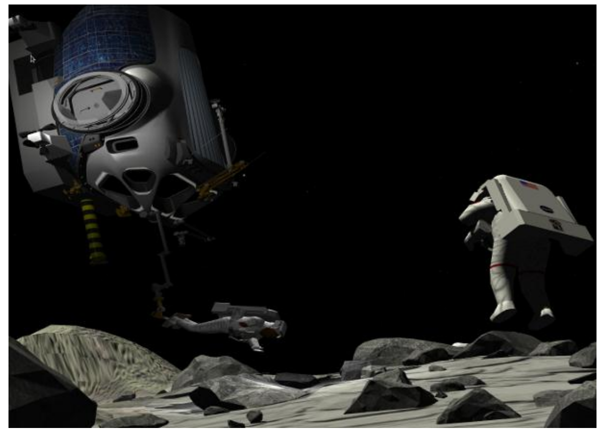

Figure 1. Screenshot of MMSEV NEA simulation showing MMSEV with one EVA crewmember attached to an astronaut positioning system (APS) and a second free-flying using an EVA jetpack.

The Gen 2A MMSEV is the third prototype vehicle developed by the MMSEV project. Habitability and human factors evaluation of the Gen 2A MMSEV in a high fidelity operational environment was also included in RATS 2012. The Gen 2A MMSEV was located within the JSC Building 9 hi-bay throughout the RATS 2012 test and was surrounded by high-resolution video walls displaying video generated by the MMSEV NEA Simulation (Fig. 2).

Figure 2. Gen 2A MMSEV prototype with cockpit windows surrounded by video walls.

Figure 3. Test subject inside the Gen 2A MMSEV. Video walls displaying the NEA simulation can be seen through the windows.

Test subjects inside the MMSEV used the displays, controls, and views of the video walls through the windows to operate the MMSEV and interact with the immersive simulation environment throughout the 10-day test (Fig. 3).

Test subjects moved to the nearby virtual reality (VR) Laboratory to conduct simulated EVAs, where head-mounted displays, instrumented gloves, and an EVA jetpack control module allowed crewmembers to operate within the MMSEV NEA simulation environment. During test conditions in which the MMSEV was anchored to the NEA, one test subject would perform EVA tasks from the VR lab using a simulated jetpack while a second crewmember performed anchored EVA tasks using the Active Response Gravity Offload System (ARGOS) to simulate microgravity (Fig. 4).

Figure 4. Test subject performing exploration EVA tasks in simulated microgravity using ARGOS (left) and the VR laboratory (right).

This test did not attempt to evaluate specific NEA anchoring technologies due to the immaturity of those technologies and the inability to meaningfully test them within the existing software simulation. Instead, a consistent approach was used in which MMSEV pilots manually performed 10 minutes of a precision station-keeping flying task to approximate the increased workload and propellant that would likely be required to perform an anchoring. The number of anchorings was recorded to enable post-test parametric analysis of the effect of anchoring duration on productivity and propellant usage for different exploration techniques.

Simulation telemetry and consensus subjective ratings were used to assess exploration productivity, propellant usage, workload, and acceptability during exploration traverses in test conditions incorporating different combinations of extravehicular and intravehicular crewmembers; anchored vs. free-flying operations; EVA jetpacks vs. astronaut positioning system (APS) attached to the MMSEV; and NEA size and spin rates. Human factors of the Generation 2A MMSEV prototype were evaluated by two separate two-person crews, each inhabiting the MMSEV for 3 days and 2 nights.

Results: For the operations tested, the recommended distribution of crewmembers is two in the DSH, one in the MMSEV, and one EVA. Crewmembers rated this condition as overall acceptable and experienced lower workload and greater situational awareness vs. conditions involving two EVA crewmembers. Free-flying modes were preferred vs. anchoring the MMSEV to the NEA because of decreased overhead and increased situational awareness, although propellant savings of 30% were measured with anchoring. Alternating between APS and jetpack (vs. APS only) did not improve acceptability but decreased propellant usage. MMSEV propellant usage during manual station-keeping $\propto \omega 2$ x r, where ω = NEA angular velocity and r = distance from spin axis. Human factors of the Gen 2A MMSEV were rated acceptable overall.

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References: [1] Anon. (2011). “Human Space Exploration Framework Summary”, National Aeronautics and Space Administration. [2] Abercromby, A. F. J. et al. (2012) *Acta Astronautica, doi:10.1016/ j.actaastro. 2012.02.022.* [3] Abercromby, A. F. J. et al. (2012) *Global Space Exploration Conference*, Washington, DC. [4] Chappell S. P. et al. (2012) *Global Space Exploration Conference*, Washington, DC.