Developing Science Procedures for Deep Space Gateway Habitat Mockup Ground Testing.
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Overview: The Deep Space Gateway (DSG) is a possible NASA program to place a habitat in cis-lunar orbit for periodic visits by crews delivered on the spacecraft Orion. NASA has contracted with private companies to develop concepts for the design of the habitat, and mockups will be provided for evaluation beginning in FY2019. In order to train NASA Subject Matter Experts (SMEs) for the upcoming evaluations, a series of ground tests are being conducted with available resources at JSC. The first test was conducted on 9/28/17 – 9/29/17 at JSC Building 29 in the Integrated Power, Avionics, and Propulsion (iPAS) facility using the habitat mockup named “Phoebe”. A second test was conducted at JSC Building 9 in the Habitable Airlock (HAL) mockup on 12/13/17. For both tests, science procedures were developed for crew to demonstrate the use of possible equipment and instruments that might be available in a DSG habitat. Execution of the procedures may help inform science requirements for future DSG development, and can also evaluate whatever science opportunities are available with the delivered NextStep contractor habitat mockups.

Procedures: For the Sept. 2017 test, five procedures were developed and successfully executed in the iPAS Phoebe habitat mockup.

1. **Telerobotics:** The crew successfully operated a simulated rover on the lunar surface from a workstation within the habitat. The simulation software was developed at JSC to measure latency impacts on crew telepresence operations (which was tested in a separate procedure). For the science procedure, the objective was to identify a specific rock for the crew to collect and deliver to a Lunar Ascent Vehicle (LAV). An “Execution Note (EN),” modeled after the ISS daily communication message, was developed to inform the crew of the desired rock with a suggested ground traverse path for the crew to drive the simulated rover. The simulation software was modified to provide boundary markers (to prevent driving off the simulation course) and colored identification marks for the desired rock. Crew successfully navigated the rock field, found the targeted rock, photographed the rock from multiple angles (using screen capture on the workstation), and simulated delivery of the sample to the LAV (see Figure 1). The simulation allowed the rover to become trapped on rocks (from “high centering”), and real-time monitoring required occasional removal of the rock from the simulation to allow the crew to progress. The test generated a list of desired future enhancements for the simulation software, including the need for countup/countdown timers, multiple camera angle views from the rover, and changeable rocks with a more realistic lunar landscape. It is also hoped that the EN will provide a variety of rocks of different priorities for collection to allow the crew to test alternate traverse planning for optimum efficiency.

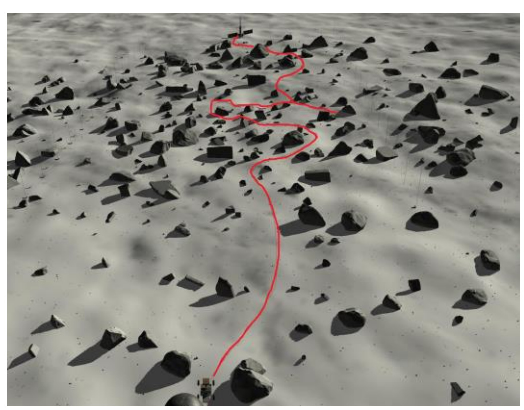
Figure 1: Example crew traverse path

2. **Remote Manipulator System (RMS) Sample Return:** The crew successfully operated a simulated robotic arm from within the habitat to retrieve a sample return canister from the simulated LAV, which had completed a rendezvous with the DSG and was free flying nearby. The simulation software was developed for the HAL and included a science airlock with two external doors that can be assessed by the arm. The procedure was mostly automated with crew monitoring the arm for clearances and range of motion limits. The test revealed this procedure benefitted from two crew working together for execution and monitoring of the arm.

3. **Telescope observations:** The crew successfully operated a simulated external telescope to observe lunar, celestial, and Earth targets defined in an EN. The HAL simulation software was modified to include this instrument, and the crew manually commanded slew and elevation parameters from the habitat workstation for observations. A new feature was added to insert and observe a lunar "flash" on the surface from a meteorite impact. The predefined orbit for the Sept. 2017 test placed the DSG low over the lunar surface, so future tests will test observations at different points of the planned, highly elliptical DSG orbit.

4. **Camera observations:** The crew successfully operated a retired ISS flight hardware Nikon camera to capture images from the simulated "window" on the habitat. Following directions from an EN, celestial, Earth, and lunar observations were conducted (although the designated targets were not all available for the simulated time period). For the Sept. 2017 test, the "window" was a television screen near the robotic workstation. The crew requested a neck strap for future tests.

5. **Sample Return Canister Transfer:** For the Sept. 2017 test, the crew successfully gathered the sample return canister from the science airlock (simulated as a prepackaged suitcase), inspected, cleaned, and repackaged the canister in a sealed bag within the habitat glove box, and then delivered the package to the Orion storage (simulated as a file cabinet). This procedure was developed to evaluate initial concepts of crew processing for lunar samples at the DSG, including consideration of planetary protection and curation protocols. The processing of possible asteroid or martian samples would be much more extensive (if even possible within the DSG habitat). The crew noted the need for velcro straps or storage shelves to anchor the electronic tablet with the procedure while working inside the glove box (a limitation of simulations in the 1g environment). Future discussions will address the need for a dedicated or inflatable glove box, or other sample processing hardware within the DSG, as evaluated from the NextStep contractor mockups.

Summary: The ground test of the HAL mockup (scheduled 12/13/17) included the procedures for telerobotics, RMS canister capture, and telescope observations. Results from this test will be integrated with the results of the Sept. 2017 test in iPAS, to modify the science procedures for more extensive ground tests scheduled for 2018. The science procedures provide an effective tool for evaluating upcoming NextStep contractor habitat mockups, and open discussion for the development of science requirements on the DSG. The assembled science team is working to write efficient procedures and create meaningful metrics to evaluate crew performance. These skills are valuable for whatever science instruments ultimately reside at DSG or other cis-lunar habitats.