USING SCIENCE GROUND TEST PROCEDURES IN HABITAT MOCKUP EVALUATIONS TO EVOLVE SCIENCE REQUIREMENTS FOR NASA'S DEEP SPACE GATEWAY (DSG).

M. E. Evans[1], D. H. Needham[2], K. R. Fisher[1], S. J. Lawrence[1], P. B. Niles[1], S. G. Harmeyer[1], H. T. Nguyen[1], W. L. Othon[1]; [1]Johnson Space Center, Houston, TX.; [2]Marshall Space Flight Center, Huntsville, AL.

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 [1]. In 2017, NASA announced the award of NextStep contracts with six private companies to develop concepts for the design of this habitat [2]. The mockups will be provided for NASA 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 at JSC. For these tests, generalized science procedures are being developed for crew and ground support to demonstrate the use of equipment and instruments that might be available in each contractor mockup. With each evaluation the procedures are modified based on lessons learned. Inputs to the DSG science requirements are also coordinated with the broader community at periodic workshops. The first of these workshops, planned for February 2018, will provide discussion and insights that will further enhance the NextStep science ground test procedures. This evolutionary process improves both the evaluation of each habitat mockup and the generation of requirements.

Procedures: For the first ground test at JSC, held in 9/28/17-9/29/17, five procedures were developed and successfully executed in the JSC Building 29 Integrated Power, Avionics, and Propulsion (iPAS) facility using the habitat mockup named "Phoebe". A second test completed 12/13/17 in the JSC Building 9 Habitable Airlock (HAL) retested the first 3 of the following procedures:

1. **Telerobotics:** For both completed ground tests, 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, informed 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. The crew successfully navigated to the one 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. In future tests, the EN will be modified to provide the crew with a prioritized list of desired rock "targets" to sample. The crew will then develop the telerobotic traverse balancing the highest priority rock samples against the encountered terrain difficulty. Post-test evaluations will provide insights to improve planning coordination and training requirements between the ground team and the DSG crew when executing this type of remote sample collection.

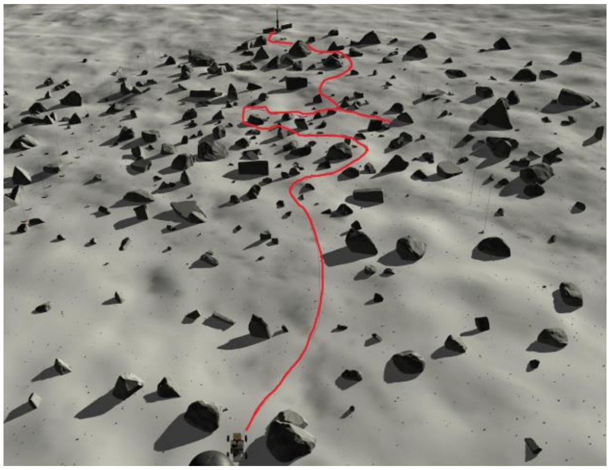

Figure 1: Example crew traverse path

2. **Remote Manipulator System (RMS) Sample Return:** The crew has twice successfully operated a simulated robotic arm from within the habitat to retrieve a sample return canister from the simulated LAV. It contains the sample telerobotically collected by the crew with the above procedure #1. The simulation is initiated with the LAV free flying near the DSG after successfully launching from the lunar surface. The simulation software, developed for the HAL, includes 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 two completed habitation tests revealed this procedure benefitted from two crew working together for execution and monitoring of the arm.
3. **Telescope observations:** The crew has twice successfully operated a simulated external telescope to observe lunar, celestial, and Earth targets defined in an uploaded EN. The HAL simulation software was modified to include this instrument, and the crew manually commanded slew and elevation parameters from the habitat workstation keyboard for observations. A future joystick for pointing the telescope would aid crew control of the instrument. A new simulation feature was added to insert and observe a lunar "flash" on the surface from a meteorite impact. The predefined orbit for the two tests 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 "Phoebe" habitat, which was a television screen located near the robotic workstation. Following directions from an uploaded EN, celestial, Earth, and lunar observations were conducted (although the designated targets were not all available for the simulated time period, so crew captured images of whatever was on the screen). The crew requested a camera neck strap for future tests.
5. **Sample Return Canister Transfer:** For the "Phoebe" habitat, an internal glove box is available. 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 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) due to exobiology concerns. 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 science procedures provide an effective tool for evaluating upcoming NextStep contractor habitat mockups, and they 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. Community inputs are welcomed to improve whatever science instruments ultimately reside on a cis-lunar habitat.

References: [1] Crusan, J.C., (2017), *Aerospace Conference, 2017 IEEE* , [2] NASA, (2017), https://www.nasa.gov/feature/nextstep-partnerships-develop-ground-prototypes