DEEP SPACE GATEWAY SUPPORT OF LUNAR SURFACE OPS AND TELE-OPERATIONAL TRANSFER OF SURFACE ASSETS TO THE NEXT LANDING SITE. David A. Kring[1,2], [1]Center for Lunar Science and Exploration, Lunar and Planetary Institute, Universities Space Research Association, 3600 Bay Area Blvd., Houston, TX 77058 USA (kring@lpi.usra.edu); [2]NASA Solar System Exploration Research Virtual Institute.

Introduction: A multi-agency team [1] introduced a design reference mission (DRM) that utilizes an exploration deep space habitat (eDSH) or Deep Space Gateway (DSG) in lunar orbit, along with the Space Launch System (SLS), Orion crew vehicle, a service module, two small pressurized rovers (SPRs), and a lunar surface lander with an ascent stage for crew. Two SPR are delivered to the lunar surface, followed by a crew of 4, which conducts a 14- to 42-day-long mission in the SPRs, before returning to Earth with lunar surface samples. The SPRs are then telerobotically driven to a second landing site, where a second crew lands. The cycle is repeated for a total of five missions. The landing sites in this scenario are Malapert massif, the South Pole, Schrödinger impact basin, Antoniadi impact crater, and the center of the South Pole-Aitken impact basin (Fig. 1). The surface ops associated with this DRM will put some demands on the DSG that are explored here.

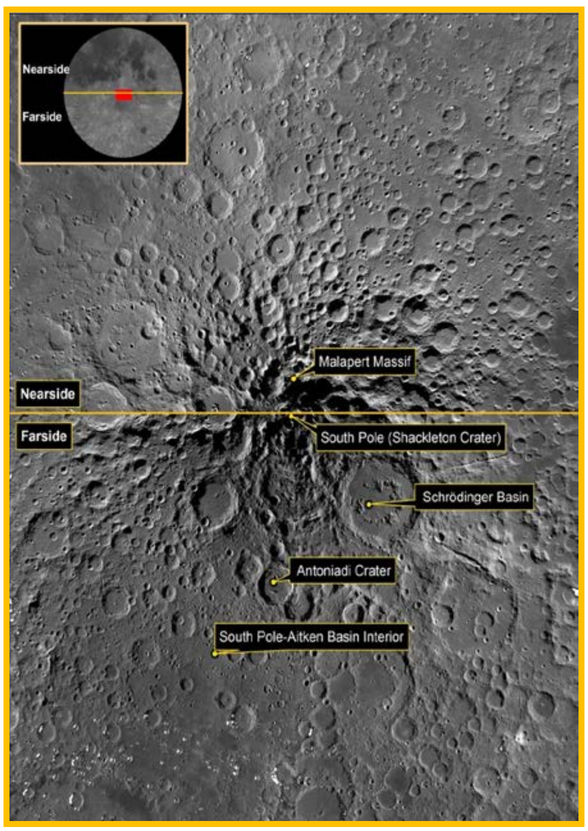

***Fig. 1.** Human landing sites in the DRM [1, 2, 5].*

Surface Traverses with Crew: A study of traverses at each of the landing sites [2] indicate they will be feasible using a flight version of the Lunar Electric Rover (LER), which is a vehicle that has been tested in 1-, 3-, 14-, and 28-day-long mission simulations in the Moses Lake basaltic sand dune complex, Washington, and the San Francisco Volcanic Field, Arizona. The 28-day-long mission simulation involved two LER (Fig. 2) and is, thus, similar in concept to the use of SPRs in the DRM.

***Fig. 2.** Dual LER in a simulation of a lunar mission involving a crew of 4 (2 in each vehicle).*

For crewed operations in the simulations, the LERs were outfitted with high-visibility windows, ForeCam, AftCam, port and starboard cameras, docking cameras, and GigaPan cameras to support both intravehicular and extravehicular activities (e.g., [3,4]). A high-definition (HD) video can be added. Ground-penetrating radar (GPR) was installed on an unpressurized version of the LER, called Chariot, during the Moses Lake test and successfully detected subsurface water. A more advanced unit was installed beneath the aft deck of the LER for an extended 14-day mission simulation at Black Point, demonstrating its application in rugged field conditions. A neutron spectrometer is another in situ resource utilization (ISRU)-related survey tool for volatiles (e.g., hydrogen) that could be installed on future LER (SPR). A compact device has been designed for NASA's Resource Prospector (RP). It produces optimum signal-to-noise when rover speeds are ≤10 cm/s (Richard C. Elphic, personal communication, 2017). While that speed is slower than the speed crew will likely use in most portions of their work, it is a speed perfectly suitable for portions of the tele-operated phase of rover operations.

Tele-operated Traverses: The SPRs can be tele-robotically driven between each of the landing sites from Earth via the DSG. A study of those traverses [5] indicate they are feasible, although descents into the Schrödinger basin and Antoniadi crater need to be verified. The traverse study revealed sufficient time exists for the rovers to prospect for volatile deposits that might be suitable for future resource recovery. Two specific survey locations were identified in Cabeus and Amundsen impact craters. The SPRs will be driven across diverse geological terrains between the landing sites, so if a robotic sampling capability was added to the vehicles, then selected sampling could expand the exploration potential of the tele-operational phase of an implemented DRM.

Data Rates: Communication with the SPRs between each landing site and with crew at each farside landing site needs to be relayed through the Orion, DSG, or some other orbiting asset (Fig. 3). Data rates will exceed 1 Mbps and should be studied in more detail to determine the bandwidth demands during each phase of the DRM. For the sequence of 5 landing sites outlined, a DSG in a large halo orbit about the Earth-Moon L2 point will provide a good communication relay [Lockheed Martin Space Systems Company, 2016, personal communication].

Sample Mass: Minimum sample masses collected by crew can be calculated for each landing site and traverse using CAPTEM recommendations [6] for the lithologies encountered. In the meantime, a notional average value can be calculated using the results of Apollo extravehicular activities (EVA). In Apollo missions 12 through 17, the sample recovery rate occurred at a nearly constant level of 2.3 kg/EVA hr/crew member [7]. If we assume 14 days of sample collection at each of the DRM landing sites, with only one of the SPR crews going EVA each day, and further assume 2 to 3 hours of EVA per day based on the previously described mission simulations, then ~130 to 200 kg of samples might be expected, not including sample containers, compared with the 110.5 kg of the Apollo 17 mission. This calculation is truly notional and needs to be refined after a rationale concept of operations (CoOps) for the missions has been developed and landing site traverses reviewed. For example, more than 14 days may be spent collecting samples during a 42-day-long mission with 28 days of sunlight. The notional value is useful, however, because it shows human missions will likely recover an order of magnitude more mass than the human-assisted robotic missions being discussed for an earlier phase of Deep Space Gateway activities [8]. It is also important to note that well-trained crew will only collect the samples needed to meet science and exploration objectives, so any samples collected should be returned to Earth.

Those samples can either be launched with crew to lunar orbit or with a cargo ascent vehicle. The samples will then need to be stowed in Orion for return to Earth. Most samples will be composed of rock and regolith and will not need any special handling not already demonstrated by Apollo. If the tele-operated SPRs prospecting for ice are tasked to sample volatiles, then the return of those types of samples my require special cryogenic handling.

Fig. 3. *(top) Artistic rendering of a small pressurized rover on the lunar surface that uses (bottom) the Orion vehicle or Deep Space Gateway as a relay to Earth. Credit: NASA.*

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