LUNAR MOBILITY STRATEGIES, TRADE STUDIES, AND MISSION SIMULATIONS.

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Introduction: The Lunar Surface Science workshop agenda was expanded to address a NASA request for the community to provide input about lunar mobility, both for crew and without crew. The Center for Lunar Science and Exploration team and its partners have investigated several attributes of mobility. It would not be appropriate to republish those results as new work, but – to be as helpful as possible – a summary of those results is presented here, along with references to those previously published results.

Integrated Robotic and Human Lunar Surface Activity: Mobile robotic precursors can reduce risk, requirements, and cost of subsequent human exploration; they can go to hazardous locations that crew cannot access; and they can expand the geographic distribution of exploration sites, although robotic assets should not be used to conduct the types of science and exploration best done by well-trained astronauts [1-4]. Prototype rovers designed to deliver 30 to 50 kg of payload to the lunar surface were investigated, including field tests of a meter-size rover with an imager and robotic arm for sample handling [3].

Coordinating Telerobotic Operations of Small Robotic Surface Assets with an Orbiting Crew: Human-assisted sample return mission scenarios were investigated utilizing two orbiting assets. A sample-laden robotic ascent vehicle either (i) rendezvouses with crew in an orbiting Orion vehicle or (ii) rendezvouses with an orbiting Gateway [5-7]. Rovers with diverse capabilities were considered, ranging from a vehicle that will operate for a single lunar daylight period to a vehicle that will operate for several years and supply samples to at least three landed spacecraft. Detailed studies of potential landing sites and traverses were produced for the Schrödinger impact basin [8-10], the highest priority landing site for addressing National Research Council (2007) objectives for NASA's lunar exploration program. In addition to the human-assisted sample return missions, small rovers can also be used to telerobotically deploy astronomical antennas on farside sites like the floor of the Schrödinger basin [11-13].

Unpressurized vs Pressurized Rovers for Crew: A trade study of unpressurized (UPR) and small pressurized rovers (SPR) in lunar mission simulations revealed that travel within an SPR was easier on crew than spending an entire day in a spacesuit. Crew had more energy at EVA stations when traveling in the SPR and were, thus, more productive. The SPR could also provide shelter during any suit malfunction, radiation event, or medical emergency [14]. The SPR provides mobility, visibility, accessibility, surface documentation, and surface sampling, making it a valuable geologic tool [15]. It potentially extends the distance travelled from the lander by a factor of 25 compared to the limit of the Apollo Lunar Roving Vehicle (LRV) and, thus, an area 625 times larger. It also greatly reduces daily spacesuit time for crew, while extending their exploration potential [15]. Rapid EVA egress/ingress is required if crew are to be as productive or more productive than Apollo crews [16]. Landing sites and traverses for human crew have been studied in the Schrödinger impact basin and elsewhere [17-21].

Teleoperation of Crew Rover: SPRs can be used to conduct surface and subsurface surveys (e.g., for ice deposits) between crewed landings using cameras, ground penetrating radar, and a neutron spectrometer system [21,22]. If SPRs also have arms and sample storage, the vehicles can collect samples in terrains not accessed by crew.

Trafficability Studies: To address concerns about the ability of rovers to traverse ISRU-relevant terrains, studies of the bearing capacity of pyroclastic materials and PSRs have been conducted [23-25].

References: Please contact the author if you are unable to locate the following documents. [1] Kring D. A. et al. (2005) *Space Res. Roundtable VII*, Abstract #2021. [2] Kring D. A. and Rademacher J. (2007) *Lunar Planet. Sci. XXXVIII*, Abstract #1595. [3] Kring D. A. et al. (2007) *NASA Advisory Council's Workshop on Science Associated with the Lunar Exploration Architecture*. [4] Kring D. A. (2007) *LEAG*, Abstract #3037. [5] Kring D. A. (2017) *Planet. Sci. Vision 2050*, Abstract #8025. [6] Kring D. A. et al. (2015) *Euro. Lunar Symp*. [7] Kring D. A. (2017) *Deep Space Gateway*, Abstract #3043. [8] Potts N. J. et al. (2015) *Adv. Space Res. 55*, 1241–1254. [9] Steenstra E. S. et al. (2016) *Adv. Space Res. 58*, 1050–1065. [10] Hurwitz D. and Kring D. A. (2015) *EPSL 427*, 31–36. [11] Burns J. O. et al. (2013) *Adv. Space Res* 52, 306–320. [12] Burns J. O. et al. (2017) *International Academy of Astronautics.* [13] Burns J. O. et al. (2019) *Acta Astronautica 154*, 195–203. [14] Abercromby A. F. J. et al. (2012) NASA/TP-2012-217360. [15] Kring D. A. (2017) *Euro. Lunar Symp*. [16] Kring D. A. et al. (2017) *NASA Explor. Sci. Forum*. [17] O'Sullivan K. M. (2011) in *Recent Advances in Lunar Stratigraphy*, 117–128. [18] Bunte M. K. et al. (2011) *Analogs for Planetary Exploration*, 533–546. [19] Öhman T. and Kring D. A. (2012) *JGR 117*, E00H08. [20] Lemelin M. et al. (2014) *Planet. Space Sci. 101*, 149–161. [21] Allender E. J. et al. (2019) *Adv. Space Res. 63*, 692–727. [22] Kring D. A. (2017) *LEAG*, Abstract #5014. [23] Bickel V. T. et al. (2019) *JGR 124*, 1296 –1314. [24] Sargeant H. M. et al. (2020) *JGR 125*, e2019JE006157. [25] Bickel V. and Kring D. A. (2020) *Icarus 348, 113850.*