TOWARDS AN UNDERSTANDING OF ROVER TECHNOLOGY NEEDS FOR FUTURE LUNAR APPLICATIONS

A. M. Stickle, S. H. Teng, S. Hasnain, D. R. Mortensen, S. J. Izon, and J. I. Núñez. Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Rd., Laurel, MD 20723, USA, angela.stickle@jhuapl.edu.

Moon to Mars Objectives: NASA's Moon to Mars (M2M) strategy and objectives document establishes long-term goals and objectives for the agency's return to the lunar surface and eventual human exploration of Mars [1]. In this strategy, "why" we explore encompasses three pillars: Science, Inspiration, and National Posture. Ensuring success in all three areas requires an architectural approach that incorporates innovation, collaboration, and partnerships that can be sustained across a multi-decadal effort. The current strategy includes 10 goals and 63 final objectives that reflect a strategy for NASA and its partners to develop a blueprint for sustained human presence and exploration throughout the solar system via the M2M endeavor; in essence, the "what" NASA is trying to achieve. These objectives cover a range of themes, and expressedly include scientific exploration and the development of interoperable lunar infrastructure.

The 2023 Architecture Definition Document (ADD) [2] provides information about processes, framework, and decomposition of objectives to allow success in achieving human exploration of the cosmos. Additionally, the 2023 ADD includes descriptions of lunar surface elements including: a Human-class Delivery Lander, and the need for a Lunar Terrain Vehicle (LTV) and Pressurized Rover (PR) to enable greater exploration access across the lunar South Pole. Lastly, the 2023 ADD includes descriptions of a set of use cases to assist in identifying particular elements and needs for each objective.

Envisioned Futures and Priorities: NASA's Space Technology Mission Directorate (STMD) strategic framework covers a broad range of capabilities and provide guidance on technology development needs and investment priorities [3] as well as strategies to support further exploration of the solar system, such as the M2M architecture. These strategy documents outline envisioned futures priorities (EFPs) that show the desired state and suggested path forward within specific capability areas (e.g., In Situ Resource Utilization (ISRU), Excavation, Construction and Outfitting (E&C), Autonomous Systems and Robotics (ASR)). These EFPs outline envisioned capabilities and functions needed to meet operational and exploration goals. A variety of mobility capabilities, autonomous E&C and ISRU capabilities are specifically featured. For example, the ASR goals [4] explicity state the desire for:

- an autonomous fast-moving science rover;
- the ability for autonomous, persistent lunar surface operations for long-range and worksite operations (traveling up to 750 km/yr);
- remotely-operated intra-vehicular robotics for maintenance and utilization;
- robust robot mobility (up to 5000 km life-cycle, accessing deep interiors and navigating steep topography) for extreme access;
- durable, maintainable robotics for heavy-duty surface work, including bulk excavation (up to 400 metric tons);
- high-volume materials transport (up to 600 km/yr) and surface construction (up to 15,000 kg carrying capacity).

Notably, ISRU functions have shared interest with Autonomous Excavation, Construction, & Outfitting (AECO), including robust and rugged mobility capabilities, and the need for maintenance and repair.

Rover Technology Development in Support of EFPs and M2M: Significant rover technology development has focused on small-scale planetary exploration rovers and bespoke scientific explorers. As demonstrated by the rovers currently operating on the surface of the Moon and Mars, these rovers are versatile in navigating the terrain and gathering *in-situ* scientific data to broaden our knowledge of planetary environments and deepen our understanding of the solar sytem formation processes. Current development of larger-scale rovers, in the form of the LTV and PR, will provide expanded capabilities in the future.

Looking forward to supporting NASA's goals of sustained human presence on the Moon and the agency's desire to demonstrate ISRU and E&C capabilities on the lunar surface in the near future, a variety of mobility cases and scales will likely be necessary to meet all the necessary demands of an expansive ISRU or E&C mission and the objectives and use cases outlined in the ADD. In this study, we assess the unique needs of a number of ISRU and E&C lunar mission use cases, crewed and uncrewed. These assessments will inform the range of capability needs of future lunar rovers, and development needed to enable success.

References: [1] NASA (2023) *Moon to Mars Strategy and Objectives Document,* NP-2023-03-3115-HQ; [2] NASA (2024) *Exploration Systems Development Mission Directorate Moon to Mars Architecture Definition Document (ESDMD-001) – Rev. A;* [3] https://techport.nasa.gov/framework; [4] https://techport.nasa.gov/file/144879