In-Situ Construction and Resource Extraction For Long-Term Lunar Surface Exploration.

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Introduction: In order to enable operations and long-term human and robotic presence on the lunar surface, we are developing a mission concept that creates scalable production of locally-sourced building materials as well as volatile products called the Magnetic Induction Construction and Resource-utilization Operations System (MICROS). The MICROS concept involves the preparing or preconditioning of planetary surfaces prior to the human arrival by creating landing/launch pads, berms, and habitat structures (concept art; Figure 1), including extraction and storage of invaluable in-situ resources and consumables (e.g. water, fuel, oxygen, shielding) for later use by crewed missions to reduce mission risk, launch cost, and enable the next generation of Solar System exploration and colonization on the Moon, which is of critical importance to the NASA roadmap [1, 2]. Landed robotic and/or crewed missions to the Lunar poles are required to obtain ground truth and assess prerequisite mission parameters such as regolith properties, trafficability, as well as volatile compositions, abundances and state.

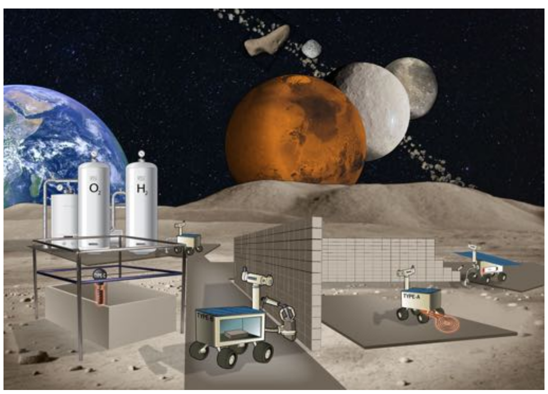

Figure 1. MICROS mission concept art showing the autonomous rovers creating and delivering construction materials and resources to sites on the Lunar surface.

MICROS Mission Concept: The integrated MICROS architecture enables coordinated autonomous robotic fabrication of vital infrastructure using Additive Construction (AC) methods with unprocessed surface regolith and resource extraction. MICROS will address outstanding problems in space exploration, including shielding for a crewed mission's prolonged exposure to radiation, roads and rover trafficability, reduction of launch mass, In-Situ Resource Utilization (ISRU) of volatiles, and ejecta/exhaust plume mitigation. Ultimately, Magnetic Induction (MI) technology coupled with the MICROS robotic architecture directly addresses key objectives of the ARTEMIS and Moon-to-Mars initiative by enabling ISRU, which in turn will enable long-term human exploration of nearly any planetary surface in the Solar System.

Additive Construction on the Lunar Surface: The construction and brick making on the Lunar surface done by MICROS utilizes MI heating and sintering. This works by applying an alternating current through loops of copper coils wrapped around a ferrous metal crucible (i.e., a bored iron cylinder or vessel). The oscillating magnetic field from the coils (solenoid) induces a magnetic field in the crucible, which, based on Ampere's law ($\mathcal{E} = -N\partial\Phi_{\mathcal{B}}/\partial t$), produces induced eddy-currents in crucible. This current-induced "friction" rapidly heats the regolith in the crucible, which has melting points of ~ 1260 °C (primarily silicates on the Moon). to explore lunar ISRU applications, including radiation shielding to protect astronauts.

Resource Capture: Resource extraction and volatile capture are integrated into the MICROS architecture as a natural extension of the regolith heating process. Lunar regolith contains volatiles that undergo a phase change to vapor or are released from a chemically bond state upon heating. Surface construction architectures that involve enclosed regolith heating can be structured to integrate resource extraction. MICROS will work in concert with systems developed for bulk resource extraction, such as those for sourcing ores for propellant production and human consumables, e.g. H_2O, CO, H_2S, NH_3,O_2, SO_2, CO_2, and H_2 [4].

Figure 2: Magnetic induction based heating of a steel crucible run at 7.5 kW. Steel crucible reached a temperature of ~1500ºC.

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