MAANA ELECTRIC'S TECHNOLOGIES FOR SPACE RESOURCE UTILIZATION: A EUROPEN PRIVATE-SECTOR PERSPECTIVE.

F. J. Guerrero-Gonzalez[1], A. Lovagnini[1], V. Goncharov[1] and L. Celiento[1], [1]Maana Electric SA, Foetz, 3895, Luxembourg, francisco.javier@maanaelectric.com.

Introduction: Maana Electric, founded in Luxembourg in 2018, is a European private firm with the ambition of becoming the utility company of the Solar System. Maana develops proprietary In-Situ Resource Utilization (ISRU) technologies to accelerate the development of a viable cislunar economy and support future infrastructure across the Earth–Moon system.

Regolith handling and beneficiation: In October 2025, Maana, as part of the LuMA team, participated in the second ESA/ESRIC Space Resources Challenge, which focused on two critical steps of the ISRU value chain: excavation and beneficiation. These operations are fundamental since resources cannot be utilized unless material is first acquired, transported, and conditioned.

Figure 1. Field demonstration during the second ESA/ESRIC Space Resources Challenge at ESA/DLR LUNA facility. Image credit ESA/ESRIC.

Following the challenge, Maana and its Luxembourgish partners have been awarded a development contract to mature particle-size classification. Maana will deliver a robust, adaptable beneficiation system capable of producing controlled regolith-size fractions tailored for various space-resource extraction and in-situ manufacturing processes. The system seeks to improve durability when in contact with abrasive regolith simulants, and to mature ancillary handling elements such as hoppers, feeders, and conveyors. We will further explore the combination of particle-size separation with complementary techniques, such as proprietary magnetic mineral concentration, to supply optimized feedstocks downstream in the ISRU value chain.

Metal and oxygen extraction from regolith: Maana's technological core, since its inception, has been the extraction of metals and oxygen from planetary regolith. Central to this effort has been the development of electrochemical processes capable of operating in molten media, either through molten salt electrolysis (MSE) or molten regolith electrolysis (MRE). These processes enable direct electroreduction of the minerals present in lunar and Martian soils in a bath of molten salts or oxides maintained above their melting points. Metal cations are reduced to solid or liquid metals at the cathode, while oxygen anions migrate towards the anode, where they are oxidized and released as gaseous O_2.

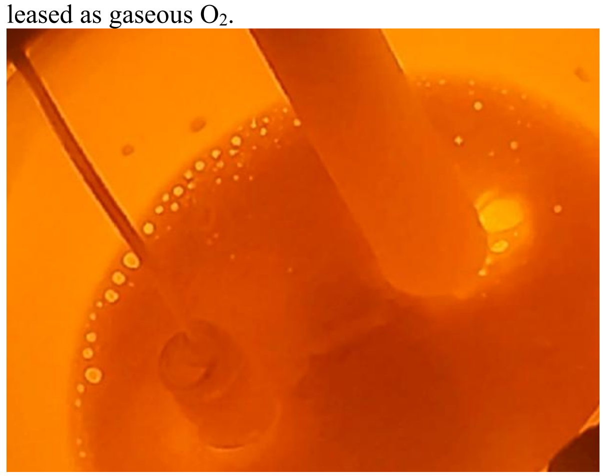

Figure 2. Electrochemical reduction of LHS-1.

Maana's current development strategy has prioritized MSE due to its lower operating temperatures compared to MRE, thereby reducing thermal-induced degradation and extending system lifetime. Our first line of work focuses on the electroreduction of dissolved regolith in molten fluorides, forming the basis of our SOURCE (Silicon and Oxygen from Unprocessed Regolith Electro-Chemical Extraction) flagship mission, which targets silicon extraction (alongside other metals and oxygen) from lunar soils. Our technology leverages principles of the industrial Hall–Héroult process, adapted to planetary conditions by selecting low-melting electrolytes compatible with oxygen-evolving anodes and resistant to long-term bath poisoning [1].

In parallel, Maana is also contributing to ESA's ISRU-DM mission, aimed at demonstrating the FFC process for oxygen and metal extraction on the Moon. Within this activity, Maana is responsible for demonstrating the feasibility of the process through materials selection and testing, including durable oxygen-evolving anodes and corrosion-resistant ceramics and metals [2], as well as developing an electrochemical reactor breadboard which will be integrated and tested up to TRL5 in 2027.

Beyond these large-scale metal and oxygen extraction developments, Maana is also advancing individual critical subsystem technologies required for future

ISRU architectures. One such effort is the current development of a modular Micro-ElectroMechanical System (MEMS)-based gas compressor, designed to provide a compact, low-mass, and low-power alternative to conventional pumping systems to meet mission-specific needs ranging from ISRU oxygen processing to ECLSS, thermal management, propulsion feed systems, or CubeSat microfluidics.

Lunar night survival: Lunar night survival is a critical requirement for the development of any space resource economy on the Moon. Extreme temperature conditions compromise the ability to keep equipment operational and to ensure the continuity of surface activities. To address this challenge, Maana is developing a thermal solution based on metallothermic reactions using lunar regolith to produce heat during the lunar night. These reactions ($M_a + M_bO \rightarrow M_aO + M_b + Energy$) are solid-state combustions, in which oxygen is transferred between two metals (M_a and M_b). The exothermic reaction occurs with the release of heat in proportion (in the ideal and adiabatic case) to the difference between the formation enthalpy of the two oxides (M_aO and M_bO).

The technology uses local regolith resources in their mineralogical form and ISRU-based metals extracted via molten salt electrolysis. Additionally, it refines metals from the reactants, which may be used for in-situ manufacturing.

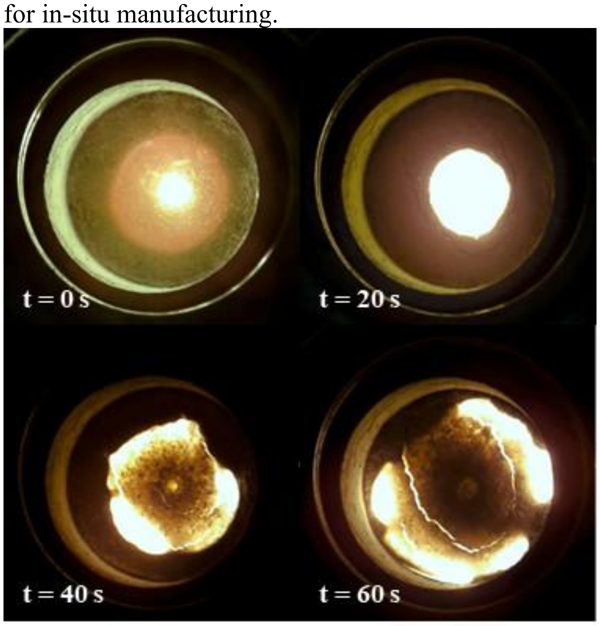

Figure 3. Propagation of an Al/LMS-1 thermite mixture [3].

The initial technology development successfully reached TRL 4 for the combustion chamber [3], demonstrating proof-of-concept for the metallothermic reaction process and the basic system configuration. The current phase is increasing the technology's maturity by building an integrated system demonstrator capable of performing the whole technological chain from sample preparation to heat acquisition and product removal. The system is based on a scalable architecture capable of delivering up to 250 kWh of thermal energy, sufficient to sustain a small lunar shelter through the night.

Cross-cutting technologies: Several ISRU and night survival systems, including molten-salt electrolysis reactors, metallothermic processes, radioisotope heating units, and solid oxide fuel cells, operate at high temperatures, where minimizing thermal losses is essential for energy efficiency. To support these needs, Maana is developing lightweight, high-temperature insulation materials, characterized and tested for lunar and Martian conditions, in collaboration with European terrestrial material manufacturing experts.

In parallel, we are advancing dust-mitigation technologies, as abrasive, electrostatically charged regolith can significantly degrade system performance. Our developments include high-power electrical connectors tolerant of severe dust exposure and ongoing work on Electrodynamic Dust Shield (EDS) solutions and optical scratch-resistant coatings to protect critical components, such as radiators, solar modules, optical systems, and space suits.

Environmental testing infrastructure: Reliable testing in simulated planetary conditions is essential for validating ISRU and night survival systems. We are contributing to the development of the Dusty Thermal Vacuum Chamber (DTVC), to be hosted at ESRIC in Luxembourg, offering high-vacuum operation, temperature ranges from –180 °C to +160 °C, controlled dust deposition, and payload volumes up to 2.3 × 1.5 × 1.45 m (L × W × H).

In parallel, Maana is building additional in-house environmental testing infrastructure, including dusty vacuum chambers with internal dimensions of 1.35 × 0.85 × 1.15 m (L × W × H) to support subsystem-level development and rapid prototyping. In addition, we have developed controlled regolith deposition methodologies to reproduce relevant dust-exposure conditions and to qualify dust-driven degradation under representative conditions.

References: [1] Guerrero-Gonzalez F.J. et al. (2025) *ICES-2025-441*. [2] Guerrero-Gonzalez F.J. et al. (2026) *Space Resources Week*. [3] Lovagnini A. et al. (2024) *IAC-24-IPB, 14, x85363*.