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22nd IAA SYMPOSIUM ON BUILDING BLOCKS FOR FUTURE SPACE EXPLORATION AND DEVELOPMENT (D3)
Interactive Presentations - 22nd IAA SYMPOSIUM ON BUILDING BLOCKS FOR FUTURE SPACE EXPLORATION AND DEVELOPMENT (IPB)

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ACCELERATED COMBUSTION OF METALS FOR EXOTHERMIC HEATING (ACME): SURVIVING THE LUNAR NIGHT THANKS TO ISRU PARADIGM

Abstract

In-Situ Resources Utilization (ISRU) is a branch of space exploration studying processes that utilize resources extracted locally (in-situ) on extraplanetary surfaces to provide goods and services. In this frame of study, Maana Electric proposes an innovative concept for long-term energy storage on the lunar surface based on the ISRU approach. This problem is especially relevant when challenging lunar nights, which are a notorious limit to long-term missions on the lunar surface due to the extremely low temperature and long duration. The Accelerated Combustion of Metals for Exothermic Heating (or ACME) proposed by Maana Electric is based on metallothermic (thermite) reaction and uses minerals extracted and processed in-situ to provide thermal power following the general equation $\mathrm{M1}_{\mathrm{reactant}} + \mathrm{M2O}_{\mathrm{reactant}} \rightarrow \mathrm{M1O}_{\mathrm{product}} + \mathrm{M2}_{\mathrm{product}} + Energy$. The concept uses minerals extracted in-situ as reactants oxides ($\mathrm{M2O}_{\mathrm{reactant}}$). Maana Electric conceptualized ACME as part of a closed-loop ISRU concept where the product oxides ($\mathrm{M1O}_{\mathrm{product}}$) can be recovered during lunar day and converted again in metal form ($\mathrm{M1}_{\mathrm{reactant}}$) with the indirect benefit of oxygen production. From this perspective, the reactor functions as an innovative energy storage system, where the energy spent to regenerate the reactants from the products is later released during the lunar night as the thermite reaction is triggered. The main difference with respect to conventional energy storage devices is the temporal stability of the reactants (which preserve the chemical energy even for decades) and their temperature resilience (which allows ACME to be operated even at extremely low temperatures). Additionally, ACME can also be seen as an ISRU metal extraction rector, as it is able to refine the minerals excavated in-situ ($\mathrm{M2O}_{\mathrm{reactant}}$) in metals ($\mathrm{M2}_{\mathrm{product}}$) which can be used for in-situ fabrication of items.
This paper presents the work conducted by Maana Electric on ACME R&d activities in the frame of an ESA Discovery project between 2021-2023. First, it provides a review of most promising metallothermic reactions making use of lunar minerals. Secondly, it proposes a trade between alternative ignition techniques, heat transfer architectures and system-of-system integration on the lunar segment. Later, the architecture of the ACME breadboard is detailed, providing a description of the results of tests performed to verify the critical performance of the reaction in vacuum environment. Finally, we outline the R&d activities presently carried out at Maana Electric aiming to upscale ACME to an autonomous breadboard operated in relevant environment.