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PARADIGM CHANGE IN SPACE UTILIZATION: CONCEPTUAL DESIGN STUDY OF A LUNAR SPACE STATION FOR IN-SPACE MANUFACTURING

Abstract

From the dawn of the Space-age, the exploration and exploitation of space have been severely constrained by the expense of overcoming Earth's gravitational well. In addition, machinery manufactured on Earth is limited by the dimensions of rocket fairings, and must withstand the high vibration and acceleration forces associated with the launch. This paper presents the conceptual design study of the crewed lunar space station "Lunar Manufacturing Outpost" (LUMO), which provides a solution to all of the aforementioned issues by offering in-space manufactured products. It thus has the potential to initiate a paradigm change in space utilization, fostering the establishment of a lunar economy. LUMO's conceptual design study has been conducted during the "Space Station Design Workshop (SSDW) 2022" at the Institute of Space Systems of the University of Stuttgart (Germany).

An annual supply of one ton each of aluminum, silicon, and water, preprocessed from in-situ resources by a lunar base is assumed. 95 kg/year of supplementary materials such as copper and doping material are supplied from Earth. A resulting yearly output of 750 m^2 Monolithic Perovskite/Silicon Tandem Solar Cells, 309 m^2 silicon mirrors, and 266 kg of LOX+LH2 propellant is estimated. The microgravity conditions prevailing in orbit offer a variety of significant processing advantages, e.g. higher manufacturing

temperatures and absence of container-induced contamination due to containerless processing, absence of sedimentation and absence of lunar dust. These result in higher product homogeneity and purity, which makes in-orbit manufacturing advantageous over ground-based options. The purity of the products is further improved by vacuum. The proposal identifies technological challenges regarding the low Technology Readiness Level of manufacturing processes. Risks and possible mitigation strategies have been proposed. The key risk identified is that in-situ manufacturing processes may not reach technological maturity by 2050, which is the proposed start date for 50 years of operation. The lifetime-cost of the 231 ton and 1560 m^3 space station is estimated to be $75 billion.

LUMO is developed as an autonomous space station, but can be adapted to serve as an extension of the Lunar Gateway. The solar panels can be used for space-based solar power and electric propulsion missions. The mirrors can be used to concentrate sunlight on solar panels, melt regolith, or as planetary sunshades to mitigate climate change. LUMO's in-space manufactured products from in-situ resources will accelerate the exploitation and exploration of space and herald a new era of orbital (re)supply stations.