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17th IAA SYMPOSIUM ON BUILDING BLOCKS FOR FUTURE SPACE EXPLORATION AND DEVELOPMENT (D3)
Strategies & Architectures as the Framework for Future Building Blocks in Space Exploration and Development (1)

Author: Prof. Jekanthan Thangavelautham
University of Arizona, United States, jekan@email.arizona.edu

Mr. Aman Chandra
University of Arizona, United States, achandra@email.arizona.edu
Mr. Erik Jensen
University of Arizona, United States, edjensen@email.arizona.edu

AUTONOMOUS MULTIROBOT TECHNOLOGIES FOR MARS MINING BASE CONSTRUCTION AND OPERATION

Abstract

Beyond space exploration, the next critical step towards living and working in space requires developing a space economy. One important challenge with this space-economy is ensuring the low-cost transport of raw materials from one gravity-well to another. The escape delta-v of 11.2 km/s from Earth makes this proposition very expensive. Transporting materials from the Moon takes 2.4 km/s and from Mars 5.0 km/s. Based on these factors, the Moon and Mars can become colonies to export material into this space economy. One critical question is what are the resources required to sustain a space economy? Water has been identified as a critical resource both to sustain human-life but also for use in propulsion, attitude-control, power, thermal storage and radiation protection systems. Water may be obtained off-world through In-Situ Resource Utilization (ISRU) in the course of human or robotic space exploration.

Based upon these important findings, we developed an energy model to determine the feasibility of developing a mining base on Mars that mines and exports water (transports water on a Mars escape trajectory). Mars was selected as water has been found trapped in the regolith in the form hydrates throughout the surface at an average of 5% by mass with bigger deposits in Northern and Southern Polar Ice Caps. Our designs for a mining base utilize renewable energy sources namely photovoltaics and solar-thermal concentrators to provide power to construct the base, keep it operational and export the water using a mass driver (electrodynamic railgun). Using the energy model developed, we determined that the base requires 2.6×10^6 MJoules of energy per sol to export 100 tons of water into Mars escape velocity. 97.8% of the energy obtained from renewable power sources is to power the mass-driver. Only 0.54% of the energy was required to excavate, process and collect water. If the base was occupied by 100 human workers, 1.66% of the energy would be needed for sustaining life-support, food productions and healthy-living.

Our studies found the key to keeping the mining base efficient is to make it robotic. Teams of robots (consisting of 100 infrastructure robots) would be used to construct the entire base using locally available resources and fully operate the base. This would decrease energy needs by 3-folds. Furthermore, the base can be built 3-times faster using robotics and 3D printing. This shows that automation and robotics is the key to making such a base technologically feasible.