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SPACE RESOURCE LOGISTICS FOR HUMAN EXPLORATION TO MARS

Abstract

This paper develops an interdisciplinary space architecture optimization framework to analyze the tradeoff on in-situ resource utilization (ISRU) options, identify technology gaps, evaluate the benefits of ISRU, and optimize the design of infrastructure for various Mars human space exploration scenarios and mission profiles. It performs the trade studies from the perspective of space logistics, which takes into account the interplanetary transportation, infrastructure deployment, ISRU system operation, and the further logistics of the produced resources. The proposed framework considers space mission as commodity flows along arcs inside a network, where nodes represent orbits or planets; arcs represent trajectories. The spacecraft, crew, scientific instruments, propellant, and other payloads are considered as different commodities. Our method considers space architecture design and operation from a subsystem level to enable trade studies between ISRU technologies and in-space architecture elements in space resource logistics. A case study involving a multi-mission human Mars exploration campaign is performed to evaluate the effectiveness of existing and proposed ISRU technology concepts and system designs. The results can provide us with a better understanding of the benefits and cost of different ISRU technologies in interplanetary space transportation. A sensitivity analysis is also conducted to figure out whether lunar ISRU can be beneficial to Mars missions. Under what kind of mission scenarios or architecture designs can we make a space station be beneficial to the resource logistics for Mars missions. The results of this analysis can help decision-makers determine and optimize the roadmap of ISRU technologies. Our method provides an important step forward in system-level architecture design and evaluation for future large-scale human space explorations. It is also particularly useful to identify the level of resource information we need to design ISRU hardware and plan the mission including the in-space transportation and landing sites selection.