Paper ID: 12391
oral
student

Life support Challenges for Human Space Exploration (10)
Supporting Crews for Exploration Missions (2)

Author: Mr. Sydney Do
Massachusetts Institute of Technology (MIT), United States

Dr. Olivier de Weck
Massachusetts Institute of Technology (MIT), United States

AN INTEGRATED MODELING FRAMEWORK FOR ANALYZING THE SUSTAINABILITY OF PLANETARY SURFACE HABITATS

Abstract

In recent years, NASA has significantly increased its pursuit of developing the capability to sustain humans on Lunar and Martian surfaces, with the development path taken to achieve this based primarily on experience from the Apollo and International Space Station programs. Although these have provided a wealth of knowledge, neither program was originally architected to achieve long-term life-support in an environment void of regular resupply. Consequently, current research has focused on addressing the functional life-support needs of the crew, while interactions between these very functions, from which the behavior of sustainability emerges; have been largely ignored. A resulting outcome is the compartmentalized development of the required technologies, based on the mindset that maximizing their individual performance will correlate to maximizing the overall habitat sustainability. When interactions between these technologies are introduced however, a rich tradespace is revealed, whereby architectures consisting of lesser performing subsystems emerge as being competitive. This has implications on system complexity and cost, which subsequently impacts its overall sustainability. One such example is the interaction between the in-situ resource utilization (ISRU) and waste management (WMS) systems. Rather than optimizing each, one could offset the demand for ISRU-derived raw material with solid waste reprocessed by the WMS. Moreover, pyrolysis can be used within the WMS to convert waste to energy, thus offsetting the power requirements of both systems. This results in reduced ISRU performance and waste disposal requirements. Interactions such as these form the basis of the modeling framework presented in this paper. Based on the Object Process Methodology, a decomposition of the functions required to support a crew in a given environment is performed. Such functions include water, waste and atmospheric management, power generation, food production, and ISRU techniques. These are mapped to elements of form via a database containing models of the relevant technologies. Through this, feasible habitat designs are generated, and the resultant multi-objective space explored. Here, the chosen objective is sustainability, which as per the Three E's model; is decomposed into the objectives of minimizing Environmental impact through maximizing loop closure rate, meeting Economic constraints, and Equally meeting the basic needs of the crew. Preliminary model results and key system trades are presented, and important sustainability-influencing design parameters highlighted. This work will form the basis of a comprehensive exploration of the sustainability tradespace, thereby allowing future planetary habitats, and their corresponding development paths, to be architected in a manner which truly maximizes system sustainability.