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TOWARDS THE FUTURE OF SPACE BIOPROCESS ENGINEERING

Abstract

Inspired by new measurements and imagery from the Perseverance mission, there is reinvigorated public interest in achieving a crewed mission to Mars in the 2040s. To realize such missions, we must solve multiple science and engineering challenges as described by NASA's Space Technology Grand Challenges (STGCs) for expanding human presence in space. These challenges include advancing technologies to support the nutritional, medical, and incidental material requirements that will sustain astronauts against the harsh conditions of interplanetary transit and habitation on the surface of an inhospitable alien world. Advanced biotechnologies that support flexible biomanufacturing from *in situ* resources can provide a mass, power, and volume advantage compared to traditional physicochemical strategies. However, critical bottlenecks remain that must be overcome to make Mars biomanufacturing practical and robust. Here, we will review the applications of biotechnology for offworld frontiers and endeavor to define Space Bioprocess Engineering (SBE) as the multi-disciplinary approach for the design, realization, and technical management of a biologically-driven system in a space mission context. In order to codify SBE and its importance and utility among the spacefaring communities, we will offer a perspective on the efforts that must be mounted to update the mandate for recognizing and employing SBE as a tool for enabling human exploration; specialize the metrics and methods that guide SBE technology life-cycle and development; further develop means by which SBE technologies are deployed on offworld testing platforms; and train the minds that enter the spacefaring workforce on the SBE advantages and capabilities. We present a roadmap aligning the continued research, design and testing necessary deploying a biomanufactory during long term missions in the 2040s. Our analysis suggests that the endeavor becomes far more efficient when bioprocess components are linked together into an integrated biomanufactory. The resultant cooperativity in the design provides direct mechanical linkage of processes, uses compatible organisms and media, and maximizes recycling and utility of byproducts. We also present an argument for center-driven efforts are necessary in development alongside individual space technological efforts.