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TOWARDS A UNIFIED COST-BENEFIT ASSESSMENT METRIC OF MISSION, STAKEHOLDER, AND ASTRONAUT VALUES

Abstract

Looking towards the moon and beyond to Mars, the spacefaring community has been reinvigorated by the challenges of the burgeoning Artemis program. Among these many challenges will be the selection and specification of technologies within the mission architecture. To standardize exploration priorities and democratize both lunar and martian strategies, we developed a novel cost-benefit analysis (CBA) framework as a new toolbox of metrics to evaluate campaign outcomes in terms of exploration, science, and policy objectives. The goal of this framework is to further augment the mission design process by quantitatively accounting for space policy directives that foster enabling technologies, generate offworld research opportunities, maintain higher astronaut health and morale, and create more value for stakeholders. Our integration of the policy landscape also provides additional justification of return-on-investment to policymakers. We enumerate three main axes of value in our analysis method: mission, stakeholder, and astronaut value. *Mission value* is an extension of relative exploration value: a normalized measure of the exploration capability of a mission. *Stakeholder value* reflects stakeholder gains from operations, a normative proxy for terrestrial utility determined through value flow mapping. *Astronaut value* estimates the effects of decision pathways on crew members, both their comfort and efficiency. Used in conjunction with gold-standard metrics such as Equivalent System Mass (ESM), our CBA framework leverages multi-criteria analysis to explore the tradeoffs across each of the three value domains within a unified space. This framework is not itself a strategy for optimization, but rather a series of consolidated and refined factors to optimize all in one tool for tradespace assessment. We demonstrate the application of this new CBA to evaluate Space Bioprocess Engineering (SBE) technologies from recent developments to integrate novel biomanufacturing paradigms into the more grounded arenas of mission planning and closed loop life support systems. We conclude with a discussion of policy implications drawn from the application of the CBA to aid in downstream selection of specific scenario parameters and offer a potential roadmap towards democratizing mission planning across engineering, systems, science, and policy spheres.