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APPLICATION OF A TOP-DOWN SYSTEM-OF-SYSTEMS APPROACH TO ENABLE HUMAN MARS EXPLORATION MISSIONS

Abstract

Increasing human presence in space is enabled by sound architectural choices that incorporate well-balanced inputs from the areas of programmatics, logistics, systems, and mission design. Assembling these inputs requires a robust framework and toolset for rapidly analyzing, comparing and modifying varied choices. A Systems of Systems framework is developed to implement a top-down approach that informs architectural choices from the strict flowdown of requirements to satisfy mission goals. A System-of- System toolset is applied to incorporate rapidly shifting trends, and offer another check-point in the decision-making process. A traditional bottom-up approach seldom captures operational and developmental dependencies systematically. The result is a set-up that is resistant to holistic updates and offers strained discovery and tracking of potential failures. In contrast, a top-down approach which is capable of incorporating operational inputs that range from multiple stakeholder involvement, to the propagation of capability/systems failures. In the developmental domain, the proposed methodology accounts for manufacturing lead-times and schedule slips, and the implications of considering varied Technology Readiness Levels as choices for the architecture design. The top-down operational and developmental breakdown is enabled via System of System tools from previous research. A functional analysis that decomposes top-level functions into various levels of capabilities and system/sub-system allocations, forms the backbone of the proposed toolset. Based on functional analysis, we organize systems and capabilities in networks that represent the interdependencies, modeled with appropriate parametric models. These networks are then analyzed with our System of Systems tools, resulting in a quantitative assessment of robustness and resiliency of a given architecture, and in the identification of weak links that would introduce mission and technological risks. The ability to subject single or multiple nodes to both deterministic and stochastic failures also offers rapid diagnosis and traceability of diminished system performance. We demonstrate our approach on the analysis of alternative architectural choices relative to the propulsion systems, habitat systems, and entry, descent and landing technologies for exploration of Mars. For instance, a selected example conducts a trade study of potential propulsion systems including Solar Electric Propulsion, Nuclear Thermal Propulsion and Chemical Rockets. Each system represents a network of interconnected systems with unique operational and developmental dependencies. Analysis of the operational and developmental

dependencies allow a mission manager to assess not only the performance of these systems, but also the risk, robustness and criticalities present in their development and implementation.