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SPACE EXPLORATION SYMPOSIUM (A3)
Space Exploration Overview (1)

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UNDERSTANDING HUMAN SPACE EXPLORATION

Abstract

The number, size and complexity of systems currently envisioned for human space exploration missions beyond Low Earth Orbit, present an unprecedented architecture design challenge. Explicit costs and risk constraints make the challenge even more daunting. Space agencies and private companies continue to propose new visions for realizing space exploration aspirations. Following changes in the approach to space exploration architecture design, this paper argues that the underlying mindset and analysis/synthesis approach must evolve anew as well. Single-threaded, bottom-up construction of alternatives will fall short in achieving the maximum results in terms of reliability, cost reduction, risk management, sustainability, and architecture resiliency when dealing with the complexity of the present challenge. This paper introduces a new paradigm well-suited to the challenge, one that allows both problem abstraction and solution via a System-of-Systems perspective. The System-of-Systems approach acknowledges the tension between technical and managerial independence and dependence together in a holistic view of space exploration. The paper demonstrates how to account for the known interactions between complex systems and the discovery of unknown ones, the partial independence of the systems involved, and the presence of multiple stakeholders with their economic and policy considerations. In this paper, we first decompose the challenges in space exploration architecture development into specific research questions. We then introduce the System-of-Systems approach, and describe how System-of-System traits and features of space exploration – such as independence of the systems, presence of multiple stakeholders, and interactions between systems – can be dealt with via an innovative approach. This methodology complements the traditional bottom-up approach of systems engineering with a top-down, holistic view, which allows designers and decision makers to understand and analyze the behavior of complex systems, and to evaluate different architectures, under varying working conditions. The user can compare architectures based on metrics of interest, perform trade-offs between competing desired features, and identify the most promising architectures and the causes of the observed behavior. We therefore present a call for action to improve the effectiveness of analysis and synthesis of space exploration systems, and describe various methodologies, tools and techniques needed that will add to the existing methods to achieve a more effective approach to space exploration systems design. The result is an increase in reliability, sustainability, and resiliency of evolving solution options, as well as an improvement in risk and cost management in space exploration.