SYMPOSIUM ON BUILDING BLOCKS FOR FUTURE SPACE EXPLORATION AND DEVELOPMENT (D3)
Strategies & Architectures as the Framework for Future Building Blocks in Space Exploration and Development (1)

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DEPENDENCY NETWORK ANALYSIS: FOSTERING THE FUTURE OF SPACE WITH NEW TOOLS AND TECHNIQUES IN SPACE SYSTEMS-OF-SYSTEMS DESIGN AND ARCHITECTURE

Abstract

Advances in technology, and increasing size and complexity of systems are constantly urging system engineers to develop innovative tools and techniques to better address the new challenges. Space system are even more susceptible to technology improvements, since they stand on the top of mankind know-how and expertise. Moreover, complexity is a source of high risk and cost in space systems. In order to minimize the impact due to the failure of a single launch or to budget cut, space exploration up to date has been mainly characterized by a series of monolithic missions, largely independent from one another. Recently, new paths have been proposed to deal with new issues in space systems engineering: ESA developed a facility to apply the Concurrent Engineering method to the design of future space missions, thus recognizing the importance of integrated development, parallelization of tasks, and top-down approach. NASA has begun to interface spacecraft on different missions towards a common goal (Mars Reconnaissance Orbiter provides mapping of Mars, but also served as communications relay during the landing of Curiosity rover), thus adding flexibility and reliability to space exploration. Approaches aimed at increasing sustainability of space missions, and reliability and scalability of space systems (modularity, on-orbit assembly, network of intermediate exploration missions) have also been undertaken. Based on such considerations, this paper introduces new tools and techniques to address architecture and design of future space missions and systems. Recognizing the importance of interdependency between components in space systems, and among complex systems, we propose techniques to perform and exploit analysis of dependencies, both operational and developmental. We identify metrics to assess and measure the system value, based on cost and operability. Operational dependency analysis is then used to evaluate and compare different architectures and designs, both in the final stage and when partial development has been achieved. The paper then shows how the developmental dependency analysis is used to drive parallel development of component systems in order to increase flexibility and partial capability, and to reduce risk. The techniques are scalable and can be applied to a variety of scenarios. As an example of application, hypothetical exploration missions are considered, and analyzed by means of the proposed tools. The results are compared to each other and to current missions against the suggested metrics. The results show both the power of dependency analysis technique and the importance to consider such tools in future space development.