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QUANTIFYING THE IMPACT OF SYSTEMS INTERDEPENDENCIES IN SPACE SYSTEMS ARCHITECTURES

Abstract

As space systems architectures grow larger and more complex, decision makers face increasingly difficult tasks. Due to the number of systems involved in a space mission and to their complex interactions, identifying risk and criticalities is not obvious. Traditional systems engineering methodology does not always capture the impact of interactions between systems and of cascading effects of disruptions in risk assessment. The interdependencies can produce unexpected results, where systems which are not expected to have a major impact on the operational status of other systems exhibit instead high criticality. The capability of detecting this emergent behavior is extremely important for decision support, since it provides guidelines for choices of technologies to be developed and for priority of investments on the most critical systems, to reduce the risk associated with disruptions. Based on these considerations, we developed and applied models and techniques that account for interactions between systems in the operational domain. The approach followed in our Systems Operational Dependency Analysis methodology is based on a parametric model of interdependencies between systems, which is especially useful when analytical, physics-based models are not available. This model provides quantification of the direct and indirect impact of disruptions of a system on other systems, as well as identification the root causes of observed behavior. This paper describes the results of the second year of a continuing collaboration of the authors with subject matter experts from NASA which focused on the development and application of System-of-Systems engineering methodologies for analysis of space systems architecture. Expanding on our work from IAC 2018, we provide a hierarchical representation of the interdependencies between systems in a space system architecture, which adds a holistic viewpoint, based on the analysis of the

component systems and their interactions, to the traditional systems engineering analysis. We focused on the study of interactions between systems and subsystems within the elements of the NASA Gateway, which is a primary example of complex interactions which may result in high criticality of certain subsystems due to direct and indirect impact of the operational interdependencies. Following feedback from subject matter experts, the methodology was refined to increase its usability and usefulness. Results of the analysis of Gateway elements with our methodology demonstrate the quantification of the impact of disruption in subsystems and sets of subsystems on each of the other subsystems and the assessment of the criticality of constituent systems and subsystems of the Gateway.