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AUTOMATED RISK AND SUPPORTABILITY MODEL GENERATION FOR REPAIRABLE SYSTEMS

Abstract

As human space exploration missions expand beyond Low Earth Orbit (LEO) to destinations such as Cislunar space, Near-Earth Asteroids, and Mars, the logistics associated with repair and maintenance will become significantly more challenging. The logistics paradigm of the International Space Station (ISS) may not be feasible for future missions; longer mission durations increase the chance of component failures, and greater distances from Earth increase both the cost and time required for resupply. In some cases, particularly for Mars exploration missions, a contingency abort back to Earth may not be feasible in a reasonable amount of time. As a result, reliability and supportability will become more dominant design drivers. Decisions made early in the system architecting and design process can have a significant impact on the overall risk taken on during a mission, which can result in costly operational or logistics support requirements in order to ensure safe operation with a high probability of achieving mission goals. A full and timely understanding of the risk and supportability implications that architecture and design decisions will have during future mission operations - obtained at the time that those decisions are made - can help engineers develop systems that can achieve demanding exploration mission goals in a safe, reliable, and cost-effective manner. This paper presents a framework to incorporate automated risk and supportability analysis support into Model-Based Systems Engineering (MBSE) efforts in order to support risk-informed system development, focusing on repairable systems. A notional Mars surface habitat is presented as a case study. System and mission design data such as individual component reliabilities and resupply frequency are used to automatically generate risk and supportability models in Markov, semi-Markov, and Bayesian Network form. These models are then used to derive key metrics such as the number of spares required, the crew time required for maintenance, and the probability of meeting requirements. A sensitivity analysis is also performed to examine the impact of different analysis techniques and parameters on complexity and fidelity. We discuss the implications of these results with regard to the applicability of this framework to different points in the development process, as well as the potential benefits of this approach and planned future extensions. The goal of this framework is to support rapid examination of different architecture and design options and perform quantitative system trade studies while taking risk and operational/logistical requirements into account.