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Quality and safety, a challenge for traditional and new space (1)

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DESIGN FOR RELIABILITY IN PRE-DEVELOPMENT: FAULT DETECTION, ISOLATION AND RECOVERY FOR AUTONOMOUS AND HUMAN MISSIONS IN THE SUN – EARTH – MOON SYSTEM

Abstract

Since introducing the challenge of Space PERT, NASA has continued daring the acquisition of innovation and RD by instituting high-level reliability, criticality, safety, adaptability, maintainability, and supportability (RAM) requirements to originate at the conceptual life cycle phase of hardware and software development. Although designing for RAM is not a novel concept, the force of de resistant inertia to both RAM and PERT plagued the RD hardware and software acquisition with design defects costing hundreds of billions of dollars. Deep Space exploration has entered the era when RD design defects will be causing not only innumerable economic losses but also critical risks to missions and public safety. Autonomous and human missions in the Sun – Earth – Moon System and beyond will call for (a) innovative architectures dispersed throughout the Deep Space in Halo Orbits, (b) design of parking orbits around Libration L2 and L1 points, (c) telescopes in a variety of L2 Halo Orbits (including a radio telescope on the Moon's far side), (d) continuous LEO – Earth-Moon L2 communication, (e) the interplanetary transfer trajectories from LEO to various destinations, (f) reusable interplanetary transport system between Earth and Mars, (g) transfer vehicle at Sun-Earth L2, and (e) reconfigurable C2 relay of small/medium satellites in LEO. We define the space architecture prototype, describe its multi-mission scenarios and respective durations at conceptualization and functional engineering in pre-development. The feasibility of individual subarchitectures and system components was previously proven and published. The prototype integrates the individual components, simulates end-to-end mission performance, derives potential failure modes via criticality analysis, and defines failure injection and propagation models. For this prototype, we conceptualized missions and scenarios focusing on (c) servicing telescopes in a variety of L2 Halo Orbits (including a radio telescope on the Moon's far side), (d) continuous LEO – Earth-Moon L2 communication, (e) the interplanetary transfer trajectories from LEO to various destinations, and (f) ad-hoc rescue scenario for a reusable interplanetary scout formation of satellites stationed at Sun-Earth L2 and controlled by the LEO C2 relay. The prototype integrates the individual components, simulates end-to-end mission performance and defines failure injection and propagation models at the levels of mission control, spacecraft systems, data repositories, systems configuration and interfaces, limited scientific payload hardware and software. The proof-of-concept functional, expandable FDIR framework of neural networks simulation scenarios were sized at over 4.1M SLOC and estimated to complete in 60.5 months at about $2.1 Binconstantdollars$.