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SPACE SYSTEMS RESILIENCE ENGINEERING AND GLOBAL SYSTEM RELIABILITY OPTIMISATION UNDER IMPRECISION AND EPISTEMIC UNCERTAINTY

Abstract

The paper introduces the concept of design for resilience in the context of space systems engineering and proposes a method to account for imprecision and epistemic uncertainty. Resilience can be seen as the ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions. Mathematically speaking this translates into the attribute of a dynamical system (or time dependent system) to be simultaneously robust and reliable. However, the quantification of robustness and reliability in the early stage of the design of a space systems is generally affected by uncertainty that is epistemic in nature. When design progress progresses through from Phase A down to phase E, the level of epistemic uncertainty is expected to reduce but still a level of variability can exist in the expected operational conditions and system requirements. The paper proposes a representation of a complex space system using the so called Evidence Network Models (ENM): a non-directed (unlike Bayesian network models) network of interconnected nodes where each node represents a subsystem with associated epistemic uncertainty on system performance and failure probability. Once the reliability and uncertainty on the performance of the spacecraft are quantified, a design optimisation process is applied to improve resilience and performance. The method is finally applied to an example of preliminary design of a small satellite in Low Earth Orbit (LEO). The spacecraft is divided in 5 subsystems, AOCS, TTC, OBDH, Power and Payload. The payload is a simple camera acquiring images at scheduled times. The assumption is that each component has multiple functionalities and both the performance of the component and the reliability associated to each functionality are affected by a level of imprecision. The overall performance indicator is the sum of the performance indicators of all the components.