66th International Astronautical Congress 2015

SPACE SYSTEMS SYMPOSIUM (D1)
Interactive Presentations (IP)

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FRAGILITY INDEX AS A TECHNICAL PERFORMANCE MEASURE (TPM) DURING A SYSTEM LIFE CYCLE: A CASE STUDY ON ITS APPLICATION TO MONOLITHIC AND FRACTIONATED SPACECRAFT.

Abstract

In the harsh conditions that characterize the launch, orbital, and reentry environments of space systems, small failures may lead to catastrophic events. Cases like Mars Polar Lander or Ariane 5 are unfortunate examples of how a small design flaw can lead to disaster.

Traditionally, this type of potential outcomes are addressed quantitatively and qualitatively in the space sector. Reliability predictions enable achieving a given target of confidence with regards the probability of failure. Yet, they use a "working" system as input and thus they are not able to identify or measure the effects of non-nominal scenarios, such as design flaws, operating in non-nominal environments, or similar. In addition, they do not explicitly inform about the nature of underlying relationships between criticalities of causes and consequences.

Instruments such as the failure mode events and criticality analysis (FMECA), on the other hand, provide a deeper understanding about the mechanisms that result in failure and the criticality of the failure. Yet, they lack solid mathematical foundations and they are also unable to adequately address non-nominal scenarios.

In order to fill in this gap, the concept of system fragility has been proposed. A system is said to be fragile when a relatively small failure involving one or more components can lead to the destruction or inoperability of the whole system. Because fragility is an emergent characteristic of a system, it cannot be calculated as a simple function of a system's constituent elements. In addition, it may evolve during a system life cycle. Therefore, the present paper asserts that, using a Risk Informed Design approach, system fragility can be defined as a Technical Performance Measure (TPM), thus enabling its monitoring and control throughout a system's life cycle.

Several questions arise: Does the accuracy to measure system fragility change during the life cycle? Are there specific life cycle phases where Design-Against-Fragility techniques are more effective? Is it possible to identify architectural patterns that result in specific fragility trends? Aiming at contributing to answer these questions, this paper proposes a quantitative fragility index derived from a system architecture within a given solution space and explores the value and implications of fragility index as a TPM using notional monolithic and fractionated space systems.