SPACE SYSTEMS SYMPOSIUM (D1)
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A TEMPORAL LOGICAL METHODOLOGY FOR PROBABILISTIC VULNERABILITY ANALYSIS OF SPACE MISSIONS: APPLICATION TO VULNERABILITY ANALYSIS OF AN EARTH OBSERVATION MISSION DUE TO CATALOGUED SPACE DEBRIS

Abstract

Vulnerability analysis is an important step in the design of a space system, or, of its mission. Indeed, being able to estimate this vulnerability with respect to a given potential risk or threat could help to improve the lifetime of the system and the quality of the services it is designed for.

In this paper, we present a system methodology for vulnerability analysis and its application to an Earth observation mission for LEO satellites, regarding the threat of catalogued space debris. This methodology has been developed by ONERA through its V2S project focusing on Space Systems Vulnerability. An original feature of the proposed approach consists in considering the vulnerability of the space mission as a whole, instead of the vulnerability of the sole satellite. This vulnerability is computed as a difference, over the mission lifetime, of the mission's performances, under different threat levels, such as different scenarios of evolution of the catalogued space debris population.

The performance of the mission, for a given scenario, is evaluated using a temporal logical probabilistic methodology. The first step of the methodology is based on the use of a classical engineering tool: a functional analysis of the mission is performed, leading to its description as a combination of elementary functions. Specific temporal and logical operators are then used to connect these elementary functions and to build a functionnal tree wich will be used to estimate the performance of the mission. For each elementary function, a probability of success is computed with respect to time for the considered scenario, including the given level of the threat. The probability of success of the mission with respect to time is then recursively computed through the functional tree by using a tool developed by ONERA and named 'ATLAS'. Performances for scenarios with different levels of threat can then be compared for vulnerability analysis, as aforementionned.

The methodology is presented in this paper through its application to vulnerability analysis of an Earth observation mission with respect to catalogued space debris, with the corresponding functional analysis. It includes the decision process of collision avoidance manoeuvres, modeling the impact of catalogued space debris on the mission performance. The models used to compute the temporal probablity of success

of each elementary function are also presented. Vulnerability results are analyzed by considering different scenarios of evolution of the catalogued space debris population, based on ESA's MASTER model.