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A MOON AND DEEP-SPACE ACCESSIBILITY STUDY VIA SYSTEM-OF-SYSTEMS APPROACH

Abstract

The design of space missions and exploration architectures have become more complex and articulated than before, during the last decade. More ambitious mission-objectives and reduced funds availability forces the engineering teams to carefully assess all the alternatives to focus the energies only on the most promising architectures. In this paper a system-of-systems approach to space mission-architectures design, to support the engineering team and the decision-makers during the trade-off activities, is described. A system-of-systems is formed of several interacting elements and sub-elements whose overall behavior is usually different than the sum of the effects of the single elements. In particular the objective of the methodology is to support the design of complex space mission-architectures, starting from the mission objective and the major high-level requirements, by automatically generate and evaluate different scenarios. The methodology is composed of two major steps. The first step consists in the generation of the different architectures with the definition of the systems and the phases in which they will be used. The systems considered in the design session presented in this paper comprehend modules for human support in space, re-entry capsules, propulsion modules, and surface-access modules. The mathematical models of such systems are accurately described in this paper. In a subsequent step the mission architectures are quantitatively and qualitatively evaluated. In particular masses are estimated through the mathematical models of the systems that form the architectures, taking the major design variables and complexity indices into account. A comparative cost analysis is performed on the basis of known scenarios, considering mission architecture, masses, technical complexity and system design. Finally, a mission success qualitative figure is estimated through mission duration, complexity and systems TRL. As an example, a study on a hypothetical future space habitat to be implemented as a safe haven for cis-lunar missions and as a re-usable spaceship for deep-space missions is presented. The results have been obtained with the objective of minimizing the cost index of the system-of-systems and maximizing the mission success and mission value. The results presented in this paper have been obtained in cooperation with Thales Alenia Space-Italy, in the framework of a regional programme called STEPS (Systems and Technologies for the ExPloration of Space), which is a research project co-financed by Piedmont Region (Italy), firms and universities of the Piedmont Aerospace District.