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MODULAR SPACECRAFT ARCHITECTURE, A NEW PARADIGM IN SPACECRAFT DESIGN

Abstract

A monolithic spacecraft is one where functional capabilities, the subsystems which enable it to fulfill its mission, reside together inside a rigid structure. Monolithic architecture has been a fundamental concept of spacecraft design ever since man started building satellites. In the recent years the concept of fractionated architecture for spacecraft design has been proposed. In a fractionated spacecraft the functional capabilities of a monolithic spacecraft are distributed over separate modules which fly in close coordination with one another. Thus the system functions such as communication or data handling are performed by separate modules instead of being integrated into the monolith.This paper further extends this concept and presents the concept of modular architecture. In a modular architecture instead of tying a particular functionality to a specific module, as suggested by the fractionated architecture, we distribute that function across all modules. Each module hence has a fraction of the performance capability of the whole system. Thus the mission need of a monolithic spacecraft is satisfied by free flying network of modules working in close coordination with one another.

Modular and fractionated architectures have distinct advantages over a monolithic spacecraft. This is especially true in a value centric design paradigm where system value takes precedence over performance. These architectures provide a potential solution to the problems ailing the aerospace industry, namely cost/schedule over-runs, uncertainty, complexity, scalability and interoperability.

This paper introduces the reader to the concept of modular spacecraft architecture and identifies metrics which measure system value. It then compares and contrasts the performance of monolithic, fractionated and modular architectures against these metrics. A hypothetical mission is considered and spacecraft is designed using monolithic, fractionated and modular concepts. Key parameters of each design-cost, weight and performance are evaluated and compared to help us better appreciate the advantages and disadvantages of each design. A metric for measuring the system complexity, one of the primary factors behind cost and schedule over-runs of modern aerospace systems, is described. This is then used to assess the complexity of each design. We conclude by enumerating some advantages which modular architecture offers over monolithic and fractionated- faster development, scalability and interoperability, and how they can be leveraged to address the challenges facing the industry.