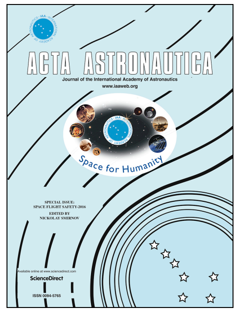
Accepted Manuscript



Value-centric design architecture based on analysis of space system characteristics

Q. Xu, P. Hollingsworth, K. Smith

PII: S0094-5765(17)31126-8

DOI: 10.1016/j.actaastro.2017.12.017

Reference: AA 6597

To appear in: *Acta Astronautica*

Received Date: 9 August 2017

Revised Date: 29 October 2017

Accepted Date: 11 December 2017

Value-Centric Design Architecture Based on Analysis of Space System Characteristics☆

Q. Xu[a,*], P. Hollingsworth[a], K. Smith[a]

[a]*School of Mechanical, Aerospace and Civil Engineering, The University of Manchester, George Begg Building, Sackville St, Manchester, M13 9PL*

Abstract

Emerging design concepts such as miniaturisation, modularity, and standardisation, have contributed to the rapid development of small and inexpensive platforms, particularly cubesats. This has been stimulating an upcoming revolution in space design and development, leading satellites into the era of "smaller, faster, and cheaper". However, the current requirement-centric design philosophy, focused on bespoke monolithic systems, along with the associated development and production process does not inherently fit with the innovative modular, standardised, and mass-produced technologies. This paper presents a new categorisation, characterisation, and value-centric design architecture to address this need for both traditional and novel system designs. Based on the categorisation of system configurations, a characterisation of space systems, comprised of duplication, fractionation, and derivation, is proposed to capture the overall system configuration characteristics and promote potential hybrid designs. Complying with the definitions of the system characterisation, mathematical mapping relations between the system characterisation and the system properties are described to establish the mathematical foundation of the proposed value-centric design methodology. To illustrate the methodology, subsystem reliability relationships are therefore analysed to explore potential system configurations in the design space. The results of the applications of system characteristic analysis clearly show that the effects of different configuration characteristics on the system properties can be effectively analysed and evaluated, enabling the optimization of system configurations.

Keywords: Conceptual design, Value-centric design, System characterisation, Configuration formulation

1. Introduction

Emerging technologies, such as widely-used microtechnology and nanotechnology derived from the electronics industry, offer significant opportunities for the miniaturisation of space systems[1]. The concept of modularity associated with commercialisation not only completely changes the labour-intensive and bespoke situation of the existing space industry by promoting their standardisation and reconfigurability[2], but also obviously drives the reduction of design, integration and testing time and associated costs[3]. Therefore, these innovative concepts and technologies have contributed to the rapid development of small and inexpensive space platforms, e.g., cubesats and nanosats, stimulating an upcoming revolution in space design and development.

New design concepts have also promoted a big breakthrough in space system capabilities, some even overturning the conventional understanding of space. Duplicated configurations are capable of broadening the range of space missions and simultaneously reducing the design requirements of individual units to some extent. Distributed systems, which refer to a cluster of satellites cooperating as a virtual satellite in the form of spatial separation, with each sharing the communication, processing and payload[4], have offered an excellent carrier for modularity, mass production and the use of the Commercial Off-The-Shelf (COTS) products. Such a configuration is believed to be flexible, robust and cost-effective throughout the lifecycle[5], filling the vacancies of flexibility and robustness in traditional systems and creating additional values to the systems.

However, current design, production and certification methodologies generally spend lots of time and money on the integration and testing of large, complex and customised systems[6, 7, 8], which do not inherently fit with the modular, standardised, and mass-produced characteristics of these innovative concepts. Since "smaller, faster, and cheaper"[9, 10, 11] has been one of the latest driving factors for spacecraft design, new analysis and design methodologies are urgently required to deliver such capabilities effectively. Therefore, a new insight for future space mission design and analysis will be proposed in this paper. To describe and analyse space systems diversely

☆This paper was presented at the International Astronautical Congress in 2016 in Guadalajara, Mexico.

*Corresponding author.
Email addresses: qin.xu-2@manchester.ac.uk (Q. Xu), peter.hollingsworth@manchester.ac.uk (P. Hollingsworth), kate.smith@manchester.ac.uk (K. Smith)