Paper ID: 26613
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SYMPOSIUM ON BUILDING BLOCKS FOR FUTURE SPACE EXPLORATION AND DEVELOPMENT (D3)
Systems and Infrastructures to Implement Future Building Blocks in Space Exploration and Development (2)

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DESIGN MARGIN UTILIZATION IN COMMERCIAL SATELLITE CLOUD COMPUTING SYSTEMS

Abstract

Design margins are an inevitable cost overhead to all space development programs; spacecraft systems need in fact to be designed to comply with performance requirements throughout the lifecycle of their mission, while withstanding performance degradation due to space environment interactions, and tolerating mission and design uncertainties. Typically, design margins remain unused for prolonged periods of time; consider for instance the case of the excess power produced by a solar array of a spacecraft at beginning of life, or spare transponder capacity in large telecommunications satellites.

This paper explores the use of design margins in the context of an innovative concept for space infrastructure development known as the Federated Satellite Systems approach. Unused resources are associated with design margins of spacecraft missions; such resources could be in principle traded in a cloud computing environment, establishing an space cloud of satellite resources that include, among others, space-to-ground link capacity, payload data storing and processing, and inter-satellite communications.

Previous work presented at the IAC 2013 in Beijing, China, has illustrated the potential of establishing ad-hoc satellite federations using the International Space Station as a single-node case study for resource sharing with neighboring satellite missions in Low Earth Orbit. This paper extends the analysis to a multi-node federation of suppliers and customers, composed of satellite missions with different purposes, sizes, and resource capacities.

Resources are considered as commodities that can be traded in the space cloud, in a similar way to what is done by terrestrial smart grids for power generation and distribution. The paper illustrates how the main benefit delivered by space cloud is the ability to optimize overall resource allocation among federated spacecraft, maximizing the overall utilization efficiency of satellite missions. The approach is of particular interest to large organizations such as space agencies, willing to optimize the overall investment associated with their space mission portfolio as a whole, and to small satellite missions seeking for innovative approaches to reduce mission development time and cost.

The paper discusses the main mechanisms of efficiency increase enabled by a space cloud, thus formulating different strategies that can be pursued to implement federated computing environments in space, at different levels of impact on the overall spacecraft design and increase in mission complexity. The paper concludes with a quantification of the necessary conditions required for missions of different purpose, size, and capacity, to positively benefit from a federated approach in their design.