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Author: Prof. Alessandro Golkar
Skolkovo Institute of Science and Technology, Russian Federation

Mr. Alexander Rudat
Massachusetts Institute of Technology (MIT), United States
Prof. Edward Crawley
Massachusetts Institute of Technology (MIT), United States

A DELPHI-BASED FRAMEWORK FOR SYSTEMS ARCHITECTING OF IN-ORBIT EXPLORATION INFRASTRUCTURE FOR HUMAN EXPLORATION BEYOND LOW EARTH ORBIT

Abstract

The current debate in the U.S. Human Spaceflight Program focuses on the development of the next generation of man-rated heavy lift launch vehicles. While launch vehicle systems are of critical importance for future exploration, a more comprehensive analysis of the entire exploration infrastructure is required to avoid costly pitfalls at early stages of the design process. This paper addresses this need by presenting a Delphi-Based Systems Architecting Framework for integrated architectural analysis of future in-orbit infrastructure for human space exploration beyond Low Earth Orbit. The paper is structured in three parts.

The first part consists of an expert elicitation study conducted between November 2011 and January 2012 involving fifteen senior experts and decision-makers concerned with human spaceflight in the United States and Europe. The elicitation study included the formation of three expert panels representing exploration, science, and policy stakeholders to be engaged in a 3-round Delphi study. Rationale behind the Delphi approach, as translated from social science research, is discussed. A novel version of the Delphi method is presented and applied in the context of technical decision-making and systems architecting.

The second part of the paper describes a tradespace exploration study of in-orbit infrastructure coupled with requirements definition analysis informed by expert elicitation (Part 1). Tradespace exploration is conducted by means of systems architecting tools that have been developed at M.I.T. in the Space Systems Architecture Research Group. Requirements and stakeholder goal uncertainties are explicitly considered in the analysis. The final result is an integrated view of perceived stakeholder needs within the human spaceflight community. Needs are translated into requirements and coupled to system architectures of interest for further analysis.

The third part of the paper develops recommendations for policy-robust system architectures and identifies effective trade-offs between exploration goals, policy, and science return needs. Results are presented in form of statistical analysis conducted on the model presented. Results include a correlation analysis between exploration, science, and policy goals. Design of Experiments (DoE) techniques are used to identify main effects and main interactions across architectural design variables and proposed proxy evaluation metrics. Pareto analysis is used to identify architectures of interest for further consideration by decision-makers. The paper closes with a summary of insights and develops a strategy for evolutionary development of the exploration infrastructure of the incoming decades.