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TECHNOLOGY DEVELOPMENT TARGETS FOR COMMERCIAL IN-SPACE MANUFACTURING

Abstract

In-Space Manufacturing (ISM) promises to revolutionize space systems by reducing mass, lowering costs, and enabling entirely new designs through the orbital fabrication of components in the space environment in which they are intended to operate for their entire life. In comparison, current space systems are constrained by the fact that components are built on Earth, launched aboard a rocket, and then operated in orbit for years at a time with little to no opportunity for resupply or repair. Because ISM changes many long-standing launch-related design constraints, a new approach for the design of space systems must be developed. This effort is complicated by the existence of various proposed commercial ISM architectures, each with their own technologies, products, and costs. Instead of attempting to estimate these highly uncertain quantities, this analysis focuses on identifying the key system drivers, maximum allowable lifecycle cost, and minimum required performance for an ISM architecture to be cost-effective relative to the existing launched approach.

This analysis is accomplished by first identifying the design constraints that are relaxed using ISM, such as constraints driven by launch loads, fairing volume, standard gravity, and launch schedule. These constraint categories are then used to form generalized classes of ISM application areas for further analysis, which includes structurally optimized systems, volume unconstrained systems, Earth-return systems, and on-demand manufactured systems. For each of these classes, a bottom-up cost model is developed that captures the impact of key system drivers on lifecycle cost. Then, Buckingham Pi theorem is used to identify nondimensional groups of input design variables, such as the ratio of launch cost to material cost, or the ratio of areal density of launched components to that of ISM components. The breakeven point between launched and ISM components is identified as a function of these nondimensional groups, which gives technology development targets for commercial viability. The nondimensional groups are then computed for historical attempts at ISM, as well as for current and future ISM concepts, to identify how technology developments have impacted the nondimensional parameters.

Using the presented approach, the ISM application areas that prove most promising are identified and their sensitivity to future developments, such as falling launch costs, is explored. In addition, it is shown that proposed ISM architectures can be evaluated for commercial viability by evaluating the relevant nondimensional parameters. This analysis, which spans the broad ISM application space, can be used to inform ISM technology roadmapping efforts.