Design Principles for the Development of Space Technology Maturation Laboratories Aboard the International Space Station

by

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ABSTRACT

This thesis formulates seven design principles for the development of laboratories which utilize the International Space Station (ISS) to demonstrate the maturation of space technologies. The principles are derived from the lessons learned from more than two decades of space technology research at the MIT Space Systems Laboratory and the existence of unique resources aboard the ISS. The thesis provides scientists with a design framework for new laboratories and an evaluation framework to responds to a call by the National Research Council to institutionalize science activities aboard the ISS.

Experience from previous missions and research on the resources available at the ISS led to the development of the SPHERES Laboratory for Distributed Satellite Systems (DSS), which constitutes the experimental part of the thesis. SPHERES allows tests in a representative, risk-tolerant environment aboard the ISS to demonstrate metrology, control, and autonomy algorithms for DSS. The implementation of ground-based and ISS-based facilities permits incremental technology maturation by enabling iterative research; algorithms can mature through multiple research cycles with increasing complexity. The SPHERES Guest Scientist Program supports research by multiple scientists: since the Spring of 2000 SPHERES has enabled research on formation flight, communications requirements, mass properties identification, autonomous rendezvous and docking, and tethered formation flight.

The design principles were formulated by first identifying the features of the SPHERES laboratory which allow it to fulfill the MIT SSL Laboratory Design Philosophy and utilize the ISS correctly, and then finding the applicability of these features to space technology maturation research. The seven principles are: *Principle of Iterative Research*, *Principle of Enabling a Field of Study, Principle of Optimized Utilization, Principle of Focused Modularity, Principle of Remote Operations and Usability, Principle of Incremental Technology Maturation*, and *Principle of Requirements Balance*. The design framework is used to assess SPHERES and suggest a new design iteration which better satisfies the design principles. The evaluation of SPHERES concludes that it is ready for operations aboard the ISS, since the modular design of SPHERES allows most of the proposed design changes to occur after the initial deployment.

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