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Paper Session II-B - International Space Station Phase I Risk Mitigation Experimental Process Enhanced the Phase 2/3 Development

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The International Space Station Phase 1 Risk Mitigation Experimental Process Enhanced the Phase 2/3 Development

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Abstract:

The International Space Station (ISS) Program initiated a Launch Package/Stage (LP/S) Phase 1 Program in late 1993. The Launch Package/Stage (LP/S) Phase 1 Program was developed to evaluate, in the space environment, certain hardware, software, operational procedures, and models directly relevant to the design and development of the ISS. The individual projects were selected based on several factors. One of the most important was the potential for reducing or eliminating identified potential risks associated with the assembly and EVA supported maintenance. Of addition importance was proving methods for monitoring crew health, confirming models used for the station design, and testing prototype hardware. Hence the term, Risk Mitigation Experiments or RMEs. Numerous candidates were studied, and a subset were approved for fast track development and manifesting on specific Shuttle flights, which were to be devoted primarily to performing the defined experiments, in many cases while docked to the Russian Mir space station. Midway through the program, the results of the RMEs are already proving to be of significant benefit. Important design enhancements and operational issues created by the zero-g environment and long-term operations that could be resolved early-on were identified to reduce costs and improve the operational efficiency of the ISS in Phase 2/3. Typical results include the deployment and verification of the docking module, the data and analysis confirming the contamination produced by the existing Mir space station environment is not as concentrated as predicted, confirmation of a capability for attitude data exchange between the Space Shuttle and Mir, and development and proof of a structural analysis tool using photography rather than more costly mounted sensors.

Overview of the LP/S Phase 1 Objectives:

The Mir program was started over a decade ago as part of the Russian space program and consists of the core module and three attached modules. The Mir core module provides for habitation and life support, the utilities including, thermal control, power, and data and provides docking ports. The Kvant 1 module functions include astronomy, life support, and Progress and Soyuz compatible docking ports. The Kvant 2 module added the capability for remote sensing and provides the EVA airlock for Mir. The Kristall module was added to provide materials production, remote sensing, and an Androgynous Peripheral Docking System (APDS) docking node used by the Shuttle since STS-71.

The ISS Phase 1 Shuttle-Mir Program defined a set of Risk Mitigation Experiments (RMEs) to operate during a four year period prior to ISS assembly. These RMEs test current designs, demonstrate certain on-orbit operations and characterize the Mir environment to provide advanced inputs for the benefit of Phase 2/3 reducing the risks of ISS development. The RMEs verify and certify ISS subsystems and demonstrate technologies and operational procedures to reduce logistic and/or operation costs. RMEs also validate the structural math models used in the verifica-

tion of the structural loads dynamics, characterize the 51.6 degree of inclination environments in terms of debris, radiation, contamination, and electromagnetic interferences, validate the ISS flight control by using GPS attitude and navigation, demonstrate active isolation systems in zero-g environments, and validate certain zero-g sensitive subsystems and components that will be used for development of oxygen generation, water, and radiation monitors.

Summary of the LP/S Phase 1 Process:

The Phase 1 process was designed to operate concurrently with the International Space Station Phase 2/3 development of an international station orbiting in low earth orbit. The Launch Package/Stage Phase 1 Integrated Product Team (IPT) was composed of representatives of the Phase 2/3 IPTs including the vehicle office, safety and mission assurance, analysis integration, operations, science and utilization, budget and contracts, the Space Shuttle, and subsystems providers. The IPT team developed a process to solicit experiments which would provide timely results to the development teams of the space station.

The proposed risk mitigation experiments (RMEs) were evaluated in terms of benefit to the program, maturity of design and hardware/software, and funding availability. Each proposed RME was required to list the ISS requirements, including analysis and testing for verification, that the RME would benefit. Any benefits or reduction of the ground testing and verification analysis was also evaluated. If possible, the principle investigators (PI) or ISS sponsoring subsystem IPT quantified the cost avoidances and/or savings. The PI had to show how the flight results would be integrated into the design and testing schedule of the ISS. The ISS subsystem IPT had to confirm that the results would be available in a timely manner. The PI had to identify the cost break-down and the proposed source of funding. In some cases this was a NASA organization, in others it was the PI's organization. Finally, the PI had to identify other agency's support required to achieve the goal of the experiment. For example, off gassing or vibration testing might be required at another NASA center.

The IPT board reviewed and prioritized the experiments, and submitted them to three main groups for a two week evaluation. The relevant subsystem IPT representative, Risk Mitigation IPT representative, and safety and mission assurance representative submitted their individual evaluations to a Phase 1 experiment lead who was responsible for coordinating the evaluation. An integrated report and recommendation was made to the full board which voted to sponsor or disapprove the experiment. In addition, the budget was reviewed and the funding source was evaluated for commitment to completion of the experiment.

The RMEs were ranked and selected based on the risk mitigation which they provided to Phase 2/3 and/or the cost savings to the program for test and verification. Through this process approximately thirty-six experiments were sponsored.

After approval, the Phase 1 IPT monitored the development of the experiment, processed the documents required for manifesting on the American or Russian launch vehicle, processed the documents required for operations in the Shuttle, Spacehab and/or Mir, coordinated the crew training implementation, supported the real-time operations from the Customer Support Room or through the American control room interfacing with the Mir control center in Russia, and distributed to relevant and necessary parties the post-flight sixty day and final one year reports.

Conclusions:

The Phase 1 program is proving that for a complex, assemble-as-you-go program such as ISS, a test or demonstration effort can provide timely, cost-effective analysis results and operations knowledge. The Phase 1 RMEs have supported a more effective development, integration and on-orbit assembly of flight elements. The have demonstrated analysis the savings by confirming or improving the models which Phase 2/3 has used for design. The crew safety during ISS assembly EVAs has a higher assurance level because the crews will be using proven hardware such as the heated gloves. As mankind moves forward, as an international community, in space science, exploration and development, the lessons learned on the ISS will become very valuable in designing our approach for future U.S. or joint programs.