The Space Congress® Proceedings | 1998 (35th) Horizons Unlimited

Apr 28th, 2:00 PM

Paper Session I-B - Engineering for the ISS Lifetime

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Engineering for the ISS Lifetime

Introduction

The International Space Station (ISS) begins its life with the first element being delivered to space on a Russian launch vehicle, followed shortly thereafter by U.S. and Russian launches of additional elements to be mated on-orbit. Subsequent flights by the U.S., Russia, and potentially Japan and ESA, will deliver hardware and software developed by the International Partners/Participants including U.S., Russia, Canada, Italy, Japan, Europe, and Brazil. The overall ISS functionality will change dramatically during the early flights. With each new installation, the structure and subsystems will mature into the planned assembly-complete functional configuration. This configuration will be sustained for the lifetime of the Space Station.

For the ISS Program, Sustaining Engineering is phased to begin after the delivery of each hardware or software item to NASA. This differs from the approach used by many programs which is to begin the sustaining phase after all development, testing, functional checkout, and initial usage periods have been completed satisfactorily. For the complex ISS Program, however, this more traditional approach is a luxury that cannot be afforded. Design and development of ISS hardware and software are accomplished in phases, to maintain a feasible launch and assembly schedule. Similarly, the hardware and software are delivered to NASA in phases. This means that some elements actually will be launched and activated on-orbit, while other elements are still literally “on the drawing board.”

Therefore, Sustaining Engineering on the ISS Program is defined as the design engineering support needed after the development of the hardware and software items are completed and these items are delivered to NASA. This design knowledge is required during launch site processing, on-orbit assembly and activation, and throughout the operational phase to ensure that the assembled Station fully supports the scientific endeavors for which it was designed.

Internationally Developed/Internationally Sustained

The International Space Station is being developed as an international program and will continue to be an international venture in the sustaining phase. The International Partners and Participants will provide sustaining engineering for the hardware and software that they develop, but once integrated on-orbit, many subsystems cross the interfaces between elements. Thus, ISS sustaining activities will be integrated, international endeavors. Anomalies will be coordinated between NASA and each International Partner/Participant affected by the occurrence. The International Partner/Participant will participate in assessment of the anomaly, and in the development of potential design or operational resolutions. Integrated analytical models of the ISS will be updated to reflect information provided from the International Partners/Participants, based upon the on-orbit performance of their systems and elements.

Sustaining Engineering Challenges

A primary role for sustaining engineering is to develop hardware or software modifications as required in response to unexpected events or to enhance system capabilities. Challenges facing the Sustaining Engineering team in performance of this role include: capture of the history of the hardware, the long-term analyses of performance trends for determination of degraded operations, configuration management of the flight hardware and software to maintain an accurate representation of the on-orbit systems, the identification and retention of critical skills, and capture of the unique knowledge base generated during the development phase of the program. Inherent in this role is the responsibility to ensure that the integrity of the interfaces is maintained.

To effectively sustain the ISS, historical information must be retained on the hardware, and strict configuration control must be maintained on modifications to the hardware and software. A Hardware History Retrieval System is being developed for the ISS Program, with features such as indexing to allow quick access to the available information for a specified part number, installation location, etc. This system will include documents, photos, computer records and audio/video recordings used during fabrication, test, checkout, operation, refurbishment, and maintenance of the flight hardware throughout the life of that hardware. Configuration Management will maintain databases that capture the requirements documentation, track the time and cycle for limited life items, and include approved waivers and deviations.

As in most development programs, some attrition of key personnel will occur prior to completion of the operational phase. For sustaining engineering, this means the critical skills must be identified, and if possible retained, beyond the initial design/development cycle. Engineers may be reassigned to other programs but remain available through the development contractor, while others may retire or accept positions with other companies. Methods are being developed and implemented to capture the unique knowledge generated during the design, development, fabrication, and testing activities.

Sustaining Engineering & Development Co-existing

Disciplines involved in Sustaining Engineering are reflective of those required during the development phase. The engineers who perform sustaining engineering tasks are typically not new hires or recent transfers from other programs. To successfully accomplish the tasks, the engineers must be intimately familiar with the design and expected performance of the components, and the potential collateral damage that could occur if degraded performance is allowed to propagate. Because some elements will be launched and activated while other elements are being developed, the design engineers represent critical resources that must be shared between the development organizations and the sustaining engineering functions.

Analytical models used by the development engineers in determining the thermal profiles, the structural loads, and the power distribution usage will be updated to reflect the actual measured and observed values from the on-orbit vehicle. In addition, computer software tools utilized during design analysis and verification, will be utilized to analyze the impacts of measured parameters that may differ from the prelaunch predicted values. Based upon their development experience, the engineers will update the predicted models, conduct analysis of the on-orbit subsystems, and apply the knowledge gained to the future components or elements still in development.

Sustaining Before Flight

For the U. S. elements, sustaining engineering responsibility begins with official delivery of the element to the NASA. This delivery may occur several months prior to flight, with numerous activities yet to be conducted before the element is launched. Engineers knowledgeable of the hardware and software design are required to support launch site processing of hardware and software, resolution of contingencies or anomalies, review of plans and procedures, and development of deviations/waivers. During critical operations, on-site engineering support is needed to ensure that questions, issues and anomalies are addressed in a timely manner that will prevent unnecessary delays in the processing flow, and possibly the launch. These engineers also are responsible for coordinating across the various functional areas of the ISS Program when an anomaly represents a characteristic flaw that must be corrected on common equipment items already integrated into the on orbit systems or scheduled on future flight elements.

Sustaining During Assembly

The team of engineers assigned to support particular ISS flights or assembly stages will be tailored based upon the types of hardware and software to be launched on the particular flight, and based upon the existing on-orbit subsystems and elements from previous flights. For example, the team that supports the First Element Launch, which consists solely of the Russian Functional Cargo Block (see Figure 1), will have a considerably different knowledge base than the team that supports the Assembly Complete configuration (see Figure 2).

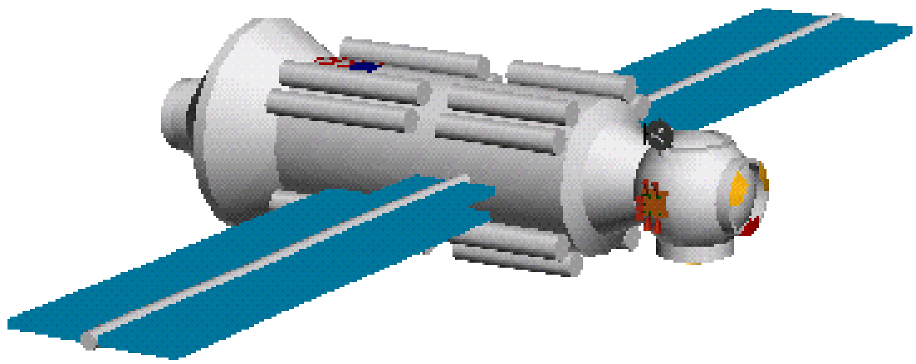

Figure 1. ISS First Element Launch Configuration

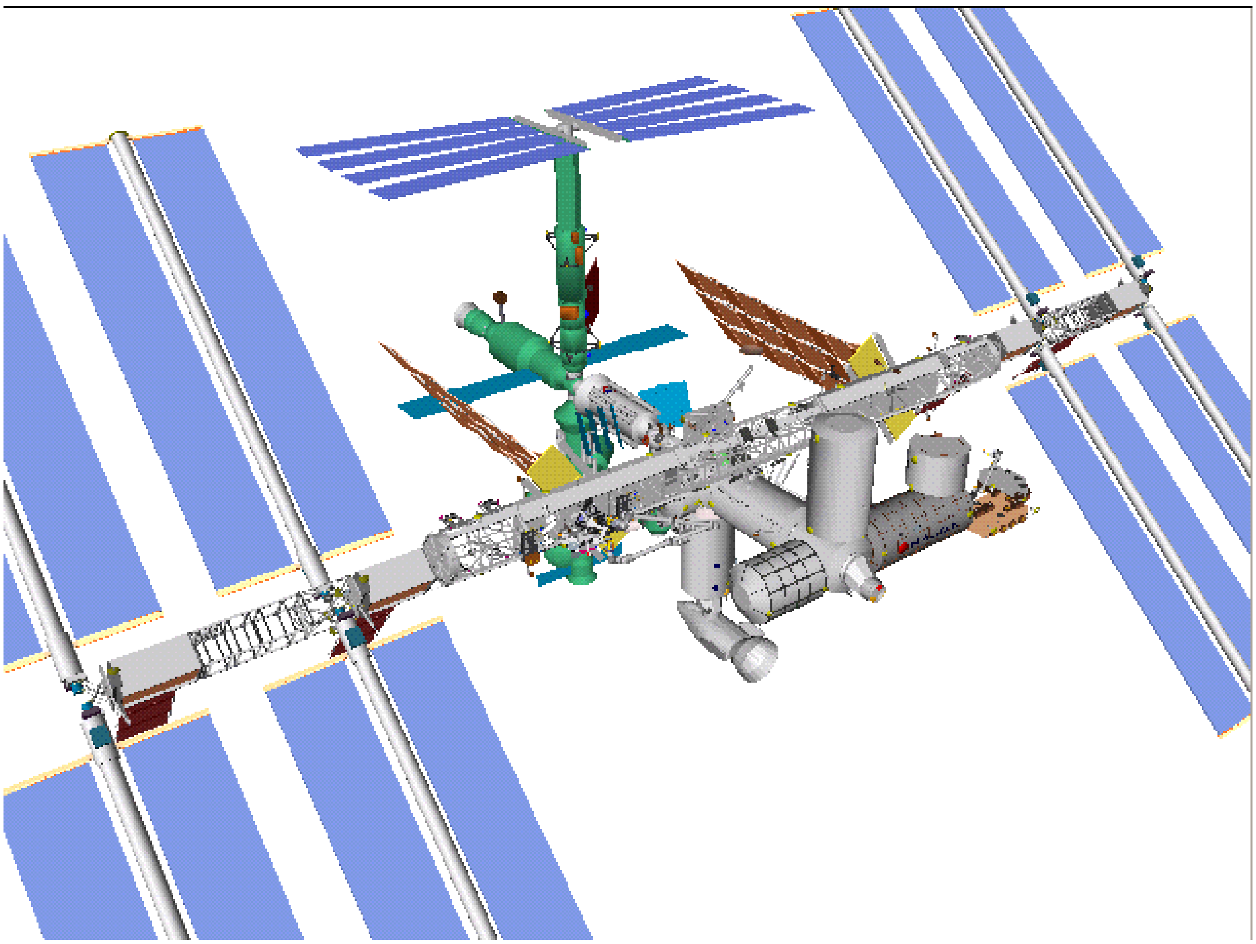

Figure 2. ISS Assembly Complete Configuration

Engineering support during the launch, assembly, and on orbit checkout phases will be provided from several locations, with the primary location in Houston, Texas at the Johnson Space Center's Mission Control Center (MCC). Additional engineering support will be located at development sites within the U.S., and at control centers and development facilities at international locations.

The MCC Flight Control Team conducts the real-time interaction with the crew to accomplish the planned timeline, and to provide the initial response to pre-mission predictable off-nominal modes. In the event of an anomaly, the Flight Control Team will continue their interaction with the on-orbit vehicle, while the sustaining engineering team analyses the anomaly and develops a coordinated resolution plan. Consider that during the Space Shuttle and Russian launch missions (which deliver additional ISS elements, ISS flight crew, and resupply items), the anomaly also may impact or be the result of activities involving the launch vehicle. Impacts from anomalies, whether resolved or unresolved, must be assessed for possible incompatibilities with the elements or subsystem components scheduled on the upcoming flight, and may necessitate a delay in the launch schedule.

Engineers will be on console for selected activities and will be on call during quiescent times. On-console support includes monitoring the data as the elements are mated on-orbit and the subsystems are activated. The initial activation and checkout periods, and major subsystem reconfigurations, are crucial periods during which the engineers must observe the responses of the components and must be prepared to provide a timely response if questions or issues arise. In the event of an anomaly, real-time observation of the event greatly increases the engineer's ability to provide timely resolution.

Console positions to be covered, based upon the specific elements and subsystems activities scheduled in the timeline, include: Electrical Power System (EPS), Thermal Control System (TCS), Environmental Control & Life Support (ECLSS), Guidance, Navigation & Control (GN&C), Communications & Tracking (C&T), Command & Data Handling (C&DH), Avionics Integration, Extra-Vehicular Activities (EVA), Robotics, Structures & Mechanisms, Safety, and the Sustaining Engineering Lead. International Partners will have a console available during the initial launch, mating and checkout on-orbit for their specific elements, and during other times as negotiated.

Sustaining engineering will be responsible for analyzing anomalies and developing recommended resolution plans. Decisions concerning hardware/software modifications will be handled at the appropriate level of Program management dependent upon the technical areas of impact, urgency of the modification, and the programmatic cost and schedule impacts. If an International Partner's elements are involved, then the level of coordination and decision-making will be elevated to the appropriate multilateral decision forum.

When hardware design changes are required on U.S.-provided equipment, the ISS Program will direct the implementation of the development. Prior to incorporation into the on-orbit vehicle, the modified hardware will undergo testing and/or analyses to verify compatibility with the existing systems. Similarly, any updates made to the flight software will be verified prior to uplink to the International Space Station.

Keeping ISS Going Strong

For the long-duration ISS operations, engineers will be on call during quiescent periods rather than maintain full staffing of the consoles during these periods. For the purposes of planning, quiescent periods are those times between flights when no additional subsystems are scheduled for start-up, and no major subsystem reconfigurations are scheduled. When the need arises, individual engineers or the entire sustaining engineering team can be called in to work an issue or anomaly.

Status reporting will be streamlined to the maximum extent possible, since the planned lifetime spans several years of combined development and assembly, followed by the operational phase in the assembly complete configuration. An initial step in streamlining the status reporting is accomplished via remote computer access to the telemetry data downlinked from the ISS. For example, at the beginning of the work day, the Electrical Power System engineer would log into the archived data system to check recent status as well as check the data downlinked during the previous night. After performing trend analyses or performance assessments, the engineer would notify the sustaining engineering lead, possibly via E-mail, and if the subsystem was performing nominally, would resume normal work activities.

During the operational phase, enhancements and obsolescence of parts may necessitate additional sustaining engineering efforts. New technology may enable the ISS to provide even greater capabilities, with less crew time required to maintain the systems. The result would be increased opportunities for scientific achievements. To take advantage of new technologies, engineers knowledgeable of the existing on-orbit configuration will be utilized to assess feasible methods for incorporation into the Space Station.

Closing Comments

Sustaining Engineering has a critical role in the ISS Program, beginning with the first element delivery to NASA. Prior to that time, the planning and interface agreements must be established. Communications links, databases and control board structures must be in place, and personnel must be trained to perform console operations to facilitate our ability to respond to the real time issues in an efficient and effective manner. The principal objective for sustaining engineering is to enable optimum performance of the International Space Station during its assembly and beyond. Knowledge garnered from space-based experiments has been demonstrated to have the capacity to improve the quality of life on Earth, and with the support of the dedicated Sustaining Engineering team, the capabilities of the ISS should continue to support and even expand the realm of microgravity experimentation.