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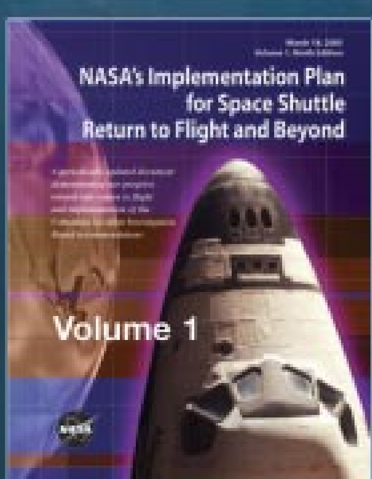
NASA's Implementation Plan for International Space Station Continuing Flight



A document demonstrating our commitment to application of the Columbia *Accident Investigation Board recommendations and observations in support of safe continuing flight of the International Space Station*

NASA's Implementation Plan for International Space Station Continuing Flight

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February 15, 2005
Revision 2

An electronic version of this implementation plan is available at http://www.nasa.gov/news/highlights/returntoflight.html

Revision 2 Summary
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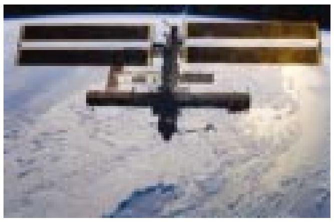


Revision 2 to *NASA's Implementation Plan for International Space Station Continuing Flight* ("ISS Continuing Flight Plan") completes our response to the applicable recommendations and observations of the *Columbia* Accident Investigation Board (CAIB), as well as additional ISS Continuous Improvement actions directed by the ISS Program. Given the progress achieved to date and the plans for ongoing commitment, approximately one year from now the ISS Program will reassess its performance to confirm that identified improvements have been sustained. This Revision 2 replaces in its entirety the document released on January 30, 2004. Change bars indicate those areas modified since the initial release.

As noted previously, NASA's progress in many critical Shuttle Return To Flight (RTF) areas continues to be reflected in updates to the Shuttle Program's Volume 1 of NASA's response to the CAIB Report. It includes descriptions of the ISS Program participation in assuring adequate on-orbit inspection and repair and contingency crew support capabilities. The following highlights are indicative of the ISS Program's ongoing commitment to safe and productive flight operations:

Contingency Shuttle Crew Support (CSCS). The Space Shuttle and ISS Programs have made progress in defining and planning for a CSCS capability. The two programs continue to conduct analyses to show that for the first two Shuttle flights, at a minimum, it is possible to launch a rescue mission during the time that the Shuttle crew can be safely sustained on the ISS. The ISS Program has improved its definitions of ISS resources, risks, and support durations associated with CSCS. The ISS Program also has new power and oxygen storage/generation capabilities in work or under consideration that can improve CSCS and nominal ISS capabilities. As an ongoing effort, NASA continues to refine planning for the unlikely event that CSCS capability must be used.

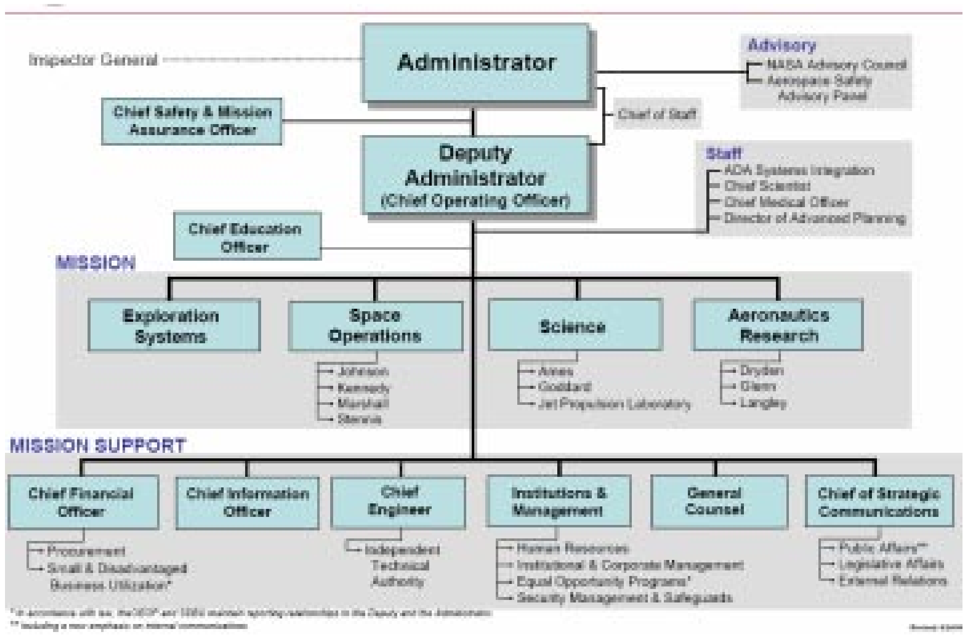
ISS Support For Orbiter Inspection and Repair. Beyond the analysis and modeling that ISS is conducting in support of Orbiter inspection and repair for the initial Shuttle missions, the ISS Program is aiding in the definition of solutions for future missions. To avoid the mass and volume penalties of repeatedly flying a large inspection/repair boom, options are being considered for permanently stowing a mechanical extension on ISS to augment the existing robotic manipulators.

ISS Continuing Flight Safety and Success. The ISS Program has completed several two person extravehicular activities (EVAs) with the vehicle continuing to operate under ground control. These external sorties demonstrate the resilience of the ISS system. Preparing for and executing EVA with only two persons on board provided invaluable insight into our ability to support a time-critical contingency EVA. Prior to performing these operations, the general thinking was that a contingency EVA would be relatively straightforward. The planning and execution brought to light the real complexities associated with operating in this mode. The ISS system is very complex and extreme attention to detail is required. This external work has again proven the ability of the Russian and U.S. teams to work together on a truly joint activity. Lessons from these EVAs and basic day-to-day operations can be directly applied to the Exploration Initiative.

Vision For Space Exploration. As promised in the summary of Revision 1 of this document, Revision 2 reflects the status of the ISS Program's response to the Vision for Space Exploration announced by the President of the United States on January 14, 2004. With this new approach to sustained, achievable, and affordable human and robotic space exploration, ISS plays an even more crucial role in paving the way for human space exploration beyond low Earth orbit. As directed, NASA will complete assembly of the ISS and retire the Space Shuttle by the end of this decade. NASA will focus U.S. use of the ISS on understanding how the space environment affects astronaut health and in developing countermeasures. ISS will also be used as a test bed for future human spacecraft systems, such as life support. Some current ISS hardware and many operational lessons will be directly applicable to this Exploration Initiative. To keep ISS operational for these exploration development activities after Shuttle retirement, the ISS Program expects to rely on a new strategy of spares replacement. Prior to Shuttle retirement, the ISS Program may position essential large spares on orbit and may increase its inventory of ground-based spares. After Shuttle retirement and absent any new return capability, the ISS Program may rely on a philosophy of disposable sparing rather than the current ground depot approach. Aiding these logistics plans is the current lower than expected failure rates for external replaceable hardware. In anticipation of an increased reliance upon international and domestic commercial launch services after Shuttle retirement, NASA budget plans already allocate resources for procurement of these launch services. A request for information was issued in late 2004 which is planned to lead to a request for proposals.

New ISS Completion Configuration. Consistent with the lessons learned from the CAIB Report and the Vision for Space Exploration, on July 23, 2003, NASA and the International Partners unanimously endorsed a new plan for ISS completion by the end of the decade. This plan accommodates on-orbit elements from each of the Partners and enables increased utilization with opportunities for a crew of greater than three people. This endorsement provides a clear basis for completion of programmatic and financial evaluations with subsequent agreements to be reached on a transportation and logistics framework that supports the assembly and operation of ISS. Russian Soyuz vehicles, the Space Shuttle, and automated logistics resupply/reboost capabilities will support this framework using existing Russian Progress vehicles and new transfer vehicles provided by Europe and Japan. This plan achieves the goal of separating crew and cargo to the ISS. Additional assessments will be conducted in 2005 to confirm this flight program, to evaluate opportunities to accelerate the launch of the Japanese and European research modules, and to establish a specific schedule to enhance the permanent crew size. NASA and the Russian Federal Space Agency (Roscosmos) reconfirmed their commitment to individually and cooperatively support continuous human presence on the ISS in 2005 by completing agreements on mutual responsibilities. The results of ongoing assessments were reviewed at a Heads of Agency meeting in late January 2005 leading to the partnership's endorsement of the ISS configuration.

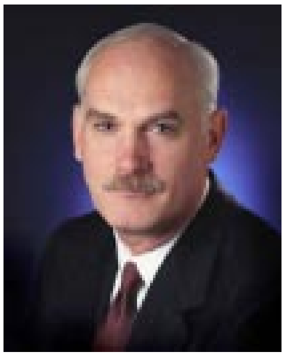
Transformation. In June 2004, NASA initiated a transformation of its organizational structure designed to better implement the Vision for Space Exploration. In response to the President's Commission on Implementation of U.S. Space Exploration Policy, the transformation restructured NASA's strategic Enterprises into Mission Directorates, realigning those offices to clarify organization roles and responsibilities. The transformation also clarified relationships with NASA Field Centers by developing clear and straightforward lines of responsibility and accountability. The ISS Program is now in the Space Operations Mission Directorate. This new organizational structure includes the Office of Space Operations at NASA Headquarters and the four Field Centers that provide fundamental support: The Johnson Space Center, Kennedy Space Center, Marshall Space Center, and Stennis Space Center



Organization and Culture. A variety of improvements in Agency and ISS Program organization and culture were completed while others remain in development. As part of the establishment of the Independent Technical Authority, the ISS Program reorganized its own Safety and Mission Assurance office and now includes the new institutionally led Technical Authority organization in its flight readiness review activities. The ISS Program is also using the expertise of the NASA Engineering and Safety Center for advice on numerous technical issues including cabin leak detection analysis, nondestructive weld verification, and micrometeoroid/ debris impact model code validation. NASA continues a number of positive steps to identify cultural obstacles to effective risk management, including seeking suggestions from external experts and from internal employees. Behavioral Science Technology, Inc. (BST) was brought in to assist NASA in making enhancements and improvements in the culture Agency wide. Behaviors were identified from the CAIB recommendations, the Diaz Report, the NASA Values and Guiding Principles (Safety, NASA Family, Excellence, and Integrity), and the One NASA Initiative. BST conducted a survey of NASA civil servants across the Agency in February 2004. The survey indicated many positive attributes already exist within NASA, but indicated three areas for improvement consistent with lower scoring categories Agency wide. These improvement areas were categorized and then tailored to each center. As one example of internal improvements, the Space Operations Mission Directorate has instituted a "Can We Talk" forum where employees can openly and directly engage upper management with issues of concern. The Agency is enacting a plan to develop and deploy an organizational culture change initiative within NASA, with an emphasis on safety culture and climate.

Other Considerations – Beyond the CAIB recommendations and observations, ISS received and evaluated inputs from a variety of sources, including the additional volumes of the CAIB Report, our own employees, our virtual suggestion box at rtfsuggestions@nasa.gov, and a Government Mandatory Inspection Point independent assessment report released in late January 2004. Many of these inputs are addressed in appropriate areas of this publication. The status of the ISS-related RTF suggestions are shown on page xi of this report**.** The remaining items that are unique to the ISS Program were transitioned to the ISS continuous improvement process for consideration. Those items that are more broadly applicable to the whole Agency are addressed by the implementation plans available at http://www.onenasa.nasa.gov/NEWS/Archives_of_News.htm.

A Message From the Associate Administrator for Space Operations



We are now entering our fifth year of continuous crew operations onboard the International Space Station (ISS) and look forward to completing assembly of the Station once we have resumed Space Shuttle flights. NASA will refocus the research onboard the ISS toward better enabling space exploration goals. Together with our International Partners, we will pave the way for our continued journey of human space exploration.

Ever mindful of those who have sacrificed their lives in this cause, we are committed to a process of continual improvement. *NASA's Implementation Plan for International Space Station Continuing Flight* represents the NASA Family's ongoing work to safely and productively employ the unique environment of the ISS and the skills of its crews to pave the way for future exploration beyond low Earth orbit to the Moon, Mars and beyond.

This plan summarizes our progress in effectively responding to the report of the *Columbia* Accident Investigation Board and our efforts to raise the bar even higher.

William F. Readdy

Continuing Flight Implementation Plan

A Message from the

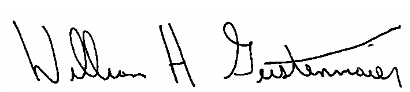
Deputy Associate Administrator International Space Station (ISS) and Space Shuttle Program, and the ISS Program Manager

During the spring and summer of 2003, the *Columbia* Accident Investigation Board exhaustively researched the root causes of the loss of the Space Shuttle *Columbia*. The ISS Program embraced the report as its own, finding parallels between Space Shuttle operations and ISS operations. This Implementation Plan for ISS Continuing Flight represents the work done by the ISS Program to move forward with improving the ISS to ensure safe and productive operations for the life of the Station.

Since the last release of the Implementation Plan for ISS Continuing Flight in January 2004, the ISS Program has worked diligently to continue productive operations of the Station. During these ongoing operations, the ISS Program worked with the Agency to embrace the *Columbia* Accident Investigation Board recommendations, address those recommendations in ways that are applicable to the ISS, and exceed those recommendations with its own continuous improvement actions.

This update to the Implementation Plan for ISS Continuing Flight is the second revision and reflects the outcomes of numerous reviews within the ISS Program and the Agency. The ISS Program team is responsible for the plans and results documented in this report. The identified organizations will ensure proper tracking, implementation and continued improvements.

The Vision for Space Exploration announced by the President in January 2004 helped to refocus NASA's mission. For the ISS Program, it reinforced our goal of completing ISS assembly and ensured the ISS role as a test bed for extended duration human spaceflight—in technologies, innovative partnerships and international cooperation. During the two years since the loss of *Columbia*, the ISS Program has strived to internalize the lessons learned by the Shuttle Program, embedding in all of our processes an emphasis on safety and a strong sense of continuous learning and improvement. These improvements will ensure that we can fulfill our challenging role in enabling future exploration programs.



William H. Gerstenmaier
Manager, ISS Program

Michael C. Kostelnik
Deputy Associate Administrator
ISS and Space Shuttle Programs

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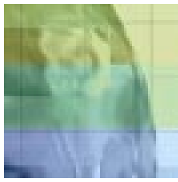

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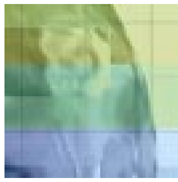

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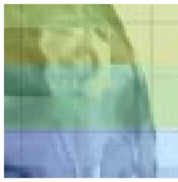

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PREFACE

The loss of the Space Shuttle *Columbia* and its crew was devastating for the entire NASA family. For the International Space Station (ISS) Program, finding our way through this tragic loss begins with an unwavering commitment to learn from this tragedy. We will reshape the ISS Program based on those lessons, and carry out the Administrator's directive to continue our mission of building, operating, and performing research on the ISS effectively and safely.

We are committed to those actions that will help return the Shuttle to flight and, in turn, will support our exploration and science objectives. The crew of *Columbia* was dedicated to this vision of science and exploration and devoted their lives to further it. It is our job to continue their vision.

This document details the ISS plans for accepting the findings, complying with the recommendations applicable to ISS, and embracing the *Columbia* Accident Investigation Board (CAIB) Report. The CAIB Report identifies systemic issues that directly or indirectly affect the way we plan, develop, and operate. In this document, we address those CAIB issues and describe how the ISS Program is moving forward on a comprehensive set of process and vehicle improvements.

This ISS Continuing Flight Implementation Plan captures a snapshot of our review of lessons learned from the *Columbia* accident and how we will continue to implement these lessons into the ISS Program. This document provides an overview of the ISS Program's response to the CAIB recommendations and observations and to process improvement actions. Part 1 provides a detailed discussion of activities undertaken by NASA to implement the applicable CAIB recommendations. Part 2.1 discusses additional NASA actions taken as a result of internal reviews and working group recommendations in addition to those made by the CAIB. Part 2.2 contains our responses to applicable CAIB Report observations. Part 2.3 addresses the concerns raised in Appendix D.a of the CAIB Report.

The *Columbia* tragedy serves as strong reminder that space flight is harshly unforgiving of poor communication, engineering deficiencies, overconfidence, system or human error, and inaccurate risk assessments. The ISS Program's part in the return to flight efforts requires us to continue to identify, understand, control, mitigate, and contain risk while accomplishing the mission entrusted to us. We do so with the memories of our dear friends and colleagues—the crew of STS-107—serving as both inspiration and an imperative to succeed safely.

Continuing Flight Summary

Overview

The *Columbia* Accident Investigation Board (CAIB) addressed both the direct and the contributing causes of the *Columbia* accident and documented its findings in the CAIB Report, Volume I, issued in August 2003, and in Volumes II–VI released in October 2003. The CAIB Report addressed issues critical not only for the Space Shuttle Program, but for NASA as a whole. NASA accepts its findings, will comply with the recommendations, and embraces the Report. The Space Shuttle Return to Flight Planning Team is focused on the actions necessary to return the Shuttle safely to flight. ISS Program personnel are participating fully in these important initiatives, and their joint efforts are addressed in Volume 1 of NASA's response to the CAIB Report: *NASA's Implementation Plan for Space Shuttle Return to Flight and Beyond*. In addition, NASA continues in-depth assessment of its organization with the objective of aggressively implementing corrective actions. NASA chartered the ISS Continuing Flight Team (CFT) to review the CAIB Report, determine the areas that are applicable to the ISS Program, and ensure there are actions in place addressing those areas. The purpose of this document—Volume 2 of NASA's response to the CAIB Report: *NASA's Implementation Plan for International Space Station Continuing Flight*—is to document these findings and our progress towards completion of necessary actions.

Reaping lessons learned from the *Columbia* accident and the CAIB's findings started immediately after the accident. While the CAIB conducted its investigation, the ISS Program began an intensive effort to examine its own processes and operations to reduce risk under a continuous improvement initiative. One objective was to identify the existence of any risk not reduced to the lowest level and to focus management attention on the residual risks that cannot be eliminated. As the CAIB released its findings, the ISS Program assessed them for applicability. Other continuous improvement activities were derived from the experience the ISS Program gained from four years of crewed ISS operations and six years of ISS system operation.

Continuing Flight Team Assessment and Implementation Plan Organization

The CFT assessed every CAIB recommendation and observation for applicability to the ISS. Most of the CAIB recommendations and observations, as originally written, were specific to Space Shuttle design or processes. Others affected NASA safety and engineering processes as a whole. However, the CAIB Report does provide valuable lessons learned for the ISS Program. The ISS Program developed an "ISS Corollary" to clarify the ISS applicability of each CAIB recommendation and observation. Part 1 of this volume addresses the CAIB recommendations as they apply to the ISS. Part 2.1 of this volume addresses many of the ISS Program self-generated areas of continuous improvement. Part 2.2 of this volume addresses the CAIB observations as they apply to the ISS. Part 2.3 addresses the additional recommendations and observations found in Appendix D.a.

Where the underlying intent of any CAIB issue is addressed by another recommendation documented in Part 1 or a continuous improvement area or CAIB observation documented in Part 2, the location of the text that addresses the subject is referenced.

Reaping the Benefits of the IMCE Assessment

The CAIB Report makes several references to the ISS Management and Cost Evaluation (IMCE) Task Force that conducted an in-depth review of the ISS Program cost, schedule, technical, and management infrastructure. This Task Force was a direct result of the President's fiscal year 2002 (FY2002) Budget Blueprint, which laid groundwork for attaining cost control and regaining ISS Program credibility needed to reach the ISS's full potential and to meet its international commitments. The Task Force conducted independent assessments of the ISS Program in August and September 2001 and provided 12 recommendations to NASA in an IMCE report released on November 1, 2001. These recommendations provided a roadmap to improve the ISS Program management and cost controls.

In response to the IMCE findings and recommendations, the ISS Program implemented a reliable and effective cost-estimating and management system that provides a structured and disciplined program to manage cost and risks.

ISS Operations Are Ongoing

The grounding of the Space Shuttle fleet following the loss of *Columbia* had a profound effect on the ISS Program. The loss of capabilities provided by the Space Shuttle resulted in a delay in the assembly of ISS and greatly reduced the cargo upmass available for resupply and research. The loss of downmass has impacted our ability to return failed hardware, results of scientific investigations, and environmental samples. In response to these challenges, a plan to allow continued crewed operations of the ISS was developed and agreed to by all ISS Partners. This plan requires the Russian Progress spacecraft be used to supply cargo and that crews be rotated with the Russian Soyuz vehicle. This plan is being implemented with the cooperation and efforts of all Partners.

Since the Space Shuttle was grounded, four ISS crews were launched on Russian Soyuz vehicles and sustained by Progress cargo craft. The current two-person crew, Expedition 10, comprised of Commander Leroy Chiao and Flight Engineer Salizhan Sharipov, is on board the ISS, conducting science and maintaining ISS systems.

Before Expedition 10 launched to the ISS the Program recognized the crew's food supply would need to be very closely monitored until the arrival of a Progress resupply ship. Since maintaining onboard crew consumables and managing limited resources are challenging tasks, the amount of food onboard is one of the consumables tracked weekly and reviewed in depth at each Flight Readiness Review. A December 2004 audit of onboard food revealed that actual quantities were less than expected. Although crew safety was never an issue, the ISS Program created an independent panel to determine how the food supply on ISS was inventoried and to recommend improvements. NASA medical and nutrition experts work continually with crews to ensure their diet is sufficient to maintain their health. Ongoing communication between the crew and ground team, an immediate response using established process, and a flexible operational system allowed the quick resolution of this supply concern. The Progress delivered approximately 5,000 pounds of critical cargo, including 61 containers of rations, to the ISS on December 25, 2004.

The ISS Program team remains focused on conducting its mission while safely supporting our crew.

ISS Partnership Is Strong

The ISS International Partnership has stepped up to the challenge of keeping the ISS crewed and operating safely as NASA works through the activities to return the Space Shuttle to flight. Although the grounding of the Space Shuttle has provided a challenge to ISS operations, the spirit of partnership that built the ISS will sustain it through this difficult period.

One of the keys to the success of the ISS Program, due to its integrated international nature, is establishing and maintaining clear communications and coordination among the International Partners, and at all levels of the Program structure. As experience is gained in operating the ISS, improvements are realized in communications and increased effectiveness.

NASA will continue to work closely with its International Partners and keep the lines of communication open as the ISS Program implements process improvements and enhancements as a result of lessons learned from *Columbia*. These changes will be implemented within the framework of our international agreements.

Conclusion

NASA's Implementation Plan for International Space Station Continuing Flight summarizes the results of our review of the lessons learned from the loss of *Columbia* and the ISS continuous improvement initiative. It identifies current responsive implementations, outlines technical and management options under consideration to improve the ISS Program and reduce risk, and identifies forward work where solutions are in development.

As ISS continues to fly, the safety of the crew and the vehicle are paramount. Learning from the loss of *Columbia* and its crew, we must remember that while the Shuttle fleet is grounded, we still have U.S., Russian, and other International Partner astronauts flying in space. Providing a safe environment for them to conduct research and maintain the ISS is our ongoing focus.

ISS SUGGESTIONS

As part of NASA's response to the *Columbia* Accident Investigation Board recommendations, the Administrator asked that a process be put in place for NASA employees and the public to provide their ideas to help NASA safely return to flight. With the first public release of *NASA's Implementation Plan for Space Shuttle Return to Flight and Beyon*d on September 8, 2003, NASA created an electronic mailbox to receive Return To Flight (RTF) suggestions. The email address is "RTFsuggestions@nasa.gov." A link to the email address for RTF suggestions is posted under the Return To Flight link on the NASA webpage at http://www.nasa.gov/news/highlights/returntoflight.html.

The first e-mail suggestion was received on September 8, 2003. Through late 2004, NASA received a total of 2683 messages, averaging 56 messages per week. NASA has responded to each message individually, including answering any questions contained in the suggestion, and providing information about where the message will be forwarded for further review and consideration. As NASA approaches Shuttle RTF, it is transitioning from development to implementation. During this transition, NASA will continue to maintain the RTF suggestions email box and will periodically review the suggestions received.

The ISS Continuing Flight Team (CFT) has concurrently reviewed the RTF e-mail suggestions to evaluate any applicability towards the ISS Program. The CFT identified 71 suggestions that are specifically or generically relevant to the ISS Program.

The following categories summarize the suggestions received in the RTF e-mail suggestion box that are applicable to the ISS:

Aerospace Technologies – Use of other space vehicle technologies to supplement ISS capabilities

Culture – Improvements that could affect decision-making processes and manager/employee relationships.

ISS – Programmatic changes that could improve operations.

ISS Safety – Improvements in specific areas of ISS Safety and Mission Assurance

NESC – Technology areas that assistance from the NASA Engineering and Safety Center could be sought for independent technical analysis.

SSP Safety - Safety practice improvements common to Space Shuttle and ISS Programs.

Leadership and Management – Improvements in Agency and Program training and leadership skills development.

Imagery and Inspection – Technical improvements in NASA's ability to perform internal and external vehicle imagery surveys.

Table 1 on the following page provides some examples of suggestions received to date. Many of the suggestions are addressed later in the text of this CFT Plan as areas that are being implemented or studied.

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Sorting Category	No. of Suggestions	Example Suggestions
ISS	2	(1) Rather than rely on Shuttle, use domestic or foreign expendable launch vehicles to deliver ISS elements and cargo to orbit. (2) Establish an Employee Bill of Rights. "Must be empowered to take responsible actions that will contribute to safety, quality and productivity. Employee rights are guaranteed without threat or fear of reprisal (right to challenge business as usual, right to be heard, right to expect commitment to safety and quality, right to place quality before production and schedules, right to feel genuine pride in products and services).
ISS Safety	20	(1) Use Operational Risk management models used by USAF or DOE Nuclear Program. (2) Consolidate and standardize trending for nonconformance systems between centers and programs. Have only one PRACA database for all manned programs. (3) Create DCMA-like core training for all QAS and S&MA personnel at all centers. (4) Consolidate SSP-41173 and NSTS 5300.4 and create one human space flight S&MA requirement document. (5) Establish suggestion program at centers and major contractors (like DOD).
NESC	3	(1) Ensure the center engineering orgs remain independent by not relying upon programs for all resources. (2) Use brainstorming techniques to creatively identify ways that systems may fail by coincidences and trains of events. Include designers, operators and qualified outsiders.
SSP Safety	12	(1) Use an external, independent company for safety and failure analysis. (2) Conduct a complete review of KSC QPRD defined inspections of flight hardware. (3) Apply ARC developed quantitative model based analysis and on-board systems approach to risk management to represent complex systems. (4) For reoccurring problems, NASA QA should be involved in root cause analysis, corrective action definition and implementation.
Leadership and Mgmt	5	(1) Human fatigue and max work time violation statistics should be presented at each FRR and should be tracked/reported as a requirement of major contracts. Managers and employees should receive awareness training. (2) All technical, project and support personnel should attend leadership and lessons learned training when newly hired and throughout career as requirement for upward mobility.
Imagery and Inspection	5	(1) Use a tethered or free flying robotic inspection satellite (e.g., AERCam) to examine and possibly repair suspected external problems. (2) Implement impact detection sensors that indicate location and force.
Culture	23	(1) Implement awards program for significant cost savings. (2) Create strong center to center transfer program. (3) Hire an external consultant firm or university experts to assess NASA culture, org structure, decision procedures. (4) Use 360 degree feedback from subordinates, peers and customers as criteria for senior management evaluation, reward and promotion. (5) Conduct monthly forum where employees can present ideas, issues and concerns (Can We Talk) using techniques based on "Appreciative Inquiry", "Deep Change" and "Fierce Change".
Aero Tech	1	Contract with Russia for Soyuz access to ISS.

Part 1

The International Space Station's Response to the *Columbia* Accident Investigation Board's Recommendations

The following section details NASA's response to each applicable CAIB recommendation in the order that it appears in the CAIB Report.

Columbia Accident Investigation Board

Recommendation 3.2-1

Initiate an aggressive program to eliminate all external tank thermal protection system debris shedding at the source with particular emphasis on the region where the bipod struts attach to the External Tank. [RTF]

International Space Station (ISS) Corollary: The ISS Program should verify that its debris and contaminant generation and protection processes are adequate to prevent damage to both the ISS and visiting vehicles.

Note: The ISS response to Recommendation R3.2-1 was approved by the ISS Program Integration Control Board (PICB) on September 8, 2004. All actions related to assuring completion of this effort and ensuring continuous improvement are the responsibility of the PICB.

BACKGROUND

Although this recommendation addresses threats from loose hardware generated during the launch of the Space Shuttle, the ISS Program recognizes that the safety of the ISS vehicle and other visiting vehicles also depends on avoidance of debris source threats. These debris sources include both controlled debris (typically frozen particles generated by dumping of liquids) and uncontrolled debris (unplanned release of objects from an ISS element or a visiting vehicle).

ISS PROGRAM IMPLEMENTATION

The ISS is required to avoid debris generation by its own elements and visiting vehicles (i.e., Shuttle, Soyuz, Progress, Automated Transfer Vehicle, H-II Transfer Vehicle). Existing NASA requirements, such as SSP 30426, *Contamination Control Requirements*, impose limits upon generation of external contaminants. SSP 50235, *Interface Definition Document for International Space Station Visiting Vehicles*, includes applicable requirements for visiting vehicles. In addition, NASA Policy Directive (NPD) 8710.3B requires that orbital debris generation be minimized.

In terms of hardware design, NASA's structural verification, acceptance, and integration process for flight hardware largely precludes the uncontrolled release of sizable objects from the ISS or any visiting vehicle.

In the absence of an explosive or propulsive release, there is no mechanism for generating a large velocity difference between the ISS and the debris object. Macroscopic objects occasionally released by the ISS or visiting vehicles (paint flecks, small pieces of plastic film, etc.) pose a minimal threat to the ISS. Atmospheric drag and orbital mechanics tend to induce such debris to deorbit without re-contacting the ISS at hazardous velocities.

The re-contact behavior of small (<100 microns), high-velocity particles produced during thruster firings and water dumps has been the subject of extensive analysis, testing, and orbital mechanics studies. Risks due to direct impact and re-contact are understood and controlled.

Operational steps are also taken to preclude threats associated with potential debris sources. Technicians and quality personnel conduct inspections to eliminate any foreign object debris prior to launch. Closeout imagery of the cargo records the general level of compliance and aids troubleshooting. During orbital operations, NASA closely manages extravehicular activity (EVA) procedures and training to minimize the jettison of solid materials into space in proximity of the ISS. If deemed necessary, objects to be jettisoned are jointly coordinated and sent on a safe trajectory that precludes return to the ISS. Overboard dumping of wastes in space is minimized and tightly controlled by NASA and the International Partners. Flight rules are in place that govern overboard waste dumping.

An example of an operational control identified during this assessment is the elimination of Shuttle waste water dumps while docked to the ISS. This pending procedure is intended to stop such dumps by the time the Japanese Experiment Module is attached. While nominal water dumps yield vapor that is not a safety hazard and is only a contamination threat to external science experiments, elimination of such dumps does reduce the chances that an off-nominal ice buildup could occur as have occurred in the past. Not dumping Shuttle water while docked eliminates this unlikely off-nominal possibility. The ISS also has operational controls that reduce the risks of impacts between ISS elements. For example, robotic and EVA crew maneuvers are analyzed, trained, and performed with extreme care to prevent hazardous contacts. Visiting vehicle activities are choreographed to minimize docking port relocations and improper contact.

Periodic recorded imagery from visiting vehicles and external cameras helps to verify the current safe condition of the ISS exterior. Ground-based radar tracking reported to NASA by the U.S. Air Force provides additional useful information on orbital debris threats.

STATUS

The ISS Program has examined two generic scenarios of potential concern regarding impacts from small accidentally released particulates. The first scenario determined whether the initial energy of any released ISS particulate is sufficient to cause damage to other ISS structures. The second scenario analyzed possible re-contact of a released particulate on subsequent orbital trajectories.

In the first scenario, the environmental forces acting on the ISS are very different than during Shuttle launch. With the ISS on orbit, there are no strong aerodynamic drag forces that can impart a large delta-velocity or cause a high kinetic energy impact by a separating particulate.

In the second scenario, the risk of particulate re-contact on later orbits is determined by the initial velocity, mass, and dimensions of the debris. To assess this risk, extensive orbital dynamics calculations were conducted by both U.S. and Russian trajectory specialists to evaluate the possibility of ice particle re-contact caused by ISS water dumps and propellant purges. Analysis demonstrated that re-contact with the ISS at velocities higher than the initial release velocity is not possible. These ice crystal studies are generic in that a range of ballistic coefficients and masses was evaluated and extrapolation to more massive objects is straightforward. Orbital perturbations from gravitational field, solar activity, and satellite drag effects cannot produce a net acceleration relative to the parent spacecraft to enable such hazardous re-contact collisions. NASA continues to examine whether high-energy impacts can occur as visiting vehicles approach and rendezvous with the ISS, but, to date, analysis indicates that atmospheric drag and orbital mechanics greatly reduce the possibility of re-contact and, when coupled with current operational techniques to preclude debris release, make the probability of an ISS-generated piece of debris striking another orbiting vehicle on approach to ISS extremely low.

Lessons learned from close calls during early assembly activities have driven increased use of analytical tools to model the current position of external hardware and increased focus on the importance of operational controls.

A new effort is under way to reduce the risk of ISS debris impact. This effort is developing a formal policy to define the conditions under which an object can be intentionally jettisoned from the exterior of the ISS. When jettison is proposed as an alternative to interior stowage, this policy will ensure that the mass properties and planned trajectories of each object are known and analyzed to verify safety. When known in advance, these objects will be recorded in increment-specific requirements documents. An existing request and approval process will be used if a special case arises during real-time operations.

FORWARD WORK

The new jettison policy will be reviewed by numerous ISS control boards and panels. Approval will be coordinated with the appropriate International Partners. The ISS Program Manager will disposition this proposed policy before the next planned ISS EVA is conducted. Implementation of this policy is expected to be managed by a new joint flight rule.

In summary, NASA believes that risk mitigation measures are in place to continually assess and control this potential hazard. ISS Program management, design engineers, crewmembers, flight controllers, training instructors, and safety teams will continue to ensure risk mitigation.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Ongoing	Complete review, approval, and implementation of new jettison policy
ISS Program	Ongoing	Maintain safety via requirements, design, verification, and operational controls

Columbia Accident Investigation Board

Recommendation 3.3-2

Initiate a program designed to increase the Orbiter's ability to sustain minor debris damage by measures such as improved impact-resistant Reinforced Carbon-Carbon and acreage tiles. This program should determine the actual impact resistance of current materials and the effect of likely debris strikes. [RTF]

International Space Station (ISS) Corollary: Assess the structural integrity of ISS protection from damaging particulate impacts as provided by its micrometeoroid and orbital debris (MMOD) shielding.

The status of ISS MMOD protection and its planned enhancements are discussed in Part 1, Recommendation R4.2-4 of this Implementation Plan.

Columbia Accident Investigation Board

Recommendation 3.3-1

Develop and implement a comprehensive inspection plan to determine the structural integrity of all Reinforced Carbon-Carbon system components. This inspection plan should take advantage of advanced non-destructive inspection technology. [RTF]

International Space Station (ISS) Corollary: Assess the structural integrity of ISS protection from damaging particulate impacts provided by its micrometeoroid and orbital debris (MMOD) shielding. Asses the integrity of pressurized ISS crew modules as provided through established design and test practices, including nondestructive inspections.

The status of ISS MMOD protection and its planned enhancements are discussed in Part 1, Recommendation R4.2-4 of this Implementation Plan. The status of safety-critical structures such as pressurized crew modules is discussed in Part 1, Recommendation R4.2-1.

Columbia Accident Investigation Board

Recommendation 6.4-1

For missions to the International Space Station, develop a practicable capability to inspect and effect emergency repairs to the widest possible range of damage to the Thermal Protection System, including both tile and Reinforced Carbon-Carbon, taking advantage of the additional capabilities available when near to or docked at the International Space Station.

For non-Station missions, develop a comprehensive autonomous (independent of Station) inspection and repair capability to cover the widest possible range of damage scenarios.

Accomplish an on-orbit Thermal Protection System inspection, using appropriate assets and capabilities, early in all missions.

The ultimate objective should be a fully autonomous capability for all missions to address the possibility that an International Space Station mission fails to achieve the correct orbit, fails to dock successfully, or is damaged during or after undocking. [RTF]

International Space Station (ISS) Corollary: Determine the adequacy of the ISS's ability to perform external and internal inspections and repair.

Note: The ISS response to Recommendation R6.4-1 was approved by the ISS Program Integration Control Board (PICB) on September 23, 2004. All actions related to assuring implementation and ongoing improvements are assigned to the PICB.

BACKGROUND

The ISS Program has extensive existing visual inspection capabilities and instrumentation to determine vehicle health. This instrumentation permits many issues to be diagnosed without visual imagery.

Additionally, ISS has on-board maintenance and repair capabilities that help to ensure vehicle and crew safety. This includes on-board spares, tools, materials, and repair procedures.

ISS PROGRAM IMPLEMENTATION

To meet the intent of this recommendation, the ISS visual inspection requirements and implementation details were re-examined to assess their adequacy. Internal systems inspection requirements were found to be adequately documented and satisfactorily implemented. External ISS systems inspection requirements relied heavily on photos taken by a visiting/departing Space Shuttle. Implementation of the external viewing requirements without the Shuttle was found to be limited. In response to this situation, the ISS Program developed a systematic approach for performing an exterior imagery survey using on-board assets.

Under the leadership of the ISS Mission Evaluation Room (ISS MER), an imagery team was established to:

- Identify specific external survey imagery requirements.
- Collect, store, and disseminate the imagery.
- Review collected imagery.
- Report findings.
- Lead follow-up investigation of potential anomalies.

The imagery team developed a plan to obtain the necessary images from truss-mounted cameras, robotic system cameras, and crew views through ISS module windows. For imagery taken by the crew, the team identified video quality requirements that can be satisfied with cameras on board the ISS.

The ISS Program has instituted a plan to periodically perform these external surveys. The external surveys support hardware configuration verification, assessment of material degradation, and identification of visible anomalies. The surveys also provide a historical set of images to assess the long-term progression of degradation and to facilitate future problem resolution. On-board assets provide viewing capability for a significant portion of the vehicle's exterior. Some surfaces cannot be viewed with on-board assets alone, as shown in figure 6.4-1-1. Viewing these surfaces requires imagery supplied by other remote assets, such as extravehicular activity (EVA), visiting vehicles, or other national assets. Note that figure 6.4-1-1 assumptions include fully functional ISS robotic and camera systems.

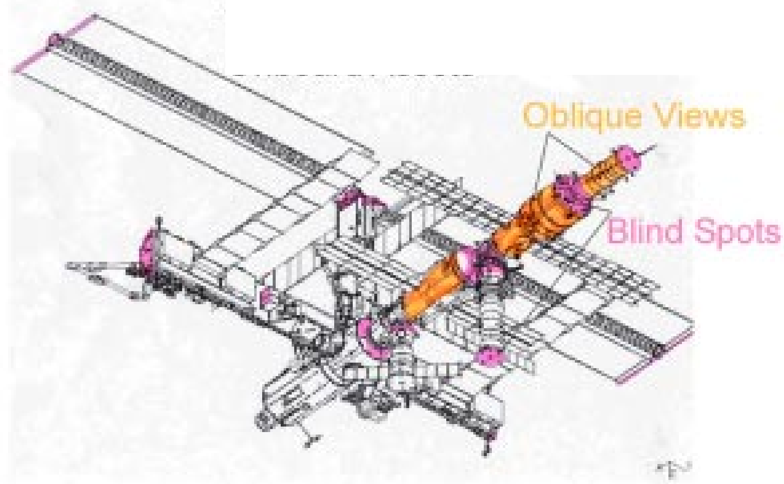


Figure 6.4-1-1. ISS external surface views that are limited when using on-board assets

Dedicated external surveys are augmented by imagery collected during EVAs. During NASA EVAs, helmet camera video and still imagery are typically used as assembly closeout documentation and to augment crewmember descriptions of the conditions or anomalies they observe. During Russian EVAs, the hand portable *Glisser* video camera is used when necessary.

To improve vehicle inspection, maintenance, and repair capabilities, NASA has specific new tools that have been in development for several years. These tools include an external fluid line repair kit, a manual electrical cable tester for internal wiring inspections, a screw extraction kit, a fiberscope and handheld infrared temperature sensor. Improvements to atmospheric and fluid leak detection and repair capabilities are discussed in the response to Recommendation R4.2-4. To extend Shuttle docked duration for science, cargo transfers, and repair activities, ISS and Shuttle are coordinating the development of a power transfer system. As described by ISS Continuous Improvement Action ISS-8, an infrared camera system is also being developed that can be used for identification of leaks and thermal performance degradations. As noted in the ISS response to Recommendation R10.3-1, the ISS Program is involved in the certification and deployment of a digital EVA still camera to ensure critical event data collection and external inspection. Imagery will be downlinked in near real time for analysis. The camera is scheduled to be deployed to ISS in 2005. Also, the ISS Program is implementing the Space Video Gateway to enable high-definition television (HDTV) live and recorded downlink capabilities. Deployment is scheduled for early 2006. With the Shuttle Program's recent investments in the AERCam free-flying robot, the ISS Program will consider supporting this potentially new capability for autonomous external inspection.

STATUS

Initial external surveys of the ISS using the external cameras, the Space Station Remote Manipulator System, and exterior windows were completed in September 2004. A report published in November 2003 captures the results of the survey using stationary external cameras (JSC-49914). In July 2004, the conclusions and recommendations of the survey conducted using the ISS remote manipulator were published in JSC-62628. The imagery results are available in the ISS Digital Imagery Management System and the reports are available at http://sn-isag.jsc.nasa.gov.

A team composed of experts representing each subsystem, the external environment, and the Kennedy Space Center has reviewed the imagery. The survey results were disseminated in three reports generated by the ISS MER. Based on the external camera imagery review, the team verified proper configuration of hardware (e.g., thermal blankets, P6 truss shoulder bolts), uncovered a structural interference problem with the Ku-band antenna (the interference has since been eliminated), identified surface anomalies on the U.S. module heat rejection system radiators, and documented discoloration of various external surfaces. The only formally tracked potential anomaly involved a suspect blanket and has since been closed as a non-issue.

The ISS Program is supporting the development of a Contingency Shuttle Crew Support (CSCS) capability for use in the event that a docked Shuttle and crew need to await rescue by another Shuttle. In particular, the ISS Program is analyzing and adjusting ISS life support consumables, spares, and stowage to maximize this contingency capability. ISS experts integrate and report their detailed results during a series of formal launch readiness reviews. Additional discussion on the Shuttle aspects of this capability can be found in SSP-3 of the NASA Implementation Plan for Space Shuttle Return to Flight and Beyond.

The ISS Program is working with the Space Shuttle Program to develop a method to inspect and effect emergency repairs to the Space Shuttle Thermal Protection System. The unique analyses that ISS experts perform include vehicle structural and orientation stability and robotic repositioning. For the long term, the ISS Program is also considering permanently stowing a robotic extension boom on board the ISS to avoid frequent delivery and return on Shuttle. Shuttle-specific efforts are documented in Volume 1 of NASA's Implementation Plan for Space Shuttle Return to Flight and Beyond, reference sections R6.4-1 and SSP-3.

FORWARD WORK

The periodic ISS exterior surveys will continue semiannually for areas viewable with the external cameras and as needed for those areas only visible with robotic or crew observation capabilities. The frequency at which the surveys (or portions of the surveys) are performed will be adjusted based on the survey findings.

New ISS modules will provide further vantage points through windows for external surveys of ISS surfaces and systems. Furthermore, two additional external video cameras will be installed on truss segments, increasing the external mapping capability. The future robotic arm enhancement called Dextre or the special-purpose dexterous manipulator will have built-in video cameras that can be used for detailed inspections.

NASA is currently certifying EVA digital still cameras to be deployed by Shuttle return to flight. Once successfully certified, these cameras will be used to obtain high-resolution imagery that can be downlinked after an EVA for analysis and to inspect areas that cannot be viewed by external video cameras or through ISS windows.

As in the past, upon return to flight, Shuttle imagery assets will be used to survey ISS external surfaces. Orbiter-based imagery provides views of ISS external surfaces not visible from ISS assets and supplies additional views of areas from different perspectives. In light of the planned Shuttle retirement after ISS assembly completion, the noted improvements in EVA and robotic imagery will become more important.

The Soyuz vehicles docked to the ISS are inspected to the extent possible. Due to the rendezvous and docking attitude of the Soyuz with respect to the ISS, it is not current practice to inspect or obtain imagery of the entire Soyuz vehicle on orbit. The ISS Program, in coordination with our International Partners, will evaluate the need for additional requirements in support of external inspection of all visiting vehicles.

While the ISS Program continues its efforts to improve its own on-orbit repair capabilities, it will also support the needs of the Shuttle Program for return to flight and beyond. This support includes CSCS capability and analysis of the ISS services that assist with emergency inspection and repair of Shuttle thermal protection systems.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Operations	Nov 03 (Complete)	Report on results of stationary camera inspections
ISS Operations	Jul 04 (Complete)	Report on results of robotic camera inspections
ISS Operations	Sep 04 (Complete)	Complete first periodic exterior survey using crew viewing through windows
ISS Program	2005	Deploy digital EVA camera
ISS Program	Early 2006	Enable HDTV downlink capability
ISS Operations	Semiannually during each ISS Increment	Continuing periodic exterior survey using external cameras
ISS Operations	Annually	Continuing periodic exterior survey using robotic and crew survey
ISS Operations	Ongoing	Anomaly resolution and spot imagery support
ISS Program	Ongoing	Improve ISS maintenance and repair tool capabilities
ISS Program	Ongoing	Support Shuttle inspection and repair

Columbia Accident Investigation Board

Recommendation 3.3-3

To the extent possible, increase the Orbiter's ability to successfully re-enter the Earth's atmosphere with minor leading edge structural sub-system damage.

International Space Station (ISS) Corollary: Assess the structural integrity of ISS protection from damaging particulate impacts as provided by its micrometeoroid and orbital debris (MMOD) shielding.

The status of ISS MMOD protection and its planned enhancements are discussed in Part 1, Recommendation R4.2-4 of this Implementation Plan.

Columbia Accident Investigation Board

Recommendation 3.3-4

In order to understand the true material characteristics of Reinforced Carbon-Carbon components, develop a comprehensive database of flown Reinforced Carbon-Carbon material characteristics by destructive testing and evaluation.

International Space Station (ISS) Corollary: Assess the structural integrity of ISS protection from damaging particulate impacts provided by its micrometeoroid and orbital debris (MMOD) shielding. Asses the integrity of pressurized ISS crew modules as provided through established design and test practices, including nondestructive inspections.

The status of ISS MMOD protection and its planned enhancements are discussed in Part 1, Recommendation R4.2-4. The status of safety-critical structures such as pressurized crew modules is discussed in Part 1, Recommendation R4.2-1.

Columbia Accident Investigation Board

Recommendation 3.3-5

Improve the maintenance of launch pad structures to minimize the leaching of zinc primer onto Reinforced Carbon-Carbon components.

International Space Station (ISS) Corollary: Review the status of ISS efforts to sustain and improve its ground facilities involved in the processing of flight hardware.

Note: The ISS response to Recommendation R3.3-5 was approved by the ISS Program in December 2004. All actions related to assuring implementation were closed and responsibility for forward actions was assigned to the Kennedy Space Center (KSC) ISS/Payloads Processing Directorate.

BACKGROUND

While originally deemed not applicable, the question of the health and maintenance of ISS related ground facilities is important to programmatic safety and success. This response summarizes the continuing efforts to sustain and improve ISS related facilities.

ISS PROGRAM IMPLEMENTATION

Beyond the ongoing internal efforts to maintain ground test equipment, the ISS Program participates in the Agency's overall efforts to assess and maintain its ground facility assets. These needs are addressed via the annual Program Operating Plan, Construction of Facilities process, and the integrated Real Property Strategic Plan. Each NASA center also develops more detailed plans.

STATUS

Each NASA center provides an overview of the status and maintenance of its ground facilities in a variety of reports, including a center-specific implementation plan and a facilities master plan. The latest center implementation plans were released in early 2004. A good example of a master plan is KSC's "Cape Canaveral Space Port Master Plan," which can be found at http://www.floridaspaceauthority.com/projects/planning.html.

As an example of the ISS Program's diligence in this area, recent reviews of ground facilities identified humidity exposure concerns for some ISS spare parts stored at KSC. Further reviews were conducted to assess temperature/humidity excursions during the 2004 hurricane season. A response plan was prepared and is being implemented to verify initial conclusions that no harm has yet been done to the effected hardware and to prevent reoccurrence through improved monitoring and procedures.

The status of the ISS Program's efforts to maintain its ground support equipment is discussed in Part 2.2, Observation O10.11-1, of this Implementation Plan.

FORWARD WORK

Complete plans to correct humidity concerns with KSC's ISS storage facilities.

Continue attention to facility maintenance and upgrades through the annual Program Operating Plan, Construction of Facilities process, and the Real Property Strategic Plan.

Close engagement with the Space Shuttle Program in the development of the Shuttle Facilities Transition Plan.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Jul 04 (Complete)	Implement initial humidity mitigation efforts at KSC storage facility
ISS Program	Mid 05	Finish remainder of KSC storage facility humidity mitigation efforts
ISS Program	Ongoing	Assess and implement ISS facility changes per Agency prioritization processes

Columbia Accident Investigation Board

Recommendation 3.8-1

Obtain sufficient spare Reinforced Carbon-Carbon panel assemblies and associated support components to ensure that decisions related to Reinforced Carbon-Carbon maintenance are made on the basis of component specifications, free of external pressures relating to schedules, costs or other considerations.

International Space Station (ISS) Corollary: Assess the ISS inventory and pipeline of critical spares in light of ongoing flight operations experience and limitations.

Note: The ISS response to Recommendation R3.8-1 was approved by the ISS Vehicle Control Board (VCB) on September 20, 2004. All actions related to assuring implementation were closed and responsibility for ongoing management was assigned to the VCB.

BACKGROUND

Although the ISS has no Reinforced Carbon-Carbon panels, there are a number of systems required to provide life support and sustain operations. The ISS Program reviewed its spares provision plans and processes to minimize sparing decisions that could be subject to schedule pressures and found them adequate for continuing operations.

After the Shuttle accident and in response to the *Columbia* Accident Investigation Board recommendations, the ISS Program reviewed its logistics and maintenance plans to ensure that sparing plans are adjusted for the extended Space Shuttle downtime. This process continues as the downtime is extended and critical decisions affecting spares must be made. A spare is currently pre-positioned on orbit for many of these critical orbital replacement units (ORUs). Since the loss of *Columbia*, Progress and Soyuz capacity has limited the ability to deliver limited-life items and large ORUs to orbit and the Progress vehicle cannot return hardware to the ground for repair, although a limited number of small items are being returned on the Soyuz.

ISS PROGRAM IMPLEMENTATION

The ISS Program uses a combination of simulation analysis and in-depth technical understanding to determine sparing for the ISS. Functional availability is the chief criteria used to determine adequacy of sparing. This methodology uses a predictive measure to assess the continuous on-orbit operation of ISS. Availability is defined as the percentage of time that an ORU or a function is operating. Key data and assumptions for functional availability include reliability data, spares quantities and locations, repair times, redundancy, manifest limitations (flights per year, cargo capability), crew limitations, and on-orbit stowage locations. Reliability data include items such as mean time between failures, duty cycle, induced failure factor, and condemnation rates.

ORU data were obtained from the ISS developer and their vendors to understand the hardware and failure impacts. Special attention was placed on hardware performing a critical function to ensure that the proper number of spares is procured.

ISS sparing plans incorporated a schedule that was based on ensuring that a spare ORU would be available at least 45 days prior to launch of that element. In selected cases, that requirement was met by having a production asset available initially while awaiting the actual spare from the manufacturing line. In all cases, that requirement was met, and spares delivery schedules continue to meet that requirement. Below the ORU level, shop replacement units and piece parts are being procured to support a repair turn around time (RTAT) of 270 days. To support this RTAT, long lead parts (greater than 18 months to acquire) are procured and stocked. For operating flight hardware, all long lead parts were procured. Additional long lead parts for flight hardware not yet activated are on a schedule to be delivered by July 2005.

The flight quantities used to determine required spares quantities included Nodes 2 and 3. Spare ORUs were delivered for the government-furnished equipment hardware in Nodes 2 and 3. Some sharing of common assets between the Nodes occurred for schedule convenience for Node 2 completion. No further sharing of assets is planned for Node 3 completion. Regenerative environmental control and life support system spares are being procured by the Nodes Project Office, with input from ISS Logistics and Maintenance. These spares are due for delivery in 2005 and 2006. Sharing of common assets has not occurred at vendors, manufacturers, or depots because these vendors, manufacturers, and depots are responsible only for ORU repair and also in part because long lead parts continue to be procured.

A complete inventory of spare ORUs and repair parts is in the Government On-Line Logistics Data system. As failures occur on board ISS, each failure is assessed to determine its impact to its parent system and the ISS overall. Those items that do not impact safety or significantly impact operations are allowed to be in the backlog until upmass is available for spares delivery. Items that have safety or significant operations impacts are prioritized accordingly for manifesting on Russian Progress vehicles.

The ISS Program analyzed the potential for critical failures at each stage of assembly and developed plans to address future ISS configurations. In response to the new Exploration Vision, which calls for the retirement of the Shuttle and its delivery and return capabilities after ISS assembly complete, the ISS Program is reassessing both its near- and long-term plans for on-orbit sparing.

STATUS

Due to the Shuttle fleet being grounded, the ISS Program reassessed its on-orbit and resupply approach. Currently, the Russian Progress and Soyuz launch vehicles are the only means of delivering spares to orbit. With a few exceptions due to size constraints, the Progress vehicle volume meets the demands for the ISS to be able to sustain its internal hardware subject to manifest priorities. Some external hardware cannot be launched to orbit on Russian vehicles, but most required critical spares are already on orbit and most required preventive maintenance ORUs can be resupplied on Progress.

With current manifest constraints, the ISS Program is continually assessing workarounds to ensure that the necessary spares and items are delivered to orbit. Numerous independent studies were performed over the past few years to ensure that the ISS sparing plan is consistent with contingency situations, such as the current Shuttle downtime. These included the Aerospace Safety Advisory Panel (2001) and the Independent Assessment Team (1996 and 1997). Each of these reviews confirmed that the ISS sparing approach was adequate. The ISS Program constantly reassesses study results to ensure it has an adequate spares pipeline. While a backlog of items awaiting delivery to ISS exists, there are no immediate threats to continued ISS crew operations. The ISS Program is also implementing actions to reduce the need to launch additional equipment. For example, when possible the crew is using kits to refurbish hardware on orbit. For some items, specially designed preventive maintenance tasks are performed to extend hardware lifetime. In cases where required ISS spares are not compatible with Progress packing accommodations, the ISS Program draws upon lessons learned during Russian *Mir* operations and develops unique flight support equipment to integrate the spare into the Progress vehicle.

The flight medical officers requested an assessment of the on-board medical equipment spares, limited life items, and replacement methodology to support continued crewed operations. Several actions were taken. Due to the limited upmass capability without the Shuttle, some equipment items were redesigned to be maintained with smaller, lighter weight replacement hardware that can be accommodated on the Russian Progress vehicles. Critical environmental samples continue to return on the Russian Soyuz vehicles to ensure that the atmosphere is safe. The maintenance philosophy on exercise equipment was also changed to allow on-orbit disassembly, repair, or replacement of internal parts, and reassembly that would normally be performed by ground personnel.

To keep ISS operational after Shuttle retirement, the ISS Program must implement a new strategy of spares replacement. Prior to Shuttle retirement, the ISS Program may pre-position essential large spares on orbit and increase its inventory of ground-based spares. After Shuttle retirement and if no new return capability is identified, the ISS Program may rely on a strategy of disposable sparing rather than the current ground depot approach. There will be an increased reliance upon international or domestic commercial assets such as alternative cargo launch and reentry vehicles after Shuttle retirement.

FORWARD WORK

Beyond assessments of the impacts of the new Exploration Vision, the primary purpose of the current logistics and resupply review is to maintain and sustain the ISS and conduct safe crew operations during the Shuttle downtime. Although spares provisioning and other logistics discipline reviews are a continual process in this Program, future reassessments of the overall adequacy of spares for the sustainment of the ISS are planned. Of particular concern are spares for crew health-related equipment, such as exercise equipment and atmospheric monitoring. Recent experience with components of the Crew Health Care System highlights the need for thorough analysis and discussion of those areas critical to continuing operations during the Shuttle downtime and adequate upmass and downmass are essential elements of any risk mitigation plan.

The periodically updated and published "ISS On-Orbit Supportability Assessment Report" (D684-10162-1-2) further addresses the requirements, resources, and progress of ISS maintainability and sparing resupply. As presented to ISS management in early August 2004, there are improvements in work for the trending and reporting of on-orbit maintenance information (predicted vs. actuals, backlog, functional availability, crew time usage). The improvements in maintenance reporting began in September 2004 and will be repeated quarterly.

The ISS Program will continue activities to lessen dependence on Shuttle resupply. The ISS Program is continuing to evaluate on-orbit repair of select ORUs rather than replacement.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
Flight Medicine	Ongoing	Reassess medical support requirements
ISS Program Logistics	Ongoing	Develop and implement plans to keep ISS hardware operational during Shuttle downtime
ISS Program Logistics	Ongoing	Provide quarterly reports assessing on-board hardware failures, maintenance actions, and crew time for maintenance
ISS Program	Ongoing	Develop and implement plans to keep ISS operational when the Shuttle is retired

Columbia Accident Investigation Board

Recommendation 3.8-2

Develop, validate, and maintain physics-based computer models to evaluate Thermal Protection System damage from debris impacts. These tools should provide realistic and timely estimates of any impact damage from possible debris from any source that may ultimately impact the Orbiter. Establish impact damage thresholds that trigger responsive corrective action, such as on-orbit inspection and repair, when indicated.

International Space Station (ISS) Corollary: Assess the validity of ISS computer models to provide realistic and timely support to on-orbit operations, anomaly resolution, and decision-making processes. Ensure that these models are adequate for the specific purpose, are periodically recertified and upgraded, and their limitations are known and documented.

Note: The ISS response to Recommendation R3.8-2 was approved by the ISS Program Integration and Control Board on September 1, 2004. All actions related to assuring full implementation and continual improvement are the responsibility of the Vehicle Control Board.

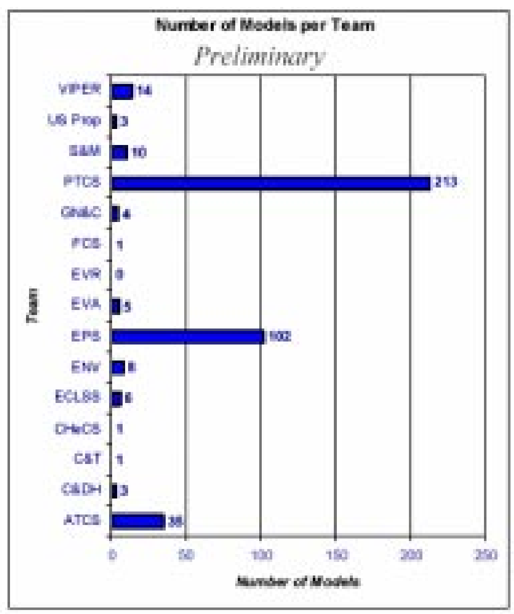
BACKGROUND

Although the *Columbia* Accident Investigation Board's (CAIB's) action was specific to the debris impacts on a Shuttle, the ISS Program also initiated steps to assess all of the analytical models and tools that are used to support on-orbit operations, anomaly resolution, and decision-making processes. ISS Program boards are reviewing the verification, conservatism, and uncertainty associated with analytical models to ensure that the model fidelity and assumptions, limitations, and boundary conditions are understood and are acceptable. The boards will address any identified improvements required as a result of their assessment.

Independent from these post-*Columbia* actions, NASA's Independent Assessment Office has performed reviews of ISS thermal modeling almost every year dating back to 1997. Examples of these reviews are reported in JS-0018 (Adequacy of Thermal Math Model), JS-9014 (EEATCS Model and Test Review), JS-9063 (Review of Thermal Math Model for Airlocks and US Lab), and JSC-98-012 (Identification of Thermal Model Validation Testing).

ISS IMPLEMENTATION

The ISS Program continually assesses all of its analytical models and strives to keep these tools state-of-the-art. Recent emphasis on these models assessments include those used for assembly and sustaining operations on the ISS vehicle, flight rule and procedure development, and those developed to support on-orbit anomalies. These assessments determine the adequacy of the level of validation, verification, and configuration control of analytical models and ensure a consistent level of configuration control across all subsystem teams. In August 2003, more than 400 total models and analytical tools were identified that the ISS Mission Evaluation Room (MER) would assess with the aid of system expert teams. The scope and distribution of the identified models is illustrated by the following figure.



Recognizing that the interpretation of data produced by math models is as important as the accuracy of the models themselves, the ISS Program has implemented steps to ensure adequate communication of the uncertainty in math modeling results. As pointed out in the CAIB Report, “engineering solutions presented to management should have included a quantifiable range of uncertainty and risk analysis.” An effort to understand sources of uncertainty in math modeling was initiated to establish a common knowledge base and terminology to be used across the Program. The ISS Program has hosted a short course on “Experimentation and Uncertainty Analysis” for analysts and managers representing Program subsystem teams.

To ensure consistent and thorough communication of conservatism and uncertainty, a presentation template has been developed as an aid for presenting analytical data to ISS Program boards or Anomaly Resolution Teams. The presentation format includes specific information on inputs to the analyses, model verification history, uncertainty factors, and conservatism. The intent of the template is to facilitate the communication between analysts and decision makers so that the key assumptions underlying the analyses, results, and solution options are understood in terms of associated risk and potential consequences. At every opportunity, when the results of assessments based on analytic models are provided, management is reminded of the level of uncertainty included in these results for the maximum understanding of risk knowledge capture.

STATUS

To accomplish the intent of this recommendation, three parallel but related efforts have been pursued.

First, a generic data presentation template was developed and is being implemented by the ISS MER for its technical reports to the ISS Mission Management Team (IMMT). A similar template has also been developed for presentations to ISS boards that contain critical-model-produced data necessary for decisions. The subsystem teams may use this template for communicating the uncertainty and conservatism included in the analyses for their specific disciplines.

Second, the ISS Program investigated the adequacy of existing analytical models and is committed to a continuous process of review to ensure adequate precision and accuracy of results.

Initial reviews of ISS models were completed for electrical, active thermal, passive thermal, environmental control, and structural systems. In general, there is good confidence in existing models, but some areas for improvement were identified that will be implemented as normal business. Identified improvements include refinements of existing models, addition of new models, and collection of additional data from ground and on-orbit tests. In a few cases, new sensors were recommended that require further programmatic review and approval (e.g., Node 1 humidity and temperature). One model area now being tracked via the ISS risk process involves validation of integrated structural math models. In addition to completing data collections using existing on-board internal sensors, new wireless sensors have been approved to be installed on the external truss elements.

As requested by the ISS Program manager, the NASA Engineering and Safety Center (NESC) is working to identify better analytical capabilities for cabin pressure leak detection. Another NESC study is also under way to assess the computer code of the micrometeoroid and orbital debris model known as BUMPER.

Third, an effort to quantify basic uncertainty in math-model-produced analysis was begun. This was initiated with a short course on “Experimentation and Uncertainty Analysis” taught to a group of analysts and managers from each subsystem. Several of the subsystem teams investigated methods for approximating the uncertainty of model analysis. After reviewing existing sources for model uncertainty tools, a plan was proposed for the development of ISS-oriented tools with the goal of improving the understanding and communication of analysis modeling error. Given the challenges associated with such tool development, for the foreseeable future each ISS subsystem team will continue to independently purpose improvements to its own models.

A parallel effort to quantify uncertainty in math model results is being pursued with the help of two major universities with expertise in this field. The ISS Program hopes to take a leadership role in this emerging technology.

FORWARD WORK

As model assessments continue, recommendations for areas where additional resources, testing, and/or on-orbit instrumentation can be used to reduce analysis uncertainty and Program risk will be identified and brought to the appropriate ISS control boards. Otherwise, as normal business, each subsystem area will independently implement its recommended improvements to model completeness and accuracy. Guidelines for configuration control of models continue to be in development and will be implemented for all subsystem teams.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
IMMT, MER	Aug 03 (Complete)	Attend training on uncertainty analysis
ISS Program	Aug 03 (Complete)	Develop MER/IMMT presentation templates
ISS Program	Feb 04 (Complete)	Systems Working Group concurred with recommendations for improvements to electrical, thermal, and environmental control models
ISS Program	Sep 04 (Complete)	Review of proposed ISS board presentation templates and results of ISS model reviews
ISS Program	Ongoing	Implement improvements to ISS math models (e.g., configuration management, new wireless sensors, and enhanced cabin pressure leak detection analysis)

Columbia Accident Investigation Board

Recommendation 3.4-1

Upgrade the imaging system to be capable of providing a minimum of three useful views of the Space Shuttle from liftoff to at least Solid Rocket Booster (SRB) separation, along any expected ascent azimuth. The operational status of these assets should be included in the Launch Commit Criteria (LCC) for future launches. Consider using ships or aircraft to provide additional views of the Shuttle during ascent. [RTF]

International Space Station (ISS) Corollary: Review the adequacy of ISS imagery capabilities with emphasis on beneficial improvements.

The ISS response to this subject is addressed in Part 1, Recommendations R6.3-2, R6.4-1, and R10.3-1.

Columbia Accident Investigation Board

Recommendation 3.4-2

Provide a capability to obtain and downlink high-resolution images of the External Tank after its separation. [RTF]

International Space Station (ISS) Corollary: Review the adequacy of ISS imagery capabilities with emphasis on beneficial improvements.

The ISS response to this subject is addressed in Part 1, Recommendations R6.3-2, R6.4-1, and R10.3-1.

Columbia Accident Investigation Board

Recommendation 3.4-3

Provide a capability to obtain and downlink high-resolution images of the underside of the Orbiter wing leading edge and forward section of both wings' Thermal Protection System. [RTF]

International Space Station (ISS) Corollary: Review the adequacy of ISS imagery capabilities with emphasis on beneficial improvements including downlink imagery.

The ISS response to this subject is addressed in Part 1, Recommendations R6.3-2, R6.4-1, and R10.3-1.

Columbia Accident Investigation Board

Recommendation 6.3-2

Modify the Memorandum of Agreement with the National Imagery and Mapping Agency (NIMA) to make the imaging of each shuttle flight while on orbit a standard requirement. [RTF]

ISS Corollary: Ensure that ISS requirements are included in the appropriate agreements and the procedures and training are in place to implement these agreements.

Note: The ISS response to Recommendation R6.3-2 was approved by the ISS Program in February 2005. Responsibility for ongoing management was assigned to the ISS Mission Management Team.

BACKGROUND

The ISS Program has the capability to take advantage of appropriate national assets to support assessments of the ISS.

ISS IMPLEMENTATION

In July 2003 NASA concluded a Memorandum of Agreement (MOA) to address recommendation R6.3-2 of the *Columbia* Accident Investigation Board (CAIB).

STATUS

The ISS Program has determined which positions and personnel require access to data obtained from external sources. The Program will ensure that appropriate personnel are familiar with the general capabilities available for support from the supporting agencies and that appropriate personnel are familiar with the means to gain access to that information.

FORWARD WORK

ISS personnel are participating in training exercises on a regular basis to identify problems and activate necessary support. These training exercises will test and evaluate tasking procedures, analysis and decision-making processes.

The operational teams will complete the development of standard operating procedures to implement additional agreements with the appropriate government agencies.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Mission Operations	Complete	Initial plan for personnel training
ISS Mission Operations	Complete	Initial ISS operational procedures
ISS Mission Operations	Ongoing	Appropriate clearances requested and approved
ISS Mission Operations	Ongoing	Test/validate operational procedures and conduct personnel training
ISS Program	Ongoing	Support HQ audits and annual assessments

Columbia Accident Investigation Board

Recommendation 3.6-1

The Modular Auxiliary Data System instrumentation and sensor suite on each Orbiter should be maintained and updated to include current sensor and data acquisition technologies.

Recommendation 3.6-2

The Modular Auxiliary Data System should be redesigned to include engineering performance and vehicle health information and have the ability to be reconfigured during flight in order to allow certain data to be recorded, telemetered, or both, as needs changes.

International Space Station (ISS) Corollary: Assess the adequacy of the ISS instrumentation system to support engineering performance, including use of wireless instrumentation systems.

Note: The ISS response to Recommendations R3.6-1 and R3.6-2 was approved by the ISS Avionics and Software Control Board (ASCB) on September 15, 2004. All actions resulting from this assessment are the responsibility of the ASCB for ongoing management.

BACKGROUND

The Modular Auxiliary Data System (MADS), which is also referred to in the *Columbia* Accident Investigation Board Report as the "OEX recorder," is an Orbiter recorder for collecting engineering performance data. MADS records data on the environment experienced by and the responses of the Orbiter during ascent and entry.

Although the ISS does not use a MADS recorder, it still depends on telemetry for engineering performance data. Because the ISS does not return to the ground for processing, most performance data are downlinked from orbit.

ISS PROGRAM IMPLEMENTATION

Engineering performance data are required throughout the life of the ISS. The S-band telemetry from ISS shares bandwidth with two channels of compressed audio. Data exchange with the ground is through the tracking and data relay satellite system (TDRSS) in geosynchronous orbit. All of the available telemetry bandwidth of the S-band has been fully subscribed since the U.S. Laboratory module was deployed in 2001.

ISS Program requirements control what data are downlinked. These requirements include vehicle performance assessment as well as real-time operational assessment. All telemetry users have the opportunity to submit requirements to this process. When requirements exceed downlink bandwidth capability, multiple telemetry formats are established to facilitate sharing.

The ISS's data architecture is based on a Current Value Table stored in the memory of the triple-redundant Command and Control System (CCS) Multiplexer Demultiplexers (MDMs). The table is updated completely at three data rates—0.1, 1.0, and 10 Hz depending on the needs of the system supplying the data. Telemetry for downlink to the ground through the TDRSS is drawn from this table at a combination of three frame rates—1, 10, and 100 times every 10 seconds. Data are not typically buffered on orbit except for predefined periods of communication outages. In that case, it is stored in either the CCS MDM solid-state mass memory or the High-Rate Communications Outage Recorder. Data recorders in the ISS are solid-state devices in the MDMs and in the High-Rate Data Recorder. Both are hardened to meet requirements of long-term operation on orbit, and they will survive at vacuum. They are not designed to survive fire or explosion.

The data architecture and telemetry structure allows telemetry from the Service Module to be returned through the U.S. S-band system to Mission Control Center-Houston and then forwarded on to Mission Control Center-Moscow (MCC-M). Russian assets can also be commanded through the U.S. communications links. Conversely, U.S. commands and telemetry can be transferred through the links between Russian ground stations and the Service Module and between the Service Module and the U.S. Laboratory.

As individual required sensors fail or become unreliable, the ISS Program replaces the sensor, recalibrates the sensor, or identifies an alternate approach to gathering the information. As new instrumentation needs are identified, add-on capabilities are procured.

Improvements to the ISS avionic systems address upgrades to engineering performance data capabilities and are focused on increasing the bandwidth for telemetry.

STATUS

The ISS Program assessment of the adequacy of ISS instrumentation and data has not identified any risks to sustained operation of the ISS.

ISS instrumentation is a combination of orbital replaceable sensors and components integral to the design of larger orbital replaceable units. Within the avionics systems, the sensors have performed very well, and sensor degradation or failure has not had any significant operational impact. Each ISS system monitors the operation of its system, including the sensors. Decisions for sensor recalibration or sensor replacement are merged into the day-to-day management of operations of the ISS.

Systems that perform functions similar to the sensor suite and recorders of the MADS were defined as formal ISS requirements, implemented as part of the basic Program, and are maintained for the life of the Program. The closest equivalent to the MADS is the Structural Dynamic Measurement System. That system is comprised of 33 accelerometers, 38 strain gauge bridges, two signal conditioners, connecting wires, and software. The accelerometers are mounted on all truss segments without solar arrays. The strain gauges are mounted on the critical rotating equipment. The signal conditioning units boost measurement inputs and record and buffer the data so the data can be sent to the ground.

The ISS Program identified additional requirements for structural measurements and environmental characterization after the initial design of the ISS. In each case, innovative solutions were accommodated without the addition of new cabling. The first of these new requirements measures structural strains and accelerations in the pressurized volume to characterize dynamic response. Internal wireless instrumentation was developed to implement this capability. Additional truss-mounted structural measurements are being added under a contract change that defines additional on-orbit instrumentation, including 12 outboard truss accelerometers (two on P4, two on P5, two on P6, four on S4, and two on S6 and additional sensors in pressurized elements to correlate the integrated model and provide valuable data to extend ISS structural life through postflight loads reconstructions with on-orbit data.

The second of the new requirements measures the voltage potential of the ISS compared to the ambient plasma as well as the ionospheric plasma electron density and electron temperature. The Floating Potential Measurement Unit measures the existence and severity of spacecraft charging hazards. Real data on spacecraft charging characteristics permit hazard control strategies that minimize overall risk to the vehicle and crew.

To increase bandwidth for sending telemetry to the ground, two approved enhancements are in work. One will upgrade the ISS computers to increase their data processing and storage capability and to make all the data available for Ku-band downlink. This upgrade will allow all ISS telemetry to be downlinked continuously. The second enhancement will increase the bandwidth of the Ku-band data stream to the ground from 50 megabits per second to 150 megabits per second. The change also increases data transmission from the ground station at White Sands, New Mexico, to Houston and Huntsville. The conceptual design and testing of this upgrade is under way.

Another upgrade under way increases the level of encryption of commands to the ISS by a more robust algorithm. It adds audio to the low-rate omnidirectional S-band and increases the processor speed and high-rate data interface capability to the MDMs. Another upgrade replaces the existing laptops with a newer model, termed the Next-Generation Laptop (NGL). The NGLs are to be deployed to the ISS for use on noncritical applications. Certification of these laptops and associated power supplies for critical applications is scheduled for 2005.

The Automated Transfer Vehicle (ATV), H-II Transfer Vehicle (HTV), Columbus Module, and Japanese Experiment Module organizations are working closely with the U.S. Command and Data Handling organization to define data interfaces and tests of the interfaces. Details of the MIL-STD 1553 data interfaces between the U.S. MDM and the computers in these vehicles and modules are already in the normal workflow, termed Standard In/Standard Out. Hardware and software integration testing has begun for the ATV to assess the performance of the data interfaces for docked operations. In addition, a project has been initiated to develop a new mechanism to transfer video bearing ATV rendezvous data from the

Service Module to the U.S. Ku-band downlink and then down to the MCC-M.

A recent request to explore relaying Russian ORLAN suit data to the ground through U.S. communication assets is undergoing engineering evaluation.

FORWARD WORK

The ISS Program will continue implementation of upgrades to the laptop computers and Ku-band systems to provide increased downlink bandwidth.

The change request to approve and implement additional external and internal structural sensors is being evaluated.

Ongoing efforts will continue to facilitate the additional telemetry accommodations for the automated rendezvous and docking of visiting vehicles such as the European ATV and the Japanese HTV.

Future avionics systems upgrades will be addressed by annual planning processes and the Integrated Space Operations Summit.

SCHEDULE

For the computer upgrade:

Responsibility	Due Date	Activity/Deliverable
ISS Program	Jun 04 (Complete)	Preliminary Design Review
ISS Program	Mar 05	Software Systems Review
ISS Program	Late 07	Delivery of first flight unit

For the Ku-band upgrade:

Responsibility	Due Date	Activity/Deliverable
ISS Program	Dec 03 (Complete)	Replace satellite link between White Sands and NASA centers with fiber-optic cable
ISS Program	Dec 05	Full 150 megabits per second

For the NGL:

Responsibility	Due Date	Activity/Deliverable
ISS Program	Mar 04 (Complete)	Deployment of NGL in Noncritical Operations
ISS Program	Sep 05	Deployment of NGL in Critical Operations

For the S-band Encryption and Low-Rate Audio:

Responsibility	Due Date	Activity/Deliverable
ISS Communi-cations and Tracking	2006	Delivery of first Flight Unit

For the truss-mounted structural sensors:

Responsibility	Due Date	Activity/Deliverable
ISS Vehicle Control Board	Mar 04 (Complete)	Recommendation presented to proceed with technical definition
ISS Program	Ongoing	Approval and implementation

Telemetry accommodations for visiting vehicles:

Responsibility	Due Date	Activity/Deliverable
ISS Program	Ongoing	Upgrade telemetry for new visiting vehicles

Columbia Accident Investigation Board

Recommendation 4.2-2

As part of the Shuttle Service Life Extension Program and potential 40-year service life, develop a state-of-the-art means to inspect all Orbiter wiring, including that which is inaccessible.

International Space Station (ISS) Corollary: Review the adequacy of risk mitigation measures for ISS wiring including flight/ground handling and state-of-the-art inspection means.

Note: The ISS response to Recommendation R4.2-2 was approved by the ISS Vehicle Control Board (VCB) in September and December 2004. All actions related to assuring implementation were closed and responsibility for ongoing management was assigned to the VCB.

BACKGROUND

While the Shuttle Program is able to take advantage of performing wiring inspections on the ground, the nature of the ISS system dictates that physical wiring inspections be performed on orbit. Internal wiring is susceptible to damage when it, or hardware nearby, is manipulated through normal daily activity on the ISS. However, the potential for damage is substantially lower than in the Shuttle Program, where almost all damage results from ground processing and repeated launch vibration. Plans are in place to perform routine wiring inspections of opportunity in high traffic areas as part of normal ISS systems maintenance. External wiring was designed to operate in the low Earth orbit environment, which includes hazards from micrometeoroids, orbital debris, atomic oxygen, ultraviolet radiation exposure, etc. In addition, the ISS is designed to have redundancy in critical systems. Controls are also in place to minimize manual cable handling prior to launch at Kennedy Space Center. Preflight testing during multi-element integrated tests verifies proper system-level electrical functionality.

ISS PROGRAM IMPLEMENTATION

Various means are used to control the risk of on-board wire damage. Wire insulation materials were selected to minimize materials aging. Almost all insulation is Teflon, Tefzel, or silicone, all of which last on the shelf for at least 30 years with negligible degradation. In addition, Kapton wiring was not utilized on the ISS vehicle. Also ISS crewmembers are trained to report hardware conditions that are out of the ordinary. When the crew is working in an area that has exposed wires, they report to the ground any time they see fraying or chafing of wires. Crew inspections have resulted in the ground being notified of wiring issues before the wiring problems induced problems with associated hardware. For example, the Service Module food warmer displayed signs of degradation of the protective covering of some wiring. Because the crew was trained to look for this type of anomalous situation, they reported the wiring degradation to the ground and corrective action was taken before any systems anomaly occurred.

Additionally, one function of the ISS Mission Evaluation Review team in the Mission Control Center is to review all telemetry data from the ISS for anomalous signatures. All anomalous signatures are investigated and, where wiring is a possible cause, inspections by the crew are given consideration by the anomaly resolution team.

Even though the ISS elements on orbit have only been in place for as many as five years, the ISS Program continually evaluates whether additional routine wiring inspections should be implemented in response to aging effects.

STATUS

The ISS Program has determined that its two-pronged inspection technique is sufficient for this phase of the ISS Program. These techniques can be summarized as:

1. Performing inspections of opportunity when wiring is exposed through normal daily activity or scheduled maintenance.
2. Relying on anomalous hardware signatures from the ISS detected on the ground from telemetry.

Wiring inspections are pursued whenever a branch of a fault tree suggests cabling is a possible cause of an anomalous signature.

The ISS Program assessed the risks of wiring aging and damage throughout the expected vehicle life. It found that present techniques and procedures for wiring inspection are adequate, but that constant attention to problem reports and quality surveillance are essential in identifying trends that can be attributed to aging.

A possible issue exists with long-term on-orbit radiation embrittlement of Teflon wire insulation located external to the vehicle. Based on analysis, the estimated life in the radiation environment is at least 10 years. Teflon wiring located internally and other wiring materials are not at risk.

Following an extensive trade study in fiscal year 2003, the ISS Program identified the current manual electrical cable test design as the most cost-effective method of identifying cable faults. The Program completed the design, certification, and delivery of its first flight manual electrical cable tester (MECT) in August 2004 for launch preparations. NASA has now implemented routine wiring inspections when preventive or corrective maintenance is being performed and has included the use of the MECT in its fault isolation procedures.

FORWARD WORK

Additional wiring inspection techniques and capabilities are continually assessed. Since the fiber-optic cable tester is already on board and a new wire cable tester has been completed, the ISS will use these techniques to periodically test the health of internal wires and the external wires out to the first set of external avionics. In addition the ISS Program continues to track the development of new wire inspection tools such as those described in the Space Shuttle Return to Flight Plan.

Testing has been initiated to better understand the risks of long-term Teflon wire insulation embrittlement. This may result in modifications to crew procedures for handling and manipulating external wiring where aging is a concern.

The ISS Program will continue to evaluate, on a case-by-case basis, whether the ISS crews need additional training to evaluate wiring against specific criteria and/or include wiring criteria within maintenance procedures. The recent experience with U.S. Laboratory window flex hoses (ref. Recommendation R6.4-1) demonstrates the need for continual surveillance of systems problems for which crew training may be a contributing factor.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	2004 (Complete)	Assess ISS wiring aging and inspection processes
ISS Program	Aug 04 (Complete)	Complete design, certification, and delivery of first flight MECT to NASA
ISS Program	Nov 04 (Complete)	Develop test plan for evaluating Teflon wire insulation life characteristics
ISS Program	Ongoing	Assess wiring aging risks and recommend needed actions

Columbia Accident Investigation Board

Recommendation 4.2-1

Test and quality the flight hardware bolt catchers. [RTF]

International Space Station (ISS) Corollary: Assess the adequacy of the ISS flight hardware nondestructive evaluation (NDE) processes for ground testing of safety critical structures.

Note: The ISS response to Columbia Accident Investigation Board Recommendation R4.2-1 was dispositioned by the ISS Program in December 2004. Ongoing management of this subject is the responsibility of the Vehicle Control Board (VCB).

BACKGROUND

The ISS Program's interpretation of this recommendation focuses on the assurance of proper analysis and testing of safety critical structures such as pressurized crew modules. For such structures, the ISS risk control philosophy calls for design to minimum risk. All habitable pressurized modules are also designed and verified for leak-before-burst performance. This is done to ensure that any initial flaw will only grow through the wall of a pressure vessel and cause safely manageable leakage rather than catastrophic rupture. Formal requirements, analysis, and testing help ensure adequate structural safety.

ISS PROGRAM IMPLEMENTATION

Top-level programmatic documents such as SSP 41000 (System Specification for ISS) ensure that all relevant requirements are imposed upon ISS hardware suppliers. For example, all pressurized elements of the U.S. segment of ISS are designed to have positive margins of safety as defined in SSP 30559 (Structural Design and Verification Requirements). For pressurized modules, these margins are typically 1.5 for proof pressure, 1.65 for yield, and 2.0 for ultimate pressure. To prevent a catastrophic failure of pressurized modules, primary structures are designed to have a safe life in accordance with SSP 30558 (Fracture Control Requirements for Space Station) and SSP-30233 (Space Station Requirements for Materials and Processes).

Verification of structural safety is commonly assured by stress analysis, loads testing and NDE of susceptible structures. Stress analysis is performed to verify that the pressurized elements have positive margins of safety using the appropriate factors of safety. The flight units of pressurized modules undergo proof pressure testing and post-test inspections. Special structural test articles are also often used to verify ultimate pressure limits.

All "safe life" structures require a fracture mechanics analysis and a design approach that complies with a Fracture Control Plan that has been approved by NASA. Fracture mechanics analysis determines the maximum allowable flaw size that could exist in the structure that will not allow flaw growth to failure in four lifetimes. For domestically provided modules, crack growth analysis is performed using the NASA/FLAGRO computer program. A fracture control summary report addresses the flaw size and type of nondestructive inspection for which safe life analysis is performed. Leak-before-burst analysis is included in these fracture control reports. International Partner modules have similar safe life requirements, although NDE testing has not been previously required.

Compliance with structural analysis, test, and inspection requirements is recorded in formal hazard reports that are managed by the ISS Safety Review Panel. Responsibility for technical assurance of structural safety also falls upon NASA's Structural/ Mechanical Working Group, its Fracture Control Working Group, and the VCB.

STATUS

All on-orbit safety critical ISS hardware has been satisfactorily designed, analyzed, tested, and operated. Existing domestic and internationally provided crew modules have been assessed and these results are formally documented.

Critical structures yet to be launched continue to be assessed and tested for safety assurance. As an example of this continued diligence, since the release of the *Columbia* accident report, the adequacy of NDE tests for pressurized modules has been questioned. For several International Partner provided modules, there were no initial requirements for NDE tests after proof pressure testing. In particular, the multi-purpose logistics modules (MPLM), Node 2, Node 3, and Columbus are affected by this ongoing study. Though past programmatic decisions approved this lack of NDE testing based on rationale such as existence of cabin pressure relief valves and the ability to detect flaw growth, concerns have been renewed about the overall life of these structures. Although the probability of a real issue is low based on the lack of flaws found during Node 3 inspections, additional testing and analysis has been authorized by the ISS Program Manager. The NASA Engineering and Safety Center (NESC) supports this additional testing and analysis, which will be completed prior to the launch of each module.

FORWARD WORK

Prior to launch, NASA will complete implementation of improved analysis and inspection of new pressurized modules. All efforts at assuring ISS structural inspection and safety will be implemented by normal ISS processes and organizations.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Jan 04 (Complete)	Request for support from NESC for pressurized module NDE
ISS Program	Dec 04 (Complete)	Approval of test and analysis plans for MPLM pressure shells
ISS Program	Prior to module launch	Structural testing and analysis of new pressurized modules

Columbia Accident Investigation Board

Recommendation 4.2-3

Require that at least two employees attend all final closeouts and intertank area hand-spraying procedures. [RTF]

International Space Station (ISS) Corollary: Review the adequacy of ISS preflight inspection processes to ensure at least two persons participate in all critical inspections at Kennedy Space Center (KSC) and other locations.

Note: The ISS response to Recommendation R4.2-3 was approved by the ISS Safety and Mission Assurance Panel (S&MAP) on September 23, 2004. All responsibility for ongoing management of related audits and surveillance is assigned to the S&MAP.

BACKGROUND

External Tank final closeouts and intertank area hand-spraying processes typically require more than one person in attendance to execute procedures. Although those closeout processes currently able to be performed by a single person did not necessarily specify an independent witness or verification, that is not the case for ISS closeouts. For the ISS, standard processing practices at all ISS contractor/government facilities, including but not limited to Marshall Space Flight Center (MSFC), Johnson Space Center (JSC), and KSC, require independent witness verification per established Letters of Delegations and Memorandums of Agreement.

ISS PROGRAM IMPLEMENTATION

ISS procedures were reviewed to confirm that requirements are adequately defined and implemented. MSFC, JSC, and KSC use similar procedures to ensure that all critical processes are witnessed by someone other than the person performing the task. Usually, contractor and government quality assurance personnel are in attendance during all processing activities. Critical inspection processes are defined as those that prevent safety or other significant processing impacts. For example, painting a logo on an element would not be considered critical for witnessing by Quality personnel, but the application of a corrosion-prevention coating would require an additional witness. Quality personnel at all sites use sampling inspection approaches as well as surveillance. There are multiple layers of oversight used to mitigate risks to the ISS Program. Defense Contract Management Agency is also used as another quality "leg of redundancy" to oversee activities throughout the ISS Program, including at some International Partner locations.

For example, in accordance with ISS Program requirements, the ISS closeout procedures at KSC are documented in KSC ISS/Payload Processing Standard Practices and Procedures (SPP) Q-16, Flight Closeouts and Configure for Test. The rigorous two-step process to flight closeouts is described in this document and applies to all ISS Program hardware processed at KSC. NASA/ISS Program personnel and the Checkout Assembly and Payload Processing contractor currently close out areas with Work Authorization Documents (WADs) that require both NASA and Boeing quality assurance stamps.

The ISS Program has strict guidelines for what will be documented in the WAD, including assurance that closeout photos are taken and that both government and contractor quality assurance personnel accept the closeout. At KSC, final area closeouts are performed by a team that includes representatives from Engineering, Materials and Process Engineering, Imagery, NASA and Boeing Quality Assurance, and the Vehicle Integration Test Team. If changes to closeouts are required, a new WAD is created referencing the previous closeout WAD and requiring that all disciplines re-perform their closeouts. If a revised WAD is determined to be simply a "delta closeout," Boeing Engineering and Boeing and government Quality Assurance are mandatory witnesses and are charged, per SSP Q-16, to determine whether Materials and Processing Engineering, Flight Crew representatives, or others are also required. Any rework will automatically require closeout photography. ISS preflight closeout imagery is further discussed in the response to R10.3-1.

STATUS

Existing ISS procedures for processing Boeing hardware have been reviewed and determined to meet the *Columbia* Accident Investigation Board recommendation for quality control of critical procedures. SSP Q-16, a KSC, NASA, and Boeing closeout procedure that is applicable to all ISS hardware processed at KSC, has been developed and released.

FORWARD WORK

Continuation of normal audits and surveillance of ISS preflight closeout processing at applicable locations.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
KSC	Aug 04 (Complete)	Completed KSC Standard Practice and Procedure Q-16
ISS S&MAP	Sep 04 (Complete)	ISS S&MAP acceptance of KSC plans
ISS S&MAP	Ongoing	Continued audits and surveillance of ISS processing sites

Columbia Accident Investigation Board

Recommendation 4.2-4

Require the Space Shuttle to be operated with the same degree of safety for micrometeoroid and orbital debris as the degree of safety calculated for the International Space Station (ISS). Change the micrometeoroid and orbital debris safety criteria from guidelines to requirements.

International Space Station (ISS) Corollary: Review the adequacy of ISS micrometeoroid and orbital debris (MMOD) protection requirements and implementation.

Note: The ISS response to Recommendation R4.2-4 was approved by the ISS Program Integration Control Board (PICB) on September 1, 2004. All actions related to assuring implementation were closed and responsibility for ongoing management was assigned to the PICB.

BACKGROUND

MMOD is recognized as a continuing concern for the ISS, the Shuttle, and other spacecraft. The current differences between the ISS and Shuttle risk for critical damage from MMOD are based on the original design specification for each vehicle. The ISS was designed for long-term exposure to both micrometeoroids and orbital debris, whereas the original Shuttle design specification was to provide short-term protection from micrometeoroids only because there was not any recognized threat from orbital debris until the late 1980s (i.e., well after Shuttle design was completed). ISS requirements call for a no more than 1:20 or 5% risk of loss of crew/vehicle, and no more than a 24% risk of non-catastrophic shield penetration across all pressurized modules and external stored-energy devices, over a 10-year life. To meet these ISS requirements, robust shielding protection and operational procedures are in place on ISS, and additional shielding protection will be implemented during upcoming assembly missions to reduce the risk of MMOD-induced threats to the crew and vehicle. ISS hardware is designed to allow MMOD shielding to be augmented over the life of the Program and this attribute has been used in augmenting the MMOD protection for the ISS *Zvezda* Service Module (SM). As enhanced shielding protection is provided on Progress and Soyuz vehicles, overall protection requirements will be fully met.

MMOD risks are predicted for two criteria of severity. The least risk concern is a "penetration" of shielding causing a hole in the pressure shell resulting in an air leak. Such leaks may be safely located and patched, or isolated by closing hatches, or could result in crew evacuation via Soyuz if the hole is too big to patch or isolate safely. The highest risk concern is for "catastrophic" penetrations that could lead to loss of crew due to rapid cabin depressurization or high-energy fragmentation (pressure vessels, module shell, control moment gyros). Assessments indicate that if any penetration were to occur, it is much more likely to be survivable then catastrophic. There is approximately a 1 in 6 chance that a penetration, if it were to occur, would be "catastrophic."

Additional background information on ISS MMOD design, analysis, and testing is accessible at http://hitf.jsc.nasa.gov/hitfpub/main/index.html.

ISS PROGRAM IMPLEMENTATION

NASA has implemented a three-pronged approach to reducing risks to the vehicle and crew from MMOD on ISS:

1. Implementing robust meteoroid/orbital debris shielding on the habitable modules where the crew lives and works, as well as on all external propellant tanks, pressurized vessels, and control moment gyroscopes. ISS shields are extensively tested in ground-based hypervelocity impact facilities and configurations modified to improve protection performance prior to flight.
2. Performing collision avoidance maneuvers during ISS operations to prevent impact from all orbital debris that can be tracked from the ground using U.S. Air Force-supplied data.
3. Developing leak detection and repair contingency procedures and risk mitigation techniques in the event an MMOD impact causes a leak in the pressure shell of the habitable modules. For instance, on-board atmospheric pressure sensors enable initial detection of a significant leak above normal losses and handheld ultrasonic tools aid in locating internal leaks. Detection

improvements in work include a new fiber-scope for difficult access areas and refurbishment and delivery of an existing trace gas analyzer for finding ammonia leaks. Effort also continues to identify a new nitrogen pressure sensor and infrared camera. While locating small leaks can be difficult (due to surrounding structures, audibly active mechanisms, and normal atmospheric flows); when an actual leak site is found, patch kits are on orbit that might temporarily seal a small leak from inside the ISS modules. More effective and permanent internal and external patches are being studied. A repair kit for external fluid lines is also being refined (Figure 4.2-4-1). Crew training and ground operational procedures are in place to react properly to a depressurization event (e.g., verify valves are properly closed, listen with sensitive audible sensors, isolate portions of the cabin, conduct internal repairs, and evacuate the ISS if warranted).

The MMOD shields on ISS are the most capable shields ever developed and flown on a spacecraft. An example of the shielding used to protect the U.S., Japanese, and European habitable modules is given in Figure 4.2-4.2. These shields measure 4 in. to 6 in. from inside to outside; and they consist of multiple layers of aluminum, ceramic cloth, and ballistic protection fabrics (i.e., "bullet-proof" materials). The Russian-provided *Zarya* Functional Cargo Block (FGB) module is protected by different shielding configurations but with similar protection capability as the U.S. shielding. The approach to *Zvezda* SM shielding is to launch with minimal shielding and outfit the module with "augmented" shielding on orbit by extravehicular activity (EVA). SM shield augmentation has begun, with some augmentation shields in place and others to be added after Shuttle return to flight. Figure 4.2-4.3 illustrates SM augmentation shields. Recent agreements will deliver additional conformal panels on mission 13A.1 and deployable shields on UF4 or UF4.1. There are plans to position the SM solar arrays in a near-vertical orientation after mission 12A.1 to provide MMOD shielding if power is supplied to the Russian segment by the U.S. segment. In addition, NASA and our Russian Partners are developing plans to enhance MMOD protection of Soyuz and Progress vehicles (Figure 4.2-4-4). Hypervelocity impact tests and analysis have been performed that demonstrate significant reductions in MMOD risk for these vehicles (by a factor of five) by adding approximately 25 kg of additional shielding on the ground. Russia's *Pirs* Docking Compartment (DC) module is also being studied for protection enhancements.

An international group led by the ISS Program is coordinating plans for development of improvements to the leak detection and repair capabilities. This includes both internal and externally applied solutions.

STATUS

MMOD shielding design and implementation is completed for the FGB, Pressurized Mating Adapters (PMAs), U.S. Laboratory Module, airlock, control moment gyros, and external pressurized tanks. If the cupola is relocated to Node 3 as planned, the port face of Node 1 will require MMOD augmentation in the form of a relocated PMA-3 or a new cover.

Final shield testing, evaluation, and verification are ongoing for hardware to be delivered to ISS in future, including Node 2, cupola, Node 3, Centrifuge Accommodation Module, and European and Japanese modules. As added protection, internal covers are being considered for selected windows of Node 2, Node 3, and Japan's pressurized module.

Initial augmentation of SM shielding is complete. Although waivers are currently in place, efforts are under way to implement additional MMOD protection for the SM, DC, Progress and Soyuz vehicles. Though implementation is contingent upon funding, RSC-Energia and NASA have demonstrated via impact testing a technical solution for reducing Soyuz and Progress MMOD risks by a factor of five. Internal covers for SM windows are also being assessed.

(Typical Configurations Illustrated)

- U.S., Japanese, and European modules employ "Stuffed Whipple" shielding on the areas of their modules exposed to the most impacts from orbital debris & meteoroids (i.e., red areas of graphic – forward and sides)
  - Nextel™ ceramic cloth and Kevlar™ fabric materials used in the intermediate bumper
  - shielding capable of defeating ~1.3cm aluminum sphere at 7 km/s, normal impact

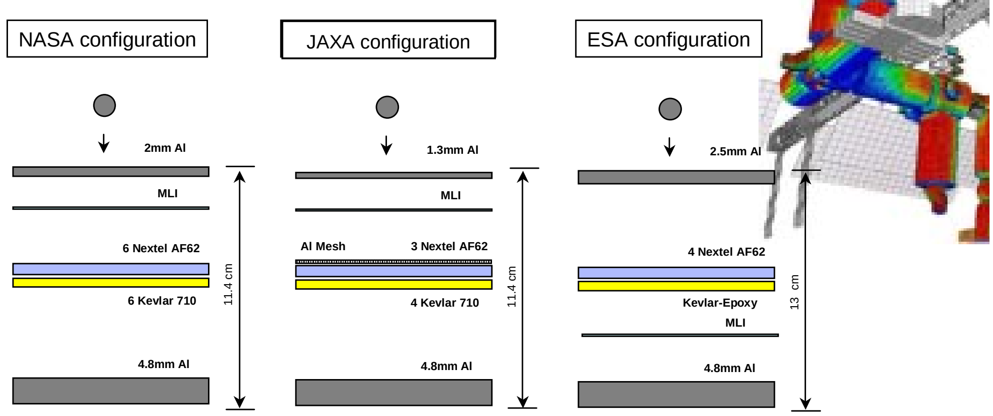


Figure 4.2-4-2. Typical MMOD shielding configuration for U.S., European, and Japanese modules

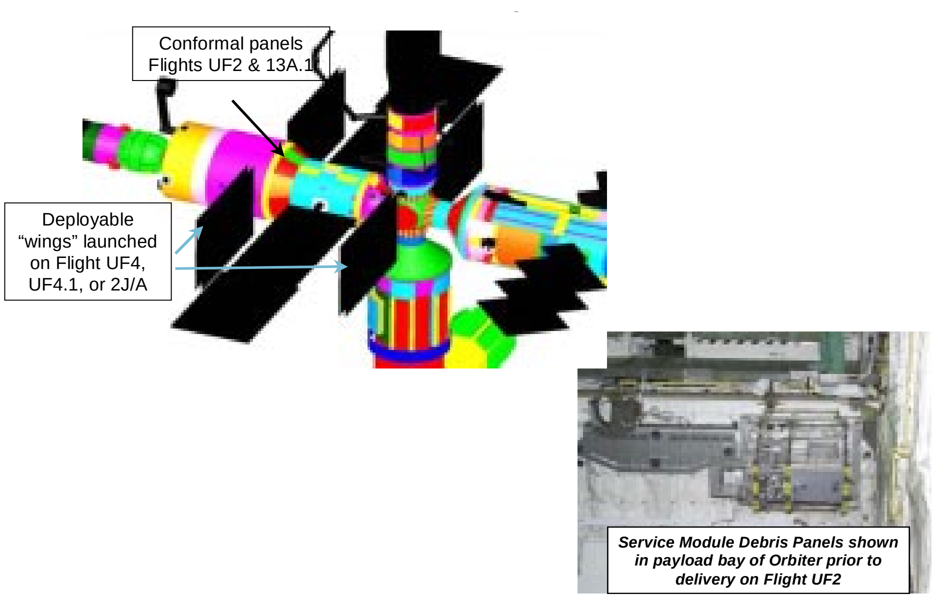


Figure 4.2-4-3. Russian SM augmentation shields.

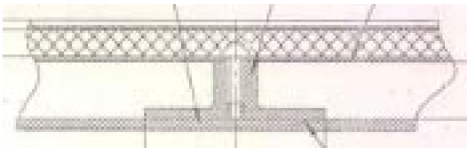


Figure 4.2-4-4. Concept for improved MMOD shields for Soyuz and Progress vehicles

The following table of risks indicates that ISS will meet MMOD safety requirements for both penetration and catastrophic penetration events given successful completion of the above plans to enhance SM, Progress, and Soyuz protection. This table is for the first decade of ISS operations (First Element Launch + 10 years) because ISS MMOD requirements are currently baselined for this time period.

Predicted ISS MMOD Risks For 10-year Time Period from First Element Launch (1998 – 2008)		
	Penetration Risk	Catastrophic Risk
ISS with no SM augmentation, no Progress/Soyuz enhancement	40% (PNP=0.6)	7% (PNCP=0.93)
ISS with SM augmentation (UF2, 13A1, UF4, or UF4.1)	32% (PNP=0.68)	6% |(PNCP=0.94)
ISS with SM augmentation and Progress/Soyuz enhancement	24% (PNP=0.76)	4% (PNCP=0.96)
Requirements	≤ 24% (PNP=0.76)	≤ 5% (PNCP=0.95)

The benefits for SM augmentation and Soyuz/Progress MMOD protection enhancement are seen more in the second decade of ISS operations. This is because of the time that SM and Soyuz/Progress are unaugmented in the first decade. ISS requirements for MMOD protection are not currently established for the second decade.

The ISS Program is also assessing an option to better control MMOD risk while the Shuttle is mated by selecting a –XVV orientation for flights starting with LF1 (STS-114).

NASA uses the BUMPER computer model to assess MMOD risks for ISS, which incorporates the latest meteoroid and orbital debris environment definitions as well as shield performance equations (or "ballistic limit equations") that are verified by extensive hypervelocity impact testing. BUMPER undergoes regular updates to assess MMOD effects from changes in ISS configuration, assembly sequence, flight attitudes, and shielding ballistic limit equations. Periodically (about every five years), the orbital debris environment model is also updated to reflect data gathered and analyses performed on the changing debris environment. ORDEM2000 is the best available environmental model of orbital debris and is the basis for the ISS risk assessment. ORDEM2000 was incorporated in BUMPER in 2002.

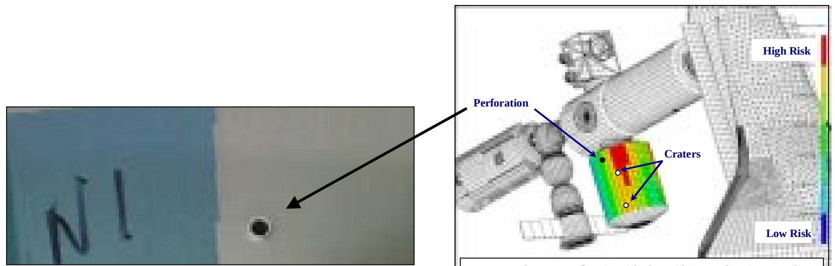
As part of the effort to identify and trend actual MMOD impact effects on ISS, NASA has implemented regular inspections of all ISS windows. The ISS Program is also using the Shuttle-returned Multi-Purpose Logistics Module (MPLM) to study representative MMOD effects and mitigation performance (Figure 4.2-4-5). NASA is further implementing regular inspections of other external surfaces, such as the large radiators that are attached to the ISS truss. NASA is in the process of gathering and interpreting external data sources (such as on-board camera views) to further correlate predicted data with actual observations.

The implications of the evolving debris environment posed by the ORDEM 2000 model are being studied for possible U.S. EVA suit protection improvements. Candidate materials that add protection without degrading crew mobility were reported to the EVA Configuration Control Board in April 2004, and hypervelocity impact and mobility testing to evaluate these candidates has been initiated.

At the request of ISS management, the NASA Engineering and Safety Center (NESC) is investigating improved methods and detecting and analyzing cabin pressure leaks. Inputs from this study will augment ongoing team reviews of basic ISS leak detection, isolation, and repair capabilities for modules, hoses, and fluid systems. The NESC is also conducting an independent validation of the computer code in the BUMPER model.

FORWARD WORK

NASA is working with our Russian Partners to expeditiously implement augmented shielding for SM and enhanced protection for Progress and Soyuz. Current planning for expedited MMOD shielding calls for SM augmentation shielding to be delivered on ISS flights 13A.1 and UF-4 or UF-4.1. Soyuz MMOD enhancement could be available as early as ISS flight 12S.



5A.1: 1.4mm diameter through-hole, 2.5mm diameter exterior crater

Impact damage occurred near predicted high-risk area

Figure 4.2-4-5. MPLM On-orbit Impact damage

Actual MMOD damage found after five flights: two perforations in outer bumper shield and 26 craters. Predicted damage using ISS BUMPER code matches closely with actual damage distribution and quantity.

Progress protection enhancement may be available as early as ISS flight 21P. Improvements to ISS leak detection and repair capabilities continue to be pursued. Mitigation of ISS MMOD risk impacts is captured in the ISS Risk Management Application for U.S. and International Partner modules, NASA spacewalk suits, Space Shuttle and ISS docked operations, and leak detection/repair capabilities.

NASA is also aware of the potential risks to the ISS from future planned Missile Defense Systems managed by the U.S. Department of Defense. The ISS Program is assessing the draft Environmental Impact Statement at http://www.acq.osd.mil/mda/mdalink/html/enviro.html and will provide comments as required.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program (Space Station Program Control Board)	Apr 04 (Complete)	Review recommendation to reorient mated ISS and Shuttle
ISS Program and NESC	May 04 (Complete)	Report results of study of cabin leak detection, analysis, and repair methods
ISS Program	Sep 04 (Complete)	Approved extension of waivers for existing Soyuz, Progress, and DC MMOD protection
ISS Program and NESC	Ongoing	Validation of BUMPER codes
ISS Program	Ongoing	Continue MMOD shielding assessments for U.S. elements and implement improvements (e.g., Node 2/3 window covers)
ISS Program	Ongoing	Coordinate with Russian partners on MMOD shielding improvements
ISS Program	Ongoing	Continue to pursue improved leak detection and repair capabilities

Columbia Accident Investigation Board

Recommendation 4.2-5

Kennedy Space Center Quality Assurance and United Space Alliance must return to the straightforward, industry standard definition of "Foreign Object Debris," and eliminate any alternate or statistically deceptive definitions like "processing debris."

International Space Station (ISS) Corollary: Review the adequacy of ISS preflight processes to ensure that foreign object debris (FOD) definitions and risk mitigation measures at Kennedy Space Center (KSC) and other locations meet proper standards.

Note: The ISS response to Recommendation R4.2-5 was approved by the ISS Program Safety and Mission Assurance Panel (S&MAP) on October 13, 2004. All actions related to assuring implementation were closed and responsibility for ongoing management was transferred to the ISS Vehicle Control Board (VCB) in coordination with the S&MAP.

BACKGROUND

In 2001, KSC Shuttle Processing re-categorized FOD into two categories, "processing debris" and "FOD." FOD was defined as debris found during the final or flight closeout inspection process. All other debris was labeled processing debris. The categorization and subsequent use of two different definitions of debris led to a perception that processing debris was not a concern. The ISS Program never used the two Shuttle definitions of debris and, consistent with standard aerospace practice, debris found at any stage during ISS processing at KSC and prior to delivery to KSC (including what Shuttle called "processing debris") is considered to be FOD. The FOD definitions, requirements, and approach throughout all ISS Program participants (KSC, Johnson Space Center (JSC), Marshall Space Flight Center (MSFC), and all other Program facilities) are consistent and led by the ISS Materials and Processes (M&P) Team.

ISS PROGRAM IMPLEMENTATION

An independent assessment of how FOD is treated within ISS facilities was conducted and resulted in several recommended improvements to the ISS FOD program.

For KSC, as the responsible contractor for payload processing, the Checkout Assembly and Payload Processing Services contractor maintains all elements of a formal FOD program, including identification, prevention, control, and correction. Their responsibilities exclude metrics and trend analysis. For ISS hardware, all contractors are bound to specific ISS Program cleanliness requirements such as are defined in *Space Station External Contamination Control Requirements* (SSP 30426) and Contamination Control Requirements (SN-C-0005). For example, these requirements flow down to local KSC Standard Practices and Procedures (SPP) cleanliness requirements, such as Payload Processing Work Area Rules (SPP O-01) and KSC Payload Facility Contamination Control Requirements Plan (K-STSM-14.2.1). These standards maintain the proper policy and procedures that address FOD and contamination prevention, control, and correction. Specific areas addressed in these standards include work area surveillance and rules, FOD barriers, roles and responsibilities, tool controls, garments and gowning, equipment and material controls, access controls, walkdowns and inspections, ingress and egress monitoring, employee awareness, and training.

Even though a robust contamination control process is already in place, ISS M&P engineers will evaluate its consistency with Shuttle FOD Control Plans under development and evaluate possible additions of metrics and trend analysis.

STATUS

ISS Program M&P engineers completed an evaluation of whether Program-level requirements documents need to be changed to standard FOD definitions with the Shuttle Program, and whether metrics and trend analysis should be required. As a result of this evaluation, a proposed ISS Foreign Object Damage/Foreign Object Debris Prevention Program requirements document was developed. ISS Program M&P engineers from JSC, MSFC, and KSC participated in the development of the document. Implementation of these requirements will meet or exceed industry standards, such as National Aerospace Standard 412 (NAS 412), Foreign Object Damage/Foreign Object Debris Prevention.

In mid 2003, an element of the ISS currently undergoing processing for launch was found to contain an excess amount of FOD. The ISS Program developed and approved an FOD removal plan at the November 3, 2003 VCB and at the March 2, 2004, Space Station Program Control Board. The element, Node 2, is undergoing pre-launch checkouts using an FOD removal plan approved by the Program. As a result of the finding of FOD in Node 2, the processing flow has been adjusted to allow engineers the opportunity to remove as much FOD as possible without major module disassembly prior to Node 2 launch. However, not all Node 2 FOD can be removed because of access issues. Therefore, during initial on-orbit entry of Node 2, the crew will have to be protected from remaining FOD with goggles and extra air filtration time. The ISS Program accepted the risk resolution plan associated with the Node 2 FOD problem. Improvements are being made to ensure that Node 3 does not have similar issues.

The ISS Program released an interim policy for implementing an FOD Prevention Program at KSC for ISS operations based on the proposed ISS requirements. KSC then modified the existing KSC ISS/Payloads Processing Contamination Control Program to satisfy the ISS interim policy.

FORWARD WORK

ISS assembly elements, logistical carriers, and science experiments are provided by many different developers; i.e., NASA, International Partners, ISS contractors, vendors, commercial science entities, and academia. Per a future change directive, NASA will baseline FOD Prevention Program requirements on each of these hardware developers, operators, and maintainers to ensure a consistent and effective approach to FOD control.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Mar 04 (Complete)	Accept risk resolution plan for Node 2 FOD removal
ISS M&P at JSC	Sep 04 (Complete)	Evaluate need for ISS Program-wide FOD Prevention Program requirements
ISS Program	Jan 05 (Complete)	Task KSC to implement interim ISS FOD requirements
NASA KSC	Jan 05 (Complete)	Implement interim ISS requirements (KSC Joint Program Directive)
ISS M&P at JSC	Feb 05	Establish ISS FOD Prevention Program requirements (Final Draft)
ISS Program	May 05	Implement FOD requirements per Change Directive
ISS M&P	Jun 05	FOD Prevention Program requirements coordinated with all Program Participants
ISS Program	Jul 05	Begin acceptance-audit responses implementation

Columbia Accident Investigation Board

Recommendation 6.2-1

Adopt and maintain a Shuttle flight schedule that is consistent with available resources. Although schedule deadlines are an important management tool, those deadlines must be regularly evaluated to ensure that any additional risk incurred to meet the schedule is recognized, understood, and acceptable. [RTF]

International Space Station (ISS) Corollary: Review ISS management tools including schedule and resource assessment processes to ensure that programmatic risks and margins are well understood and mitigated.

Note: The ISS response to Recommendation R6.2-1 was approved by the Space Station Program Control Board on October 4, 2004. All actions related to assuring implementation were closed and responsibility for ongoing management was assigned to the ISS Program Planning and Control Office.

BACKGROUND

Schedules are integral to program management and provide for the integration and optimization of resource investments across a wide range of connected systems. The ISS Program is just such as system, and it needs to have a visible schedule with clear milestones to effectively achieve its mission. The ISS Program has emphatically stated that it will not compromise system safety in any effort to optimize schedules. All activities are associated with very specific milestones that must be completed for mission success. If these milestones can be accomplished safely, the scheduled activities occur on time. If a milestone is not accomplished, the schedules are extended consistent with the need for safety assurance. ISS Program management requires greater insight into Program status than that provided by schedules alone. ISS has implemented a suite of program control tools and processes to monitor schedule-budget compatibility, elevate Program risks, and ensure that system and mission safety are not compromised in an effort to optimize integration.

The current ISS on-orbit configuration for a crew of two is stable and does not drive any particular Shuttle return to flight launch date. The ISS Program is actively maintaining assembly hardware processing activities at Kennedy Space Center (KSC) to ensure that ISS hardware is ready to support assembly when the Space Shuttle returns to flight.

ISS PROGRAM IMPLEMENTATION

To support NASA's priorities of safe and effective operations, the ISS Program maintains a development and operations schedule that is consistent with available resources.

Recent management changes in NASA's key human space flight programs contribute to ensuring that flight schedules are appropriately maintained and amended. In 2002, the Office of Space Flight established the position of Deputy Associate Administrator for International Space Station and Space Shuttle Programs (DAA for ISS/SSP) to manage and direct both programs. This transferred the overall program management of the ISS and SSP from Johnson Space Center (JSC) to Headquarters (figure 6.2-1-1). The DAA for ISS/SSP was given accountability for the execution of the ISS and Space Shuttle Programs, the authority to establish requirements, direct program milestones, assign resources, and award contracts and contract fees. The 2004 reorganization of NASA Headquarters Office of Space Flight to the Space Operations Mission Directorate has not changed this area of responsibility.

As illustrated in figure 6.2-1-2, the Office of DAA for ISS/SSP employs an integrated resource evaluation process to ensure the effectiveness of both programs. Initial resource allocations are made through the annual budget formulation process. At any given time, three fiscal year budgets in work: the current fiscal year budget, the presentation of the next fiscal year Presidential budget to

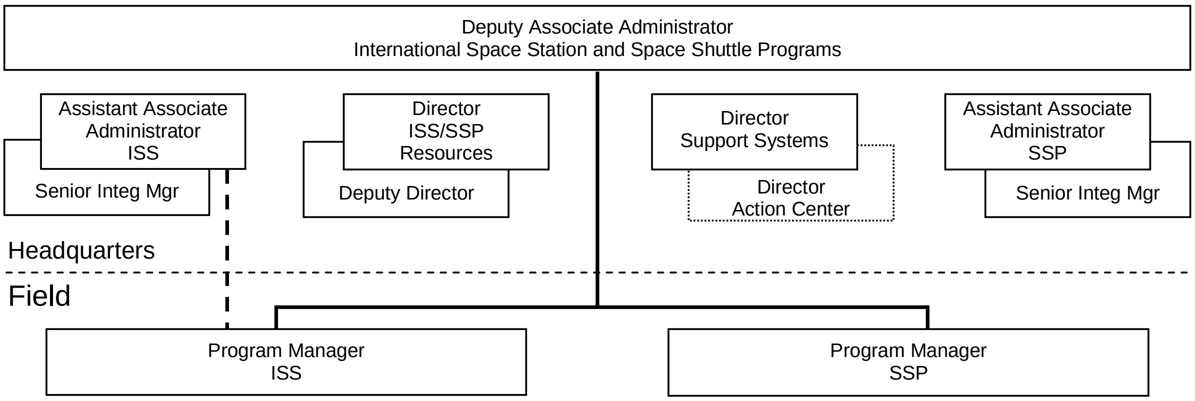


Figure 6.2-1-1. Office of Deputy Associate Administrator for International Space Station and Space Shuttle Program (Code M-1) is organized to maximize performance oversight

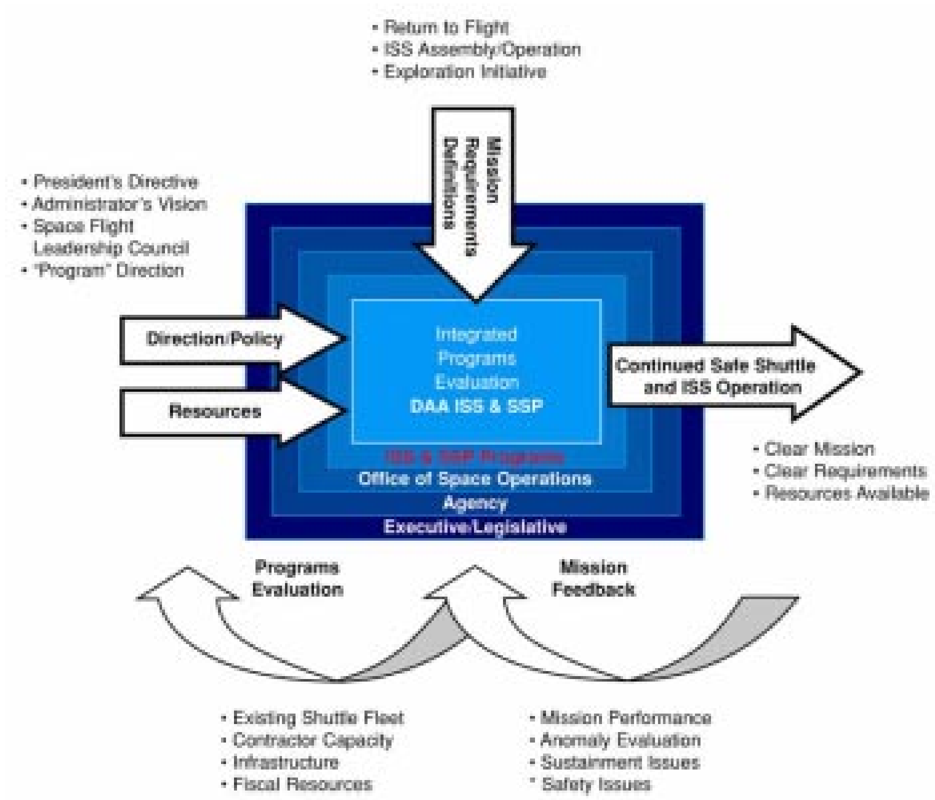


Figure 6.2-1-2. Integrated Resource Evaluation Process is used by NASA Headquarters, Code M-1

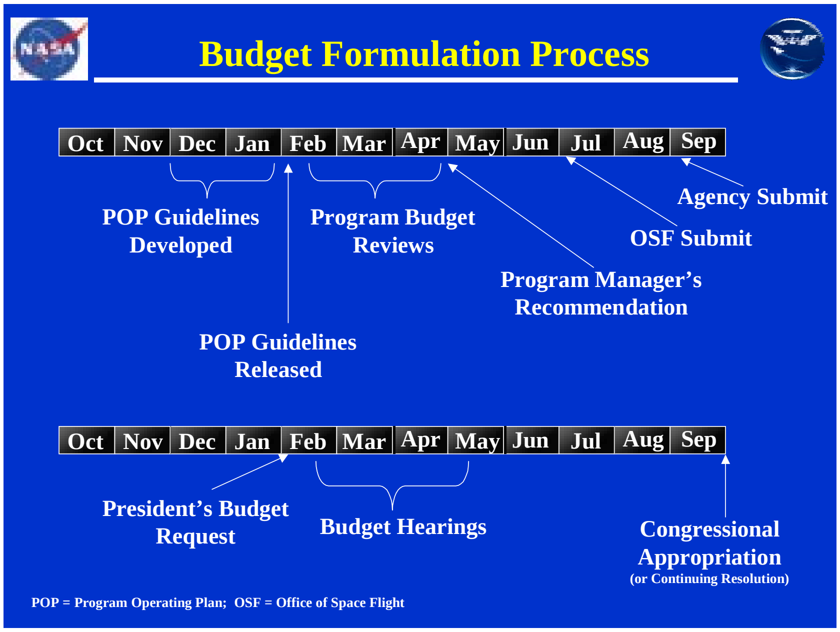


Figure 6.2-1-3. Office of Deputy Associate Administrator for ISS and SSP annual budget formulation process

Congress, and preparation of budget guidelines and evaluation of budget proposals for the follow-on year. This overlapping budget process, illustrated in figure 6.2-1-3, provides the means for reviewing and adjusting resources to accomplish ongoing schedules of activities with acceptable risk.

The ISS and Shuttle Programs' top-level schedules are also integrated and assessed for risk through actions of the Joint (Shuttle-Station) Program Requirements Control Board. Furthermore, through implementation of several ISS Program control processes and tools (such as the Program Risk Advisory Board), technical, cost, and schedule risks and their mitigation plans are assessed regularly. The ISS Monthly Program Review (IMPR) ties technical, cost, and schedule status together for each performing organization and the Program as a whole, using data collected and assessed through tools and processes developed by an office created expressly to implement new Program control techniques. The IMPR comprises, in addition to in-depth reviews of integrated Shuttle-Station schedules, a detailed technical, cost, and schedule status of the ISS Program using the Web-based One NASA Management Information System (MIS) situational awareness tool available internally at http://nasas-mis.nasa.gov/nasa_mis. The ISS data in the One NASA MIS enable senior managers in the Space Shuttle and ISS Programs to review performance indicators and risk assessments on a near-real-time basis (figure 6.2-1-4). Central to this dataset are the key Program performance indicator metrics, sorted by red-yellow-green urgency and impact coded arrows, and backed by more detailed, manager-level performance metrics. These metrics include a Program-wide Performance Measurement System based on earned-value management concepts and technical, cost, and schedule risk status directly from the ISS Risk Management Application (IRMA).

In addition to the IMPR, the ISS Program management team receives an Early Warning System (EWS) monthly report that includes in-depth assessments of ISS business data (tied to schedule and technical status), Performance Measurement System, the One NASA MIS performance indicators, and a quantitative risk assessment of those IRMA risks that are on the official ISS threats list. Special assessments are performed as needed and documented either as special sections of the EWS or as standalone reports. All EWS reports and other ISS assessment products are accessible via the One NASA MIS.

Overall Shuttle and ISS schedules must be approved by the DAA for ISS/SSP and the Space Flight Leadership

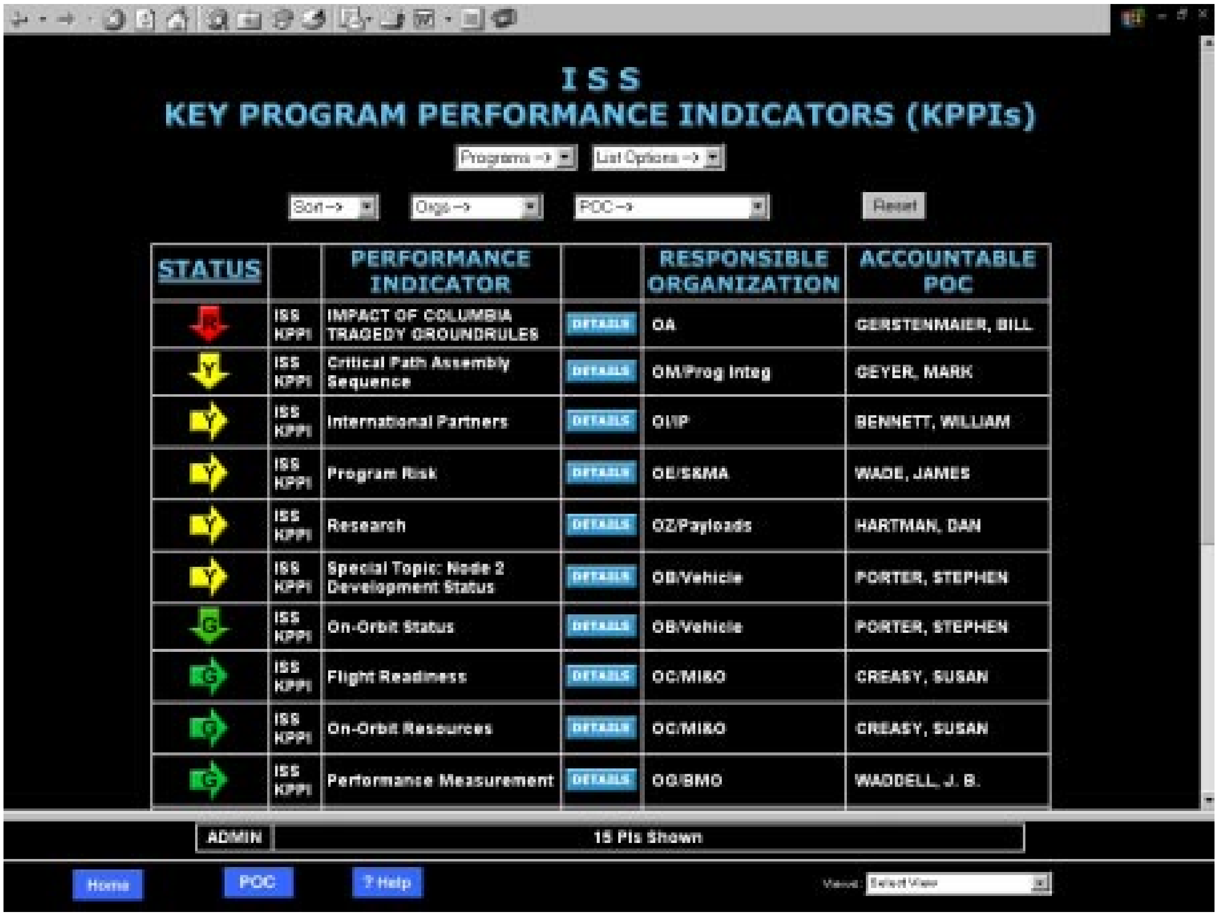


Figure 6.2-1-4. ISS key Program performance indicators

Council. The staff of the DAA for ISS/SSP also conducts daily tag-ups with Program management.

STATUS

Assessments of technical, cost, and schedule issues and risk are continually ongoing to provide ISS management with the increased information necessary to support Shuttle return to flight decisions.

During this time of return to flight preparations, ISS has accumulated many elements ready to fly that are being stored and maintained at KSC as depicted in figure 6.2-1-5. Some of the additional international elements arrived in 2004 and will continue to undergo launch preparations. This state of readiness is a positive influence upon schedules and resources once assembly resumes.

Figure 6.2-1-5. ISS elements awaiting launch at KSC

Due to the new Space Exploration Vision, which will retire the Space Shuttle after ISS assembly, extensive effort is under way to develop and coordinate a new assembly sequence that is accepted by all International Partners. On July 23, 2004, NASA and its International Partners unanimously endorsed a new plan for ISS completion by the end of the decade. This plan will accommodate on-orbit elements from each of the Partners and enable increased utilization with early opportunities for an enhanced crew of greater than three people. This endorsement provides a clear basis for completion of programmatic and financial evaluations with subsequent agreements to be reached on a transportation and logistics framework that will support the assembly and operation of ISS. Russian Soyuz vehicles, the U.S. Space Shuttle, and automated logistics resupply/reboost capabilities will support this framework with the aid of existing Russian Progress vehicles and new transfer vehicles being provided by Europe and Japan. When the new Crew Exploration Vehicle is available, it will also be an option for providing ISS support. This plan will achieve the goal of separating crew and cargo to the ISS to the maximum extent practical. Additional assessments are to be conducted in 2005 to confirm this flight program, to evaluate opportunities to accelerate the launch of the Japanese and European research modules, and to establish a specific schedule to enhance the permanent crew size. NASA and the Russian Federal Space Agency (Roscosmos) reconfirmed their commitment to individually and cooperatively support continuous human presence on the ISS in 2005 (negotiations of the 2005 Soyuz crew rotations were completed in September 2004 and formally approved in January 2005). The results of ongoing assessments were reviewed and again endorsed at the January 26, 2005, Heads of Agency meeting.

In cooperation with the Shuttle Program, ISS has modified its plans for several missions to focus on safety-related efforts. Assembly, crew rotation and science utilization were re-planned on the initial two Shuttle missions to accommodate Shuttle inspection/repair demonstrations. Based on past lessons learned, the amount of extravehicular activity while the Shuttle is docked is now constrained on later assembly flights to permit adequate time for crew handovers and cargo transfers.

As the Space Shuttle Program has identified new safety requirements, the ISS mission managers have incorporated these requirements by modifying mission content and planning to ensure the ISS Program as well as the SSP safety requirements are satisfied. In addition, mission managers continually work to understand and accommodate any changes to the ISS Program risk posture resulting from the new requirements and operational scenarios. For example, detailed assessments of the ISS Logistics Flight-1 (STS-114) to -13A (STS-117) mission and stage operations plans were reviewed and modified to accommodate new safety requirements and to minimize ISS risk. As part of ISS preparations for Shuttle return to flight, flight planning launch dates are being driven by ground processing requirements versus Shuttle launch capability. These activities are ongoing as teams are continuing to evaluate other changes that may reduce risk to the ISS Program. The strategic planning teams are incorporating these lessons in planning future missions, and are assessing options for minimizing risk and satisfying safety requirements.

Recently completed ISS contract consolidations are proving to be effective in improving resource management as validated by ongoing monitoring of contract performance. A high percentage of incumbents were selected so that work continuity was not disrupted. Furthermore, the majority of the consolidated work was not flight critical. Therefore, additional risk was not imposed on the ISS Program.

Agency-wide improvements in resource management will yield further benefits to the ISS Program. For example, newly approved new human capital legislation described at http://nasapeople.nasa.gov/hclwp/index.htm should help NASA attract and retain a world-class workforce. In early 2004, the ISS Program documented the primary and secondary competencies of all Program civil servants in the new Competency Management System (CMS). The CMS is the Agency tool now used to assess human capital assets. New integrated financial systems described at http://ifmp.nasa.gov/ and https://webtads.nava.gov are also being used to improve resource management. With the automated time and attendance systems, managers and supervisors approve the hours of all their employees on a biweekly basis. This allows the Program to review the health and well-being of its employees and to collect "burn out" metrics. This information is also available on demand via the NASA Organization Profile System. Particular attention is paid to teams that regularly expend high hours; e.g., Source Evaluation Board members, Increment teams, etc. There are restrictions on the use of overtime hours, and violations must be reported and approved in advance. NASA is a leader in collecting and recording "volunteer hours" that are performed by its employees.

To address critical staffing within the ISS Program Office, the ISS office managers meet on a bimonthly basis to review Program staffing gains and losses. Workloads, resource ceilings, and allocations are reviewed and projected over the fiscal year to align with mission priorities. "Losses" currently exceed "gains," but this does not represent a long-term trend. The "gains" have been of exceptional quality and experience and "losses" often go to directly support the Program in other organizations. Also, personnel within the Program who are seeking new challenges and experiences are reviewed to encourage such growth opportunities.

The Program conducted several Program-unique surveys in the recent past. An example is the recently completed NASA Mission Safety Climate and Culture Survey conducted by Behavioral Science Technology, Inc. (BST). NASA has been actively supporting the coaching sessions provided by BST and regularly reports to the NASA workforce specific recommendations coming out of this culture survey. The Program supported the Agency-wide Safety and Mission Success activities and included our contractor team members as well. Additionally, the centers and Program complete annual safety surveys as part of their certifications for OSHA STAR and the Performance Evaluation Profiles (PEP). Results from all of these surveys have been favorable and are reviewed for areas of continuous improvement. Program safety and health metrics for both contractor and civil service employees are reviewed monthly at the Program level and quarterly at the center and Headquarter levels. In addition, JSC provides an Employee Assistance Program and a Health and Fitness Program, which are available to all their civil service and contractor personnel.

FORWARD WORK

ISS attention continues to be primarily focused on proper management of continuing flight activities, but has now expanded to assessments that will significantly revise ISS assembly and utilization plans in concert with the new Vision for Space Exploration.

Ongoing efforts to improve ISS Program control tools and processes will continue.

ISS ground rules and constraints documentation will continue to be scrutinized to identify and resolve issues that apply to scheduling and performing mission objectives.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
NASA Headquarters	2002 (Complete)	Establish DAA for ISS/SSP
Shuttle and ISS Programs	Feb 04 (Complete)	Update EVA crew scheduling constraints in NSTS-37326
ISS Program	Early 2004 (Complete)	Record ISS staff characteristics in CMS
ISS Program and International Partners	Jul 04 and Jan 05 (Complete)	Endorse revised ISS completion configuration
ISS Program	Sep 04 and Jan 05 (Complete)	Complete negotiation of Soyuz crew rotations for 2005
ISS Program	Monthly	Employee staffing, safety, and health reviews
ISS Program	Ongoing	Annual surveys for PEP and OSHA STAR certification
ISS Program	Ongoing	Continue assessment of technical, cost, and schedule issues to support Shuttle return to flight
ISS Program	Ongoing	Continue assessment of technical, cost and schedule issues to support ISS assembly completion and Shuttle retirement

Columbia Accident Investigation Board

Recommendation 6.3-1

Implement an expanded training program in which the Mission Management Team faces potential crew and vehicle safety contingencies beyond launch and ascent. These contingencies should involve potential loss of Shuttle or crew, contain numerous uncertainties and unknowns, and require the Mission Management Team to assemble and interact with support organizations across NASA/Contractor lines and in various locations. [RTF]

International Space Station (ISS) Corollary: Assess ISS Mission Management Team (IMMT) processes in light of Shuttle Mission Management Team (MMT) changes and ensure that IMMT members are adequately trained to support ongoing flight operations.

Note: The ISS response to Recommendation R6.3-1 was approved by the ISS Program and the Continuing Flight Team in January 2005. All actions related to assuring implementation and ongoing management were assigned to the IMMT and the Space Station Program Control Board (SSPCB).

BACKGROUND

Like the Shuttle MMT, the IMMT is responsible for providing programmatic oversight and management direction associated with on-orbit operations of the ISS. The IMMT is responsible for making programmatic and technical decisions on behalf of the ISS Program when decisions must be made outside of the established mission rules and procedures, when on-orbit mission priorities must be adjusted, and when anomalous conditions present a change in risk to the vehicle, crew, and mission success.

ISS PROGRAM IMPLEMENTATION

In response to the recommendation of the *Columbia* Accident Investigation Board (CAIB), the ISS Program self-initiated a review of the IMMT charter and processes including the adequacy of relevant training plans.

With ISS operations ongoing, the IMMT is continuously expected to perform with the rigor and discipline necessary to fully and successfully execute its responsibilities. As documented in its latest charter, the IMMT meets twice per week to review the status of ongoing ISS operations. During critical ISS operations, the IMMT meets more frequently. The IMMT Executive Secretary maintains a current list of contact information for all IMMT members, and this information is updated regularly.

A proposed update to the IMMT charter was prepared to take into account lessons learned from operating the ISS for five years, and recommendations from the CAIB.

Documented work instructions and other training materials govern the support that key organizations provide in support of the IMMT. In 2004, as part of normal ongoing practices, the work instructions for anomaly resolution (MGT-OA-019) and contingency response procedures (MGT-OC-012) were updated as well as the handbook of basic console operations.

Training exercises are scheduled for the IMMT in support of critical first-time activities. These simulations include contingency cases that are specifically designed to exercise the decision-making process of the IMMT. The IMMT also conducts simulations of ISS on-orbit failures that may result in emergency scenarios, including emergency evacuation of the crew. These simulations include management personnel (i.e., IMMT members) from all Program organizations.

To ensure that Shuttle and ISS processes are integrated, the IMMT continues to participate with the Shuttle MMT in joint simulations. IMMT Managers have participated in all on-orbit training planned for the Space Shuttle MMT.

STATUS

A working version of the updated IMMT charter is complete and is in the final stages of coordination with each International Partner. When this review is complete, it will be brought to the SSPCB for formal baselining by all International Partners. The major elements of this updated charter include the definition of IMMT members, their roles/responsibilities, meeting frequency, anomaly reporting requirements, and action tracking processes. Important modifications to the charter include:

1. Strengthening the process for the review and disposition of on-orbit anomalies and issues.
2. Clearly stating the responsibilities of all IMMT members, including International Partner representatives.
3. Defining procedures for calling a special IMMT when decisions are needed before the next regularly scheduled IMMT.
4. Clarifying the role of the IMMT in certifying ISS readiness for major mission activities or events.
5. Augmenting membership with ad hoc representatives of the Technical Authority and the NASA Engineering and Safety Center.
6. Designating the leader of the IMMT to be chosen from the Operations Integration Office to ensure a focus upon the safety and success of day-to-day operations.

A basic initial certification program has been established to ensure IMMT members have a common core training program. This certification program is documented in a letter from the IMMT Manager. This training plan ensures that IMMT members are fully aware of the appropriate contingency action plans (at Agency, center, and Program level), anomaly resolution work instructions, and the CAIB Report (especially chapter 6 on decision making) and have completed at least four IMMT sessions in an on-the-job capacity. It also requires that organizations designating alternate representatives to the IMMT ensure appropriate training is provided. In addition, some members of the IMMT, including the chairperson and alternate chairperson, have received cultural awareness training. One of the objectives of this training is to sensitize decision makers and meeting leaders to their responsibilities to ensure that all viewpoints are heard and properly addressed. The chairperson and alternate chairperson have also completed the Shuttle MMT certification process and will evaluate which of these requirements is appropriate and relevant to the IMMT.

A working version of the current charter and the latest IMMT training plan has been posted at http://iss-www.jsc.nasa.gov/ss/issapt/mio/IMMT_Training.htm. Additional training materials, work instructions and operational processes are available via the ISS Management Center Web site

The ISS Program has joined with the Space Shuttle Program in planning human factors and decision-making training for its members. Through 2003 and 2004, the ISS and Shuttle Programs conducted a series of joint integrated simulations of docked mission scenarios that exercised the latest contingency processes and personnel of the IMMT and MMT.

FORWARD WORK

Ensure that all IMMT members complete the formally defined training plan.

The ISS Program is working with the JSC Human Resources Office to examine options for acquiring the services of outside consultants to observe IMMT operations and provide constructive feedback.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Nov 03 (Complete)	Draft IMMT Charter update
ISS Program	Dec 03 (Complete)	Conduct joint simulation with Shuttle Program
ISS Program	Sep 04 (Complete)	Conduct STS-115 joint simulation with Shuttle Program
ISS Program	Nov 04 (Complete)	Conduct STS-114 joint simulation with Shuttle Program
ISS Program	Dec 04 (Complete)	IMMT Training Requirements Letter
ISS Program	Dec 04 (Complete)	Working version of Charter posted for review
ISS Program	Feb/Mar 05	Conduct STS-114 joint simulation with Shuttle Program
ISS Program	Mar 05	Current IMMT members complete defined training plan
ISS Program	Apr 05	SSPCB approves IMMT Charter revisions
ISS Program	Ongoing	Maintain the IMMT

Responsibility	Due Date	Activity/Deliverable
		charter, training plans/ records, and supporting work instructions

Columbia Accident Investigation Board

Recommendations 7.5-1, R7.5-2, and R9.1-1

Establish an Independent Technical Engineering Authority that is responsible for technical requirements and all waivers to them, and will build a discipline's systematic approach to identifying, analyzing, and controlling hazards throughout the life cycle of the Shuttle System. The independent technical authority does the following as a minimum:

- Develop and maintain technical standards for all Space Shuttle Program projects and elements
- Be the sole waiver-granting authority for all technical standards
- Conduct trend and risk analysis at the subsystem, system, and enterprise levels
- Own the failure mode, effects analysis and hazard reporting systems
- Conduct integrated hazard analysis
- Decide what is and is not an anomalous event
- Independently verify launch readiness
- Approves the provisions of the recertification program called for in Recommendation 9.1-1

The Technical Engineering Authority should be funded directly from NASA Headquarters, and should have no connection to or responsibility for schedule or program cost.

R7.5-2 NASA Headquarters Office of Safety and Mission Assurance should have direct line authority over the entire Space Shuttle Program safety organization and should be independently resourced.

R9.1-1 Prepare a detail plan for defining, establishing, transitioning, and implementing an independent Technical Engineering Authority, independent safety program, and a reorganized Space Shuttle Integration Office as described in R7.5-1, R7.5-2, and R7.5-3. In addition, NASA should submit annual reports to Congress, as part of the budget review process, on its implementation activities.

International Space Station (ISS) Corollary: Same as Space Shuttle Program.

Note: The ISS response to Recommendations R7.5-1, R7.5-2, and R9.1-1 was presented by the ISS Program and approved by NASA Headquarters in January 2005. All actions related to assuring implementation and continual improvement are the responsibility of NASA Headquarters, ISS Program management, and each NASA center's technical authority office.

BACKGROUND

NASA, under the leadership of the Office of Safety and Mission Assurance (OSMA) and the Office of the Chief Engineer, NASA Headquarters, has developed a draft plan to address the Agency-wide response to Recommendation R9.1-1 – referred to as the "9.1-1 Plan" and titled "NASA's Plan for Implementing Safe and Reliable Operations." Although the *Columbia* Accident Investigation Board (CAIB) only recommended that NASA comply with Recommendation R9.1-1 (i.e., "prepare a detailed plan") prior to return to flight (RTF), NASA has already begun the reorganization steps called for in the relevant Chapter 7 recommendations.

The CAIB's independent investigation revealed areas in NASA's organization and operations that needed substantial improvement before returning the Space Shuttle to safe and reliable flight operations. The Agency's current 9.1-1 Plan addresses the fundamental changes that NASA, the Space Shuttle Program, and the ISS Program are making to improve the safety and reliability of operations, namely:

- Restore specific engineering technical authority, independent of programmatic decision-making; and
- Increase the regular and constant independent verification by the safety and mission assurance (S&MA) community of programs and Program compliance with technical requirements.

These changes were derived through careful and diligent review of the CAIB's investigation and considered implementation of their recommendations. Specifically, these changes address CAIB recommendation R9.1-1 and its accompanying recommendations R7.5-1 and R7.5-2. The ISS response to Recommendation R7.5-3 is listed separately in Part 1 of this Implementation Plan.

To put the CAIB's recommendations regarding independent technical authority into practice, the NASA Administrator designated the Chief Engineer as the NASA Technical Authority (TA). The Chief Safety and Mission Assurance Officer provides leadership, policy direction, functional oversight, assessment, and coordination for the safety, reliability, maintainability, and quality assurance disciplines across the Agency. These elements, which consist of an independent technical authority, a separate and a distinctly independent Safety and Mission Assurance, along with existing well-integrated ISS Program management structure, form a foundation for ensuring safe and reliable operations for the ISS Program.

Section I of the 9.1-1 Plan addresses the steps needed to restore specific engineering technical authority, independent of programmatic decision-making, in all of NASA's missions. Section II describes the role of Safety and Mission Assurance and how the second change increases the authority, capability, and independence of the S&MA community of programs and Program compliance with technical requirements.

To ensure a well-balanced solution to the CAIB's recommendations, NASA has initiated a variety of learning activities that would contribute to achieving a credible plan. Included in these activities were external benchmarking, consultations with industry and government engineering and safety experts, an Agency-wide options assessment, and outside consulting assistance to help the Agency assess and refocus those cultural deficiencies that are a threat to flight safety and mission success.

NASA IMPLEMENTATION

Independent Technical Authority (R7.5-1)

The 9.1-1 Plan answers the CAIB Recommendation R7.5-1 by aggressively implementing an independent technical authority at NASA with the responsibility, authority, and accountability to establish, monitor, and approve technical requirements, products, and policy.

Technical Authority

The NASA Chief Engineer, as the TA, will govern and be accountable for technical decisions that affect safe and reliable operations and will use a warrant system to further delegate this technical authority. The TA will provide technical decisions for safe and reliable operations in support of mission development activities and programs and projects that pose minimum reasonable risk to humans; i.e., astronauts, the NASA workforce, and the public. Sound technical requirements necessary for safe and reliable operations will not be compromised by programmatic constraints, including cost and schedule.

As the NASA TA, the NASA Chief Engineer is charged with developing a technical conscience throughout the engineering community; that is, the personal responsibility to provide safe technical products coupled with an awareness of the avenues available to raise and resolve technical concerns. Technical authority and technical conscience represent a renewed culture in NASA governing and upholding sound technical decision-making by personnel who are independent of programmatic processes. This change affects how technical requirements are established and maintained as well as how technical decisions are made, safety considerations being first and foremost in technical decision-making.

Five key principles govern the independent technical authority. This authority:

1. Must reside in an individual, not an organization;
2. Is clear and unambiguous regarding authority, responsibility, and accountability;
3. Is independent of Program Management;
4. Is executed using credible personnel, technical requirements, and decision-making tools; and

5. Makes and influences technical decisions through prestige, visibility, and the strength of technical requirements and evaluations.

Warrant System

The Chief Engineer will put technical authority into practice through a system of governing warrants issued to individuals. These Technical Warrant Holders (TWHs) will be proven subject matter experts with mature judgment who will operate with a technical authority budget that is independent from Program budgets and Program authority. This technical authority budget covers the cost of the TWHs and their agents as they execute their responsibility for establishing and maintaining technical requirements, reviewing technical products, and preparing and administering technical processes and policies for disciplines and systems under their purview.

The warrant system provides a disciplined formal procedure that is standardized across the Agency, and a process that will be recognized inside and outside NASA in the execution of independent technical authority.

Technical Conscience

Technical conscience is personal ownership of the technical product by the individual who is responsible for that product. Committee reviews, supervisory initials, etc., do not relieve these individuals of their obligation for a safe and reliable mission operation if their technical requirements are followed. Technical conscience is also the personal principle for individuals to raise concerns regarding situations that do not "sit right" with NASA's mandate for safe and reliable systems and operations. With adoption of technical authority and the warrant system, technical personnel will have the means to address and adjudicate technical concerns according to the requirements of the situation. The TA and TWHs provide the means for independent evaluation and adjudication of any concern raised in exercising technical conscience.

The above TA concept was approved by the NASA Administrator on November 23, 2004. Prior to this approval, the TA concepts were vetted by the Aerospace Safety Advisory Panel, the CAIB, and the Return to Flight Task Group. The Administrator's approval directed implementation using NASA Policy Directives 1240.4 (NASA Technical Authority) and 1240.1 (NASA Technical Warrant System). Additional information on the implementation of the NASA TA is now available at http://pbma.nasa.gov/ita/index.html. This site includes the approved policy directives, the TA rollout schedules, TA progress presentations, and other related documentation.

Independent Safety (R7.5-2)

The 9.1-1 Plan answers the CAIB Recommendation R7.5-2 by aggressively addressing the fundamental problems brought out by the CAIB in three categories: authority, independence, and capability.

S&MA Authority

To address the authority issue raised by the CAIB, OSMA will strengthen its traditional policy oversight over NASA programs and center line organizations with the explicit authority of the Administrator through the Deputy Administrator/Chief Operating Officer to enforce those policies. The Chief S&MA Officer provides leadership, policy direction, functional oversight, assessment, and coordination for the safety, reliability, quality, and risk assessment disciplines across the Agency. Operational responsibility for these disciplines rests with the Agency's program and line organizations as an integral part of the NASA mission. To further increase the OSMA "line authority" over field S&MA activities, NASA has taken three important steps:

1. The Chief S&MA Officer now has explicit authority over selection, retention, and performance evaluation of all center S&MA Directors, the Directors of the Independent Verification and Validation (IV&V) Center, and the NASA Engineering and Safety Center (NESC). Additionally, the Chief OSMA Officer provides valuable inputs to the ISS Program Manager on the selection, retention, and performance evaluation of the ISS Program S&MA Manager.
2. The Chief, OSMA will provide a formal "functional performance evaluation" for each Center Director to their Headquarters Center Executive (HCE) each year.
3. "Suspension" authority is delegated to the Center Directors and their S&MA Directors. This authority applies to any program, project, or operation activity conducted at the center or under that center's S&MA oversight, regardless of whether the center also has programmatic responsibility for that activity.

S&MA Independence

The CAIB recommendation requires that the OSMA be independently funded. At the time of *Columbia*, all funding for OSMA was in the corporate General and Administrative line, which is separate from all other program, institutional, mission support, and functional support office funding. As for personnel, all permanent OSMA personnel are dedicated to OSMA and, therefore, are independent of program or other mission support and functional support offices. This plan retains that independent reporting and funding approach consistent with the CAIB recommendation. This plan establishes that the institution, not the program, decides S&MA resource levels. Under the oversight of the HCEs, centers will set up S&MA "directed" service pools to allow S&MA labor to be applied to programs and projects in the areas and at the levels deemed necessary by the S&MA Directors and their institutional chain of authority. The Headquarters OSMA will, for the first time, be a voting member of the Institutional Committee wherein institutional (including ITA and S&MA service pool) budget decisions are made for the Agency.

S&MA Capability

All of the centers have reviewed their S&MA skills and resources for adequacy. In particular, the Space Operations Centers have all addressed staffing deficiencies as part of Shuttle RTF, and they have already begun hiring to fill vacancies. In addition to the changes at the centers, Headquarters OSMA has increased significantly its ability to provide functional oversight of all NASA S&MA programs. Staffing has been increased in the Headquarters office from 48 to 51 people, partly to accommodate increased liaison needs created by addition of NESC, IV&V, and new programs to OSMA oversight. This plan shows a substantial increase in OSMA capability by the addition of the responsibility and budgets for the Agency software IV&V.

These additional capabilities provide an unprecedented increase in the independent assessment, audit, and review capability for OSMA, and will reinforce OSMA's role in providing verification and assurance of compliance with technical requirements owned by the ITA. As an exception to the CAIB's ITA definition, OSMA shall continue to own safety, reliability, and quality (SRQ) process standards, including Failure Mode and Effects Analysis and Hazards Analysis processes. OSMA's ownership of SRQ process standards will enable the Headquarters office to better oversee its safety, reliability, and quality assurance policies and procedures Agency-wide. To improve OSMA insight and to reduce confusion cited in CAIB Finding F7.4-13, NASA is formalizing its S&MA Pre-launch Assessment Review (PAR) process for Shuttle and ISS and the equivalent processes for expendable launch vehicles into a new NASA-wide review process called S&MA Readiness Reviews (SMARRs).

Finally, in addressing the CAIB concern about the lack of mainstreaming and visibility of the system safety discipline (F7.4-4), OSMA has taken two actions, one long-term and the other already completed. First, with regard to lack of mainstreaming of system safety engineering, the OSMA audit plan will include an assessment of the adequacy of system safety engineering by the audited project and/or line engineering organizations. Second, concerning the lack of system safety visibility, for some years the senior system safety expert in the Agency was also the OSMA Requirements Division Chief (now Deputy Chief, OSMA). To respond to the CAIB concern, OSMA has brought on a full-time experienced system safety manager who will be the Agency's dedicated senior system safety engineering policy expert.

One of the CAIB's early public statements was that the safety organizations lack the expertise and resources to adequately conduct independent technical analysis; "there is no there there." NASA responded by forming the NESC to ensure that NASA's S&MA and engineering organizations will have access to adequate technical expertise and resources for independent, in-depth, technical reviews of NASA's programs and to be used to resolve tough or controversial engineering issues. The NESC will be comprised of technical expertise from across the Agency and will include partnerships with expert consultants from other government organizations, national laboratories, universities, and industry.

S&MA for the ISS Program

NASA S&MA support for the ISS Program consists of dedicated Program office staff, technical support from the centers, and functional oversight from the Headquarters OSMA. A senior S&MA professional heads the Program's S&MA office as the ISS S&MA Manager. The S&MA Manager has a staff of experienced system safety, reliability, and quality assurance discipline engineers, and through them directs the system safety engineering, reliability engineering, and quality engineering and assurance activities of the prime contractors as well as the technical support personnel from the various centers. The Program S&MA office also integrates the SRQ activities performed by all Space Operations Centers for the various ISS activities located at those centers.

The center S&MA Directorates provide several resources for the ISS Program. They provide technical support to the Program's S&MA Manager. They also provide independent SRQ functions in the form of independent assessments, safety and reliability panel review and approvals, and technical support as needed by center engineering and operations organizations as well as the Agency TA. The Center S&MA Directorate also provides representation to the ISS Program boards and panels where key Program decisions are developed to ensure safety processes and products are in compliance with S&MA-owned SRQ process standards. The 9.1-1 Plan increases the independence of all center S&MA personnel working for or with the ISS Program by use of a dedicated directed service pool. The S&MA Directorates at the four Space Operations Centers provide a variety of support and oversight functions for the ISS Program. They are staffed with a combination of civil service and support contractors providing system SRQ expertise and services. Their role is predominantly assurance in nature, providing the Program with functional and technical oversight of prime contractor and subcontractor engineering and operations. The civil service personnel assigned to ISS work are functionally tied to their center S&MA organizations. To avoid potential conflict of interest, the S&MA support contractors are not the same as the ISS Program/project, operations, or engineering support contractors.

To address CAIB finding F7.4-13, OSMA is rewriting the policy and process governing the OSMA PAR for ISS. The purpose of the newly named SMARR is to provide the Chief S&MA Officer with the "S&MA story" for each upcoming flight, thus preparing him for the Mission Directorate Associate Administrator for Space Operations' Flight Readiness Review. The Space Operations Mission Directorate Certificate of Flight Readiness process is being updated to clearly show concurrence by the Chief S&MA Officer on the flight readiness statement as a constraint to mission approval. The Johnson Space Center S&MA Manager coordinates the organization's inputs through the ISS S&MA Manager for the ISS Mission Management Team (IMMT). Also, an OSMA representative to the IMMT serves in an advisory/functional oversight role. The Agency is currently reviewing all Headquarters' policy and procedural requirements directives with the intent of clearing up ambiguities, such as reducing the number of outdated "mandatory" requirements and eliminating unnecessary redundancy. As in the past, resident at each Space Operations Center (except Stennis) will be a small group of Independent Assessment personnel. Their assessments are funded by OSMA, and they have access to various independent support contractors as needed to carry out their assessments.

The NESC, which will have a continuous presence at each of the Space Operations Centers, represents a substantial increase in the Agency's independent technical capability. The NESC recently completed the first of its "prototype" assessments whereby it provided a needed "second opinion" to the NASA Program Managers. The results of the first four NESC studies were presented at NASA Headquarters on May 12, 2004, and are posted at http://nesc.nasa.gov. NESC is in the process of studying numerous ISS relevant topics (several at the request of the ISS Program manager). The current list includes, but is not limited to:

- Recurring Anomalies
- "Core" Technical/Engineering Standards for NASA Programs/Projects
- Shelf Life Phenomenon for Graphite/Epoxy Overwrapped Pressure Vessels
- Improved Methods for Air Leak Detection
- Flexhose Certification vs. Operation Use Methodology
- Cooling Water Chemistry
- Post Proof Nondestructive Evaluation on ISS Modules
- ISS/Shuttle Flip Maneuver for Thermal Protection System Repair
- Soyuz 7 Helium Leak
- Orbiter Reaction Jet Drivers Wire to Wire Short
- AN-Type Fittings in ISS Node 2 Ammonia System
- ISS Control Moment Gyroscope Failure
- Micrometeoroid and Orbital Debris Model BUMPER

Finally, new since the *Columbia* accident, the software IV&V personnel who support the ISS Program at the Space Operations Centers and at the Fairmont, West Virginia, IV&V Facility are organizationally independent of the Program and are now functionally overseen and funded by the OSMA.

Center S&MA civil service staffing authority has increased as a part of Space Operations Mission Directorate Return to Flight. With the implementation of this plan, and starting with fiscal year (FY) 2005, all Center S&MA support (except Marshall Space Flight Center (MSFC) S&MA) to the ISS Program is through a directed service pool under the control of the Space Operations HCE through its four centers. It is expected that MSFC S&MA will be operating under the directed service pool by FY 2006 once it has resolved its center budgeting concerns.

FORWARD WORK

Policies for an Agency-wide TA are being implemented. Independent S&MA, as described herein, has been implemented across NASA. Engineering and Safety Standards are being assessed to determine their applicability to the TA. Cultural considerations and improvements will be included in these overall implementations as they are further evolved and understood.

The ISS Program will continue to work with center and Headquarters management to define the detailed implementation of the Agency's evolving TA plans.

NASA will submit an annual update to Congress of the status of the 9.1-1 Plan.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
NESC/OSMA	Complete	Fully functional NESC in place
OSMA	Complete	Hire new OSMA personnel
NASA Headquarters	Complete	Draft plan for TA and independent S&MA
NASA Headquarters	Nov 04 (Complete)	Policies approved for NASA TA and Technical Warrant System
TA issues policies and warrants	Dec 04 (Complete)	Initial policy/warrants developed
Annual reports to Congress	Sep 05	Annual report describing 9.1-1 Plan progress
OSMA	Ongoing	Updated flight readiness review process in place
ISS Program	Ongoing	Participate in Agency team developing enhanced engineering and safety capabilities

Columbia Accident Investigation Board

Recommendation 7.5-3

Reorganize the Space Shuttle Integration Office to make it capable of integrating all elements of the Space Shuttle Program, including the Orbiter.

International Space Station (ISS) Corollary: Perform a self-assessment of the adequacy of the ISS integration function with respect to other ISS projects and International Partners.

Note: The ISS response to Recommendation R7.5-3 was approved by the ISS Program Integration Control Board (PICB) and the Mission Integration and Operations Control Board (MIOCB) in mid September 2004. All actions related to this assessment were closed and responsibility for continuous improvement was assigned to the PICB and MIOCB for ongoing management.

BACKGROUND

The complexities of the ISS Program, including the international partnering structure, on-orbit assembly and integration, and requirement for continuous operation and science research during assembly, have necessitated a strong focus on integration since Program inception. As the ISS integrator, NASA has led the multilateral definition of integration processes that have governed ISS design, development, operation, and research capabilities. In addition, NASA integrates ISS transportation requirements across an international mix of space transportation systems (i.e., Space Shuttle, Soyuz, Progress, Automated Transfer Vehicle, and H-II Transfer Vehicle). With NASA, the Boeing Company is responsible for system integration of the end-to-end Space Station.

NASA recognizes that the ISS Program's unique mix of diverse organizational cultures and dependencies makes the Program's integration functions crucial to assuring ISS Program objectives are met, and that all issues and anomalies are resolved in a timely manner. With no precedent or blueprint for an international collaboration of this scale and complexity, NASA has evolved a centralized framework that integrates to-level decision-making across all Partners and Participants. In parallel, a decentralized framework at the worker level enhances communication and collaboration. More importantly, issue identification and resolution are integrated across teams and working groups that often include members separated by geography, time zones, language, and culture. This approach is key to the early identification of potentially significant issues and provides multiple reporting outlets to ISS Program senior managers.

The ISS Program developed comprehensive requirements and plans that are levied on itself, supporting institutions and contractors as well as the International Partners and Participants. To do this, NASA constructed a comprehensive and centralized framework of control boards and panels chaired by NASA. At the top, the Space Station Program Control Board (SSPCB-unilateral) and the Space Station Control Board (SSCB-multilateral) control requirements and resolve issues. In addition, the ISS Mission Management Team (IMMT) functions in a similar manner during resolution of real-time operational issues. The ISS boards and panels report to the SSPCB/SSCB for issues that cannot be resolved or involve significant risk or cost impact. Each tier of ISS boards and panels includes representatives from the Kennedy Space Center (KSC) and Marshall Space Flight Center, as appropriate. In addition, a system of technical teams and integration management teams has developed with responsibility for implementation of requirements as well as issue identification and resolution. The teams include ISS support organizations at the other NASA Centers. These multidisciplinary teams function in both unilateral and multilateral modes, as required, and report to the Program Boards and Panels to propose changes, identify issues, and provide recommendations. This approach underscores NASA's recognition that effective communication is a critical factor in successfully executing the Program's integration functions.

ISS PROGRAM IMPLEMENTATION

To ensure cohesive integration across the numerous disciplines, teams, and international elements, NASA established two major integration functions: the Program Integration function to focus on the strategic and systems engineering and integration (SE&I) functions; and the Mission Integration and Operations function to focus on the tactical operations aspects of launch package and increment integration. This allows the ISS Program to keep management focus on both the important long-lead decisions associated with the strategic timeframe as well as on the near-term focus required in the tactical through the execution timeframe. In addition, processes and teams have been established to ensure the necessary transition, which includes continued technical support as required.

NASA consolidated top-level strategic technical integration functions in the ISS Program Integration Office. The PICB has decision authority to review and approve changes and actions at the ISS system level. The PICB includes voting members from all major ISS organizations, Safety, Engineering Directorate, Mission Operations Directorate, Space and Life Sciences Directorate, Astronaut Office, and ISS contractors. The ISS Program Integration Office chairs the Multilateral Program Integration Control Board (MPICB) to address issues that affect more than one ISS Partner.

The Program Integration Office also performs the classical SE&I function across multiple disciplines to assure overall integrated ISS functionality. It performs SE&I assessments to optimize integrated vehicle performance, vehicle resources, external configuration, system architecture, and mission design. In addition, the office controls top-level ISS specifications, interface control documents, and release drawings. A synergistic relationship among NASA, International Partner, and contractor organizations that build, sustain, and operate ISS hardware enables NASA to effectively manage the end-to-end SE&I function.

NASA's contractor support is pivotal to successful implementation of the end-to-end SE&I function throughout the ISS life cycle by ensuring vertical integration of hardware and software teams and technical disciplines. In addition, horizontal integration across these multilateral teams and disciplines yields early identification and resolution of cross-functional and multi-mission problems, issues, and anomalies. As a result, complex on-orbit assembly and operations are demonstrated and validated preflight through detailed simulations, analyses, and integrated multi-element tests.

One example of a strategic ISS integration activity is the Stage Integration Review. The Stage Integration Review team conducts early Program-wide reviews of ISS flight stages about 20 months prior to launch to ensure that the initial operational procedures match Program needs and vehicle performance capabilities. NASA chairs a line-by-line bilateral or multilateral review, as required, of the designated flight's Assembly and Operations Support Plan. This exhaustive review has proven effective in identifying, amplifying, and then resolving "weak signals" that otherwise might have gone unnoticed. The ISS Program Manager chairs the final board.

At any point in the review processes, voting organizations can—and are expected to—halt the proceedings if a technical problem surfaces that indicates further investigation is required.

The Program Integration Office is also responsible for technical integration of future assembly elements to be provided by the European Space Agency, Japanese Aerospace Exploration Agency, Canadian Space Agency, and Russian Federal Space Agency (Roscosmos). The MPICB reviews and approves technical integration decisions that affect two or more Partners. As a result of the Program's strong focus on multilateral integration, the unique on-orbit assembly of elements provided by the U.S., Russia, and Canada to date has been achieved successfully and without incident.

NASA has similarly consolidated the tactical mission integration and operations management in the ISS Mission Integration and Operations Office. The strategic requirements and plans are further developed and refined in the tactical timeframe through the Launch Package, Increment Management, Cargo Integration, and Cargo Planning teams. The Multilateral Mission Integration and Operations Control Board is responsible for tactical-level requirements management and reports to the centralized SSPCB or SSCB.

To preserve continuity, the Mission Integration and Operations teams support the assessments and strategic requirements of the Program Integration Office and, similarly, the Program Integration Office SE&I functions continue to support the tactical teams. The Launch Package Teams ensure that the integrated issues associated with each launch mission are fully understood and coordinated with the Shuttle or Russian Launch Vehicle organization. The ISSP Launch Package Teams include representatives from vehicle systems, payloads, operations, Space and Life Sciences, Safety and Mission Assurance, and SE&I. International Partners also participate. Also, jointly chaired ISS/Space Shuttle Program Flight Integrated Product Teams were established to ensure the necessary coordination with the Shuttle

Program. For the Russian flights, a bilateral Russian Launch Vehicle Team has been established. Similarly, to fully coordinate and establish requirements for the stage and increment operations, multilateral Increment Management Teams have been established with representatives from the vehicle systems, payloads, operations, Space and Life Sciences, Safety and Mission Assurance, and SE&I.

Both the Launch Package and Increment Management Teams work closely with the development and operations teams to ensure that issues are identified and elevated. This includes issues that may be identified through the conduct of Flight Operations reviews and simulations or through launch processing at KSC. In addition, these teams continue to serve as key integrators during the preparation for the key pre-mission Certification of Flight Readiness reviews.

The Launch Package Manager and Increment Manager jointly conduct the Stage Operations Readiness Review approximately three weeks before launch as well as coordinate the ISS inputs to the Flight Readiness Reviews. Further continuity is provided as these teams also provide integration support during real-time operations in the ISS Management Center and as members of the IMMT. Post-flight, these teams coordinate the Post-Flight Review and the Post-Increment Review, which ensure that lessons learned are addressed.

To ensure top-level management review of issues affecting both the Space Shuttle and International Space Station Programs, a Joint Mission Integration Control Board, cochaired by the SSP Flight Operations and Integration Manager and the ISSP Mission Integration and Operations Manager, was established to review changes and issues affecting mission integration for both programs. In addition, a top-level Joint Program Requirements Control Board, cochaired by the SSP Program Manager and the ISS Program Manager, was established to conduct full reviews of major issues and requirements affecting both programs.

It is important to note that the ISS Program functions also are reviewed extensively by expert external management, engineering, and safety groups. These range from NASA-sponsored to federal government oversight offices to chartered bodies.

- The NASA Inspector General's Office, the Government Accountability Office, and Congressional committees and staffs routinely review ISS Program processes and functions.

- The ISS Program is reviewed by the NASA Advisory Council (NAC). Previously, NASA used NAC expertise to charter two task forces to assess ISS Program business practices: (1) the Cost Analysis and Validation study (Chabrow Report) and (2) the ISS Management and Cost Evaluation study (Young Report).

- The National Research Council also has sponsored an advisory committee and several significant studies of ISS Program management and engineering practices.

- Within NASA at the Agency level, the ISS Program is reviewed by the Program Management Committee. In addition, the Agency's Independent Program Assessment Office has reviewed the ISS Program on numerous occasions in accordance with NPD 7120. At the center level, the Johnson Space Center (JSC) Systems Management Office, which is headed by the JSC Chief Engineer, conducts independent studies of various Program activities.

- Previously, the ISS Program had a dedicated "Independent Assessment" activity, which was chartered in March 1994 by the (then) Office of Safety and Mission Assurance. This activity included assessment teams embedded in Program activities at the NASA centers and contractor facilities as well as an Independent Assessment Panel reporting to senior NASA management.

- A standing Agency review activity is led by the Aerospace Safety Advisory Panel, which oversees ISS safety.

The Agency and the ISS Program are transitioning into operations with the NASA Engineering and Safety Center and a newly formed Technical Authority (TA). Both provide an independent layer of technical integration across the International Space Station Program and the SSP. The TA is formulated to provide a technical check-and-balance approach to problem-solving, particularly as related to safety and mission success. Refer to Recommendation R7.5-1.

At the Agency level, NASA Headquarters, through the Office of the Chief Engineer, has established the policies that govern Program management, which include the policies for system integration functions as related to the project life cycle. NASA will assess the effectiveness of integration functions for all of its programs and projects. Further, the policies that govern integration will be assessed and strengthened, as appropriate, to apply to all programs and projects.

STATUS

NASA has reexamined and clarified inter-organizational roles and responsibilities to ensure seamless transition of tasks from strategic to tactical integration. For example, with the completion of currently planned Russian elements, NASA migrated the Russian Elements Office from Program Integration (development) to Mission Integration and Operations.

Based upon the 2003 ISS Program Contract Acquisition Strategy, new contracts were established to support both the Program Integration Office and the Mission Integration and Operations Office. The strategy was driven by the natural evolution from development to operational activities. A key Program objective was a smooth transition of tasks between contractors. For example, selected integration tasks previously performed by Boeing as the prime contractor have transferred to new contractors. The challenge was to ensure that no contractual barriers would impede integration across all contracts. The transition has been successful. As part of the new contract structure, the contractors are incentivized to establish associate contract agreements and to ensure integration across the contracts.

The ISS Program organization charts and top-level management documents such as the Multilateral Station Program Implementation Plan are available through the ISS Program homepage (http://iss-www.jsc.nasa.gov/ss/issapt/issapt.html). Use the Reference link on this homepage to access the Program organization charts, roles, and responsibilities.

In addition to the ISS integration functions at the field centers, refer to the latest response to *Columbia* Accident Investigation Board Recommendation R6.2-1 for a description of the responsibilities and organizational structure at the NASA Headquarters Office of Space Operations.

FORWARD WORK

The ISS Program will continually strive to strengthen ISS integration functions and organizational responsibility as conditions warrant and contractual arrangements change.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Nov 03 (Complete)	Clarification of inter-organization strategic and tactical responsibilities
ISS Program	Dec 03 (Complete)	Complete contract consolidations
ISS Program	Ongoing	Continuous improvement of integration functions

Columbia Accident Investigation Board

Recommendation 9.2-1

Prior to operating Shuttle beyond 2010, develop and conduct a vehicle recertification at the material, component, subsystem and system levels. Recertification requirements should be included in the Service Life Extension Program.

International Space Station (ISS) Corollary: Assess the ISS plans for recertification of flight hardware for service life extension. Include a review of ISS hardware that is in process for launch as well as already on orbit. Ensure that any certification limits affected by the Shuttle launch delays are identified and resolved.

The underlying intent of this recommendation is addressed in Part 2.1, ISS Continuous Improvement Action ISS-7, of this Implementation Plan.

Columbia Accident Investigation Board

Recommendation 10.3-1

Develop an interim program of closeout photographs for all critical sub-systems that differ from engineering drawings. Digitize the closeout photograph system so that images are immediately available for on-orbit troubleshooting. [RTF]

International Space Station (ISS) Corollary: Assess the existing ISS system of closeout imagery to ensure that images and video are readily available for ground and on-orbit troubleshooting.

Note: The ISS response to Columbia Accident Investigation Board Observation O10.3-1 was dispositioned by the Mission Integration and Operations Control Board (MIOCB) on September 23, 2004. Implementation of the resulting improvement activities and monitoring of ongoing activities will be ensured by the MIOCB and the Imagery Working Group (IWG).

BACKGROUND

The nature of ISS operations dictates that careful attention is placed on closeout imagery requirements in support of complex assembly operations, as well as on remote inspection and maintenance of ISS systems. Images are also used to support systems performance analyses and failure investigation. From its inception the ISS Program established the requirements to obtain images from hardware as it is built up into assemblies for launch. The processes for acquiring, processing, archiving, and distributing on-orbit ISS imagery are addressed in SSP 50521. Preflight imagery is governed by SSP 50502. These documents are reviewed on an annual basis. Lessons learned while operating the ISS for over five years have highlighted the importance of closeout imagery and led to strengthening of closeout imagery requirements and database management.

ISS PROGRAM IMPLEMENTATION

To ensure safe and effective ISS operations, NASA requires that imagery records be maintained beginning with hardware manufacturing through on-orbit assembly, operations, and maintenance. The ISS Program uses preflight and closeout imagery to document the “as flown” configuration of the modules/elements and hardware that comprise the ISS.

Images are used to support remote maintenance and inspection of ISS systems. Images are exchanged between the crew and the ground in support of ISS systems maintenance and operation. The adequacy of on-orbit ISS imagery in support of ISS systems is discussed in response to R6.4-1.

Imagery is also used in real time to support assembly operations. All ISS assembly tasks are designed to ensure that adequate imagery is provided to the crew and ground.

STATUS

Imagery Management

The IWG is responsible for managing and integrating all imagery activities for the ISS. These activities include coordinating and developing imagery requirements for all customers; acquiring, distributing, and archiving ISS imagery; defining and procuring ISS imagery-related flight and training equipment; and resolving ISS imagery issues. The IWG consists of representatives across NASA, and the multilateral IWG includes the ISS International Partners. The IWG meets weekly to assess current status and plans for future capability improvements. Additional information on the IWG and its processes and products is available at https://issimagery.jsc.nasa.gov/iwg/.

The ISS Program has a dedicated database, the Digital Imagery Management System (DIMS), containing preflight and closeout images as well as on-orbit images. It is located at https://issimagery.jsc.nasa.gov. Engineering and logistics cataloging data are submitted with preflight closeout imagery to increase the search capability of the database. At present, there is no backlog of imagery waiting to be added to the database. All imagery is retrievable from the DIMS upon demand. Images can be viewed by all personnel located within any NASA center. Those outside a NASA center must have an access request approved. Instructions to help train users to perform imagery searches are posted on the IWG Web site. Emergency assistance with imagery access is also available at all times. Any user can submit a discrepancy report if an image has missing or incorrect reference information. Through September 2004, over 2000 such discrepancies have been resolved with just over 60 remaining to be closed. The computer servers that support this database have built-in redundancy and a separate backup system, and are annually updated to improve reliability, compatibility, and performance. Since early 2001, over 30 separate changes have been implemented to improve user display and search interfaces. In addition, the Video Asset Management System database contains preflight, downlinked, and returned ISS video at http://jsc-isd-vid02.jsc.nasa.gov/screeningroom/explore.asp.

A Program Data Integration Team has been formed to assist ISS internal users in locating drawings, data, computer-aided design models, operations data, and engineering documentation. It is accessible via http://iss-www.jsc.nasa.gov/ss/issapt/pdit/helpdesk.html.

A complete imagery record of the integrated ISS configuration and crew assembly activity is maintained. These requirements are documented in SSP 50261-01, *Generic Ground Rules, Requirements and Constraints, Part 1: Strategic and Tactical Planning*. This record is required to support planning for assembly and maintenance, training of crewmembers, and failure analysis. It includes imagery to support the following important ISS functions:

1. Ensure the safety of the on-orbit crew and vehicle.
2. Support the successful assembly, maintenance, operations, and utilization of ISS, including preflight and closeout imagery.
3. Document the configuration and monitor the overall condition of ISS.
4. Evaluate the performance of the vehicle and space operations.
5. Support problem solving and troubleshooting of assembly, maintenance, operations, anomaly, and contingency functions.
6. Document crew activity (internal and external to ISS) and Earth observation.
7. Provide information about ISS activities to educational outlets, the public, and national and international media sources.

The following provides descriptions of each functional area. The procedures and processes, technical as well as managerial, associated with each of these functional areas were assessed and considered adequate.

Preflight Closeout Imagery

The ISS Program uses preflight closeout imagery to document the “as flown” configuration of the modules/elements and hardware that comprise the ISS. This imagery is primarily used to support planned and unplanned on-orbit maintenance, crew training, procedure development, and sustaining engineering. Hardware providers and mission operation organizations create preflight imagery requirements. Preflight imagery for ISS hardware is acquired for the U.S. segment as well as for International Partner-provided hardware. It was determined that camera assets are adequate to capture, submit, and process preflight imagery. Imagery is submitted with sufficient cataloging data to make it retrievable in the DIMS. This preflight imagery is used for analysis to determine the on-orbit condition of the hardware.

Primary and secondary structures, wire harnesses, fluid lines, connectors, rack buildup, and module interface imagery document the layered construction of the hardware in context. Orbital replacement units (ORUs) are spares for planned on-orbit maintenance. They are imaged before, during, and after integration, with emphasis on crew interfaces. The exterior of the module is mapped by location code, specifically the ORUs, translation paths, and workstations of each module are mapped by location code.

The Preflight Imagery Plan (PFIP) contains ISS imagery requirements to document configuration of the hardware. The hardware provider submits the PFIP to the ISS Program. System experts and imagery users review and modify the PFIP requirements as necessary. Individual PFIP requirements are traceable to the images in DIMS that satisfy those requirements. These images are available on line to support flight operations. Currently, the DIMS contains more than 65,000 closeout images that satisfy PFIP requirements through flight 9Soyuz. The International Partners supply an imagery plan at launch minus 24 months that responds to ISS Program requirements to ensure adequate photographs and cataloguing of international hardware.

Specifically, at the Kennedy Space Center (KSC) Space Station Processing Facility, ISS closeout imagery is acquired based on procedures that are documented in

Boeing Standard Practice SP-QUAL-002, *ISS Configured for Test*, and in Boeing SPP-016, *Standard Practice and Procedures*. The acquired closeout imagery is placed in the official ISS DIMS imagery database.

On-orbit Operations

ISS Program participants may require acquisition of specific images to support on-orbit operations, such as routine maintenance or capturing a series of images for media purposes. Detailed ISS on-orbit imagery requirements are defined in the Increment Definition and Requirements Document (IDRD), Annex 3, which includes the integrated on-orbit imagery requirements for each flight and increment stage. These requirements are used to develop the imagery Operations Data File (ISS Photo/TV procedures) and the operations timelines, crew training plans, and imagery distribution requirements.

Any planned on-orbit hardware reconfiguration is documented in Annex 3 and requires closeout imagery. Unplanned on-orbit reconfiguration of the hardware is documented (e.g., via reports at http://sn-isag.jsc.nasa.gov) and implemented with written procedures that require closeout imagery of the completed configuration changes. When required, this imagery is then used to update engineering drawings.

Ground Operations

The Johnson Space Center (JSC) Mission Operations Directorate Photo/TV group provides integrated imagery task instructions to ISS crews. This includes video system training necessary to acquire high-quality imagery, in-flight Photo/TV procedures, and flight execution as well as electronic still photography and video downlink training. Real-time mission support is provided through the flight control team under the leadership of the flight directors. After every flight, any techniques and processes determined needing improvement are addressed.

The Information Resources Directorate at JSC is responsible for the reception, processing, retention, and distribution of video and still imagery acquired on board the ISS. Downlinked imagery, transmitted from either the Space Shuttle or the ISS, is received at the Mission Control Center via the Space to Ground Network. It is then transmitted to the JSC Video Control Center or the Digital Imaging Laboratory. There the imagery is recorded, cataloged, archived, and distributed, per ISS Program requirements. Imagery is available through request to the Public Affairs Office.

The JSC Image Science and Analysis Group (IS&AG) provides analyses and assessments of the ISS from the photographic and video imagery acquired from ISS- and Shuttle-based cameras. Image analysis personnel use the Video Digital Analysis System to provide a full range of imagery processing, enhancement, and analysis services in support of ISS troubleshooting and problem solving, assembly, maintenance, vehicle performance, operations, anomalies, and contingencies. The ISS Mission Evaluation Room directs, in real time, the IS&AG support for troubleshooting and anomaly analysis. A wide range of other analyses, such as appendage motion studies, docking performance, and vehicle configuration, is performed at the direction of engineering, mission operations, or the ISS Program. IS&AG sponsors the ISS External Survey, a periodic inspection of the ISS exterior to detect and assess damage or changes over time. The images from these surveys are analyzed; if inadequate, higher-fidelity images are obtained using other on-board cameras or improved viewing angles.

The ISS imagery process has been in place for five years and has evolved into a mature process. The IWG will continue to lead domestic and international efforts that maintain and enhance ISS imagery systems.

The imagery format has evolved from 35mm film to digital high-resolution format. Digital technology is constantly being researched to apply to preflight and other ISS imagery. For example, the ISS Program is actively prototyping high definition television downlink for future use on ISS. A downlink demonstration is planned for late 2005 or early 2006. The ISS Program is also involved in the certification and deployment of a digital extravehicular activity still camera that should be on board ISS in 2005.

FORWARD WORK

Preflight imagery for International Partner modules being integrated and processed at KSC will be acquired per existing requirements. Additionally, per SSP-50502, ongoing reviews of the preflight imagery plans are performed to ensure that all future modules/hardware are fully compliant with ISS Program imagery requirements.

The ISS Program is studying improvements in the process used to capture differences between on-orbit configuration and the engineering drawings (ref. Recommendation R10.3-2) and whether additional on-orbit imagery is required.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Ongoing	Preflight imagery process reviews per SSP-50502
ISS Program	Ongoing	Evaluate digital on-orbit imagery capabilities
ISS Program	Ongoing	IWG weekly reviews of imagery requirements, implementations, and improvements
ISS Program	Ongoing	Annual upgrades of imagery database servers

Columbia Accident Investigation Board

Recommendation 10.3-2

Provide adequate resources for a long-term program to upgrade the Shuttle engineering drawing system including

- Reviewing drawings for accuracy
- Converting all drawings to a computer-aided drafting system
- Incorporating engineering changes

International Space Station (ISS) Corollary: Assess ISS engineering databases to ensure that they are useful and useable tools for long-term engineering purposes. Ensure the databases remain current and complete with prompt access and that training is available.

Note: The ISS response to Recommendation R10.3-2 was approved by the ISS Program Integration Control Board (PICB) on September 10, 2004. Actions related to ongoing management are the responsibility of the PICB and the Vehicle Control Board (VCB).

BACKGROUND

The ISS continues to be designed, developed, manufactured, operated and sustained by many organizations from around the globe. The nature of ISS dictates that careful attention is placed on development, control, and rapid access to engineering data (especially engineering drawings). With this in mind, NASA's strategy from ISS initiation was to develop and implement an electronic drawing repository.

Most ISS drawings reside in the Vehicle Master Data Base (VMDB). The VMDB, which has been in use since 1995, is a centralized repository that provides ISS with engineering and operations drawings and data. The VMDB provides access to view and print the engineering drawings, associated parts lists, and Engineering Orders.

It is important to note that while the VMDB is a Program-wide database, ISS is also reliant upon other drawing repositories (some managed by other organizations), such as the Engineering Drawing Control Center at Johnson Space Center (JSC), the Payload Data Library at Marshall Space Flight Center (MSFC), the Engineering Drawing Management at MSFC, the Electronic Document Management System (EDMS) at JSC, the Space Station Library at JSC (hardcopy library), and various maintenance databases. Due to historical evolution and limited programmatic contractual resources, this diversity of repositories and the lack of requirements for some data make it challenging to easily verify that all drawings are delivered and immediately available. The requirement for an ISS Program drawing tree was initially deemed unnecessary due to the fact that the Indentured Parts List (IPL) was to provide a definitive list of required ISS drawings. While the IPL provides good insight, it is incomplete in terms of some contractor, International Partner (IP) and government-furnished equipment (GFE) parts. Visibility into the drawing requirements for subcontractors and GFE is limited. ISS drawings residing at non-JSC centers are not readily accessible from other centers. The ISS drawing system is also unique because the design, assembly, and maintenance phases run concurrently. Because responsibilities for ISS drawings are not fully centralized, no one office or person is accountable to ensure that the requirements and cumulative repositories are consistent or complete.

To facilitate the currency and completeness of available VMDB drawings, ISS relies upon Engineering Release Unit (ERU) systems for inputs from its hardware developers. GFE and subcontractor hardware drawings are manually uploaded to the VMDB. On-orbit hardware status is also tracked and incorporated as appropriate. Given the dynamic nature of ISS hardware, the latest drawing revision is best determined from the associated ERU.

The VMDB drawings interface is presently the most widely used output feature of the VMDB. VMDB drawings are accessible and available to authorized Program participants via a secure Web interface. The VMDB user interface software (Java IPL Maintenance and Parts Assembly Capture Tool – JIMPACT) is also available to any authorized user. Users access the VMDB drawings for a wide range of applications such as:

- The Mission Evaluation Room (MER) and the Engineering Support Room use VMDB for sustaining engineering and real-time operations.
- The Vehicle Integrated Performance and Resources team uses VMDB to perform resource analysis and allocation.
- The Mission Operations Directorate (MOD) uses VMDB for ISS flight control operations.

Detailed drawings of IP hardware are maintained by the IPs. Formal data exchange agreements allow the necessary information to be available for all Partners in support of operations and on-orbit anomaly resolution. Some detailed drawings can only be accessed directly from Partners. Top assembly drawings are provided through data package deliveries for each design review and placed in the VMDB, while other Partner manufacturing drawings may be housed in a secure library at Kennedy Space Center (KSC), such as detailed interface drawings that allow Partner hardware to be installed or stowed in Shuttle launch fixtures.

ISS PROGRAM IMPLEMENTATION

Shortcomings in the completeness and retrieval of drawings from the VMDB have necessitated several near-term and long-term improvement efforts. An initial audit of database processes and completeness has been completed. Additional assessments are under way to identify and implement further improvements.

STATUS

To date, there are over 84,000 drawing entries, including 52,000 unique drawings with their revisions. Released engineering data, including drawings and advanced Engineering Orders, continue to be located and loaded daily from different ISS Program release systems. Government-furnished data, IP (to a higher level), and subcontractor drawings continue to be located, delivered and loaded. The ISS on-orbit stage drawings are being delivered and loaded on a regular basis. An assessment of the VMDB, documented in the VMDB Technical Analysis Report, identified that the VMDB is missing data and drawings and lacks rigorous configuration management. In addition, the VMDB has a backlog of drawings to be loaded and a number of missing drawings to be located and added to the VMDB.

While drawings continue to be added, reports are now supplied to ISS Program management that identify missing drawings and other performance metrics. This information is provided at the Monthly Managers Review.

Since the ISS Program did not require official delivery of a drawing tree, an ongoing comparison of flight manifests is performed against the VMDB IPL to determine which drawings are missing. To date, only 160 (or 0.2% of the total available) drawings have been formally identified as not available in VMDB. Of roughly 25,000 drawings queried from the Website per month, typically only 20 requests for drawings are not available in the VMDB. The VMDB team attempts to acquire such drawings as soon as they are identified.

As near-term process improvements to aid completeness and ease of retrieval for VMDB drawing users, the following enhancements have been implemented:

- The VMDB drawing process now uses the EDMS to track GFE/IP drawing deliverables. All GFE/IP drawing deliveries are tracked and accepted by the NASA Engineering Drawing Lead.
- The VMDB now accepts book form drawing deliveries in Portable Document Format (PDF).
- The VMDB creates PDF files of all drawings to facilitate viewing by all users.
- The VMDB has implemented a “drawing search” enhancement (a “Google-like” drawing title search).
- The VMDB allows Parts Lists to be associated to more than one drawing revision.
- The VMDB Website was updated to give users clearer instructions on how to locate drawings from different sources.

With the continuous operations of the Space Station, the ISS Engineering disciplines in the ISS MER access drawings and data via the VMDB on a day-to-day basis. A poll of these disciplines reveals that the time to retrieve information is well under an hour. Time to retrieve drawings and information not found in the VMDB is dependent on search complexity for information through other engineering databases, vendor contacts, and hardcopy data repositories.

When there is difficulty in locating drawings, users are directed to the VMDB help desk and/or the drawing's responsible owner. Presently the VMDB Website provides user guides, training schedules, owner contacts, and a help desk contact. Existing training efforts educate users on VMDB navigation and data retrieval. The Program Data Integration Team is also available to assist in locating the drawings as described at http://iss-www.jsc.nasa.gov/ss/issapt/pdit/helpdesk.html.

When seeking drawings, users must be aware that not every ISS-related drawing is currently obligated to be available for loading into the VMDB. In certain cases, the ISS Program did not contract for drawings. In addition, some vendors are no longer in business or are not available to deliver the drawings.

Customer Focus Groups are conducted periodically to determine the level of customer satisfaction and to ensure customer requirements are met. Membership of this forum is currently composed of representatives from the ISS Program and the Mission Control Center (MER and MOD). Process improvements are being identified on a continuous basis to ensure the clarity and completeness of the drawings input into the VMDB.

FORWARD WORK

Ongoing efforts to identify, locate, load, audit, and report the status of available drawings will continue. Additional assessments are planned that will address key aspects of the drawing system and processes (overall accountability, including accessibility of required drawings from all sources, scope of drawing centralization, need for central drawing tree, missing drawings, and data categorization to simplify access). A process based on the ISS Risk Management Application will be defined to assess the level of risk associated with missing drawings.

A list of known drawings that the ISS Program is not obligated to receive is being compiled for assessment. This list will include drawings that are either not contractually required to be delivered to the ISS Program or drawings that cannot be retrieved because the vendor is no longer in business and the drawing is not obtainable.

Participation in the VMDB customer focus groups will be expanded to include more ISS-related organizations (MSFC, KSC, JSC engineering, MOD training).

All forward work will be tracked and dispositioned by the ISS PICB and VCB.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Dec 03 (Complete)	VMDB migration to EDMS
ISS Program	Sep 04 (Complete)	Audit of VMDB drawings upload process
ISS Program	Dec 04 (Complete)	Complete loading backlog of Partner's Node 2 and Node 3 drawings into VMDB
ISS Program	Dec 04 (Complete)	Complete clarification of VMDB user instructions for locating drawings
ISS Program	Apr 05	Audit of VMDB missing drawings process
ISS Program	Ongoing	Identify drawings that are not currently obligated to be received
ISS Program	Ongoing	Additional assessments of VMDB responsibilities, requirements, and products
ISS Program	Ongoing	Locate and load necessary drawings (missing drawings that are required)
ISS Program	Ongoing	Define processes to identify additional required drawings and assess risks of missing drawings
ISS Program	Ongoing	Continue customer focus groups, monthly manager's review, and user training
ISS Program	Ongoing	VCB to ensure drawing management processes are well defined, sustained, integrated, and improved

Part 2
International Space Station Continuous Improvement Actions and Responses to CAIB Observations

This section details specific actions that the International Space Station (ISS) Program has undertaken as a result of (Part 2.1) Continuous Improvement Actions, (Part 2.2) formal observations of the Columbia *Accident Investigation Board (CAIB), and (Part 2.3) supplemental recommendations/observations made by General Deal in Volume II of the CAIB Report.*

Within hours of the Columbia *tragedy, the ISS Program formed teams to review the requirements, potential hazards, and risks associated with maintaining a continued crew presence on ISS with no Space Shuttle support. This comprehensive effort reviewed areas such as on-board availability of consumables and spare parts, hardware lifetime and certification issues, and capabilities for supporting ISS and its crew with only Russian Progress and Soyuz vehicles. All ISS Partners agreed to the strategies necessary to continue with crewed operation of the ISS.*

(Continued on back)

Over time, the ISS Program Manager initiated several actions to assess our overall risk posture in the current situation. An effort was made to reassess previous decisions to accept risk in light of observed performance of the ISS on orbit and the changes in plans from when risk was accepted. The reviews were done with the CAIB Report in mind and its mandate to avoid the trap of being lured into thinking that low-probability events will not happen simply because they have not happened in the first few years of ISS operations.

As the ISS Program proceeds into the future, it will continue to identify and institutionalize sustainable improvements that ensure the safe and successful support of space exploration.

Part 2.1
International Space Station Continuous Improvement Actions

Program teams were asked to review the entire list of Program-approved items (waivers, deviations, exceptions, etc.) that identified significant risk. The teams applied two major tests: (1) Had changes in the Program or the performance of the Space Station on orbit significantly changed the context of approval of individual items; and (2) Did the items in aggregate introduce significant additional risk that was overlooked as the items were approved individually. The experts most knowledgeable about the item were involved in the evaluation. Once these risk areas were initially identified and assessments were initiated, they became ISS Program Continuous Improvement Actions to indicate that the Program had gone above and beyond the recommendations of the CAIB Report.

Part 2.1 describes the actions and results of each Continuous Improvement Action.

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 1

The ISS Program will review all Program waivers, deviations, and exceptions for validity and acceptability.

Note: The International Space Station (ISS) response to Continuous Improvement Action ISS-1 was approved by the ISS Strategic Planning meeting on September 23, 2004. All actions related to assuring implementation were closed and responsibility for continuous improvement was assigned to the Program Integration Control Board for ongoing management.

BACKGROUND

The ISS Program process for granting waivers, deviations, or exceptions is based on a risk assessment of the specific inability to meet a Program requirement. If the assessment shows adequate risk mitigation actions are in place to prevent any serious consequence, the risk mitigation is granted. These exemptions are formally tracked and reviewed any time a flight activity could be adversely affected. A number of programmatic control boards and panels (including mission management team and flight readiness reviews) ensure that requirements and risk mitigation measures are well understood and appropriately approved with supporting rationale (as exemplified by the handling of exceptions for atmospheric monitoring, exercise equipment and crew on-orbit duration limits).

ISS PROGRAM IMPLEMENTATION

In August 2003, the ISS Program, which recognizes that waivers, deviations, and exceptions (WDE) to ISS Program requirements contain the potential for unintended risk, directed all elements to review these exemptions to Program requirements to determine whether the exemption is still valid in light of five years of on-orbit ISS operational experience. In addition, the ISS Program evaluated the exemptions to assess whether the totality of exemptions carries additional risk. Particular attention was placed on the exemptions that carry safety risks of a catastrophic nature with a short time to effect.

During this Program assessment, more than 700 waivers, deviations, and exceptions to ISS Program requirements were rigorously reviewed with no significant technical or safety issues identified. The detailed task of reviewing these exemptions was executed in two phases.

Phase 1: Each waiver, deviation, and exception was reviewed by ISS Program personnel under the auspices of the governing Program control board or panel based on the following ground rules:

- Determine whether risk posture has changed in light of the *Columbia* tragedy or since observed operation of the ISS.
- Determine whether modifications should be considered to the ISS vehicle or the requirements in due to changed risk posture.
- If the same requirement impacts several deviations/waivers/exceptions, review whether the requirement should be changed.
- Review the waivers, deviations, and exceptions for cumulative risk due to an accumulation of accepted risk over time.

The ISS Program personnel then categorized each waiver, deviation, and exception as follows:

- Category 1: The waiver is acceptable as-is. This means the original waiver rationale is still valid and there is no change in the risk posture.
- Category 2: Based on the ground rules (cited above), the item needs further assessment. This evaluation is conducted under the auspices of the governing board or panel.
- Category 3: The risk posture has changed and corrective action is required.
- Category 4: The item is obsolete or "overcome by events," such as an item that applied to one flight and that flight was executed successfully. These items will be retired, meaning these items will be archived and no longer tracked.

Phase 2: The ISS Program created a team of ISS system and discipline experts to look at each waiver, deviation, or exception not judged to have a previous disposition as valid (Category 1) or overcome by events (Category 4). This team, which was tasked to develop an in-depth risk assessment, consisted of representatives from the ISS Program Office, Mission Operations, Flight Crew, Johnson Space Center (JSC) Safety and Mission Assurance, Boeing, JSC Engineering's Chief Engineer office, and Kennedy Space Center (KSC) personnel. Other discipline experts were consulted as warranted.

Further, the team reviewed the cumulative impacts of approved exemptions to overall ISS risk. To accomplish this, the team reviewed the exemptions from an integrated system approach to identify interdependencies among individual exemptions. The risk assessments and mitigation plans continue to be tracked in the ISS Risk Management system.

STATUS

Phase 1 and 2 reviews of ISS waivers, deviations, and exceptions have been completed. Seven hundred seventeen ISS WDE were reviewed: 651 are acceptable as-is (Category 1); 62 are overcome by events and will be retired (Category 4); and four require additional evaluation (Category 2). In addition, as part of this update, categorizations were checked and updated as more information became available.

Category 2 topics are addressed as normal ongoing work and no significant technical issues are anticipated.

There are currently no Category 3 topics for "posture changed and corrective action required." Seven topics previously ranked as Category 3 were categorized incorrectly and found to be acceptable (Category 1).

The Phase 1 and 2 reviews also covered KSC processing waivers. Note that this term actually refers to changes to internal KSC processes for handling, integrating, and storing ISS flight hardware and associated ground support equipment. Any KSC change directly affecting an ISS requirement required a Program waiver, deviation, or exception as approved by the governing ISS Program board or panel. For example, the KSC Material and Engineering Review Board-generated waiver 7028, "Request for Deficient Data Waiver: Insufficient Configuration Accounting System Reconciliation for Flight 9A items," was reviewed by both the Configuration Management and Vehicle offices and determined to be acceptable as-is (Category 1).

The two-phase review process did not identify any previously unknown or unacceptable risk areas for the crew or mission success. ISS Program management agreed that the variability of WDE terminology pointed to a need to define common usages. Per management direction, Configuration Management standardized definitions as part of normal work.

The WDE team also coordinated findings with teams working other "WDE-like" areas in the ISS Program such as Station Program Notes (SPNs), the Operations-oriented Generic Ground Rules and Constraints (GGR&C), Problem Reporting and Corrective Actions (PRACAs) (ref. ISS-5), Safety Noncompliance Reports (ref. ISS-2), Failure Modes and Effects Analysis/Critical Items Lists (CILs) (ref. ISS-4), the Failure Investigation Analysis Reports (FIARs), and Quality Nonconformance Reports (NCRs).

Criticality 1 Station Program Notes

SPNs document operational workarounds for Program software. The Avionics and Software Control Board, which includes representatives of Safety organizations, the Crew office, and Mission Operations, reaffirmed that the existing process (which includes review of SPNs applicable to each flight and software transition) is comprehensive and adequate.

The majority (90%) of existing SPNs are not used to control a safety or mission success risk. While there are currently over 1,000 SPNs for more than 4.3 million lines of source code, only 6% involve safety-related issues. The SPNs continue to be reviewed and, where appropriate based upon criticality, assigned for closure in future releases of ISS software. Up to 50% of existing SPNs and up to about a third of the safety-related SPNs were closed by January 2005 with further improvements to follow as normal business in the future.

During these reviews, deficiencies were identified in the communication of software SPN implementation plans to the flight control team. Changes were implemented to improve communications between software developers and flight controllers relative to the SPN elimination status, rationale for schedule, and retirement strategy. Since October 2003, the Flight Director's office has led a weekly review of agendas and issues of ISS boards and panels with flight controllers and their representatives to enable adequate and timely coordination with software users on problems and solution plans.

Software requirements deficiencies are documented in Software Change Requests (SCRs). Disposition of SCRs is rigorously controlled by a board and panel structure with formal representation of software development, operations, crew, and safety.

As each Computer Software Configuration Item is revised and released, many deficiencies in the previous releases, some of which required Program waivers, are fixed in total or in part. Software waivers are primarily in the areas of processor and memory utilization and detailed compliance to Ada software standards. These conditions change and improve with successive releases. Improvement is documented in SCRs and subjected to the standard board and panel review and disposition processes.

Generic Ground Rules, Requirements, and Constraints

While each GGR&C waiver currently is considered to be either valid or overcome by events, the ISS Mission Integration and Operations Control Board (MIOCB) initiated activities to determine whether changes can be made to reduce future need for these waivers based on lessons learned. A plan was presented to the August 19, 2004, MIOCB in response to Action Item 1380, "Develop process improvement for Increment Definition Requirements Document (IDRD) Deviations and Waivers." The plan received MIOCB concurrence.

All deviations to GGR&C based on a two-person versus a three-person crew have been identified and mitigated through IDRD change requests. Flight rules were updated based on lessons learned.

Shuttle Crew Scheduling Constraints were developed and approved based on the Program assumption that there would be some Assembly Flights that would violate an extravehicular activity or crew time for a day docked to the ISS requirement. The Joint Program Requirements Control Board concurs on all crew scheduling constraints.

Medical Operations Requirements Document (MORD)

A revision to the MORD is in development and will include a process for the multilateral medical community to use for flight readiness assessments. The new revision to the MORD will implement the waiver/deviation process improvement approved at the August 19, 2004, MIOCB to close Action Item 1380 cited above. The process will ensure that increment-specific medical requirements, linked to the MORD, are captured in the appropriate Program documentation and provide acceptable risk mitigation. For example, the JSC Space Life Sciences Directorate (SLSD) generates deviations addressing unmet MORD criteria. The SLSD issues flight readiness exceptions against endorsements such as environmental monitoring. Such issues generally are captured as Program Risks (e.g., Risk 4706 for water monitoring). Progress on risk mitigation and implementation plans then are briefed to the Program Manager at each Program Risk Advisory Board. Risks are reassessed and acceptance reconsidered at each Certification of Flight Readiness (CoFR) and Stage Operations Readiness Review (SORR).

Payload Exceptions and Deviations

The ISS Payload Office waiver review of the Preliminary Interface Revision Notices (PIRNs) issued against their top Program requirements documents included reevaluation of 360 previously accepted risks, of which 117 are safety related. No Category 3 items were identified. The review initially identified 24 potential Category 2 items, all of which were evaluated in depth and re-categorized with rationale to Category 1 or 4. The ISS Payload Control Board concurred on categorization of 251 PIRNs as Category 1 and 109 PIRNs as Category 4, along with team recommendations and observations.

Safety and Mission Assurance (S&MA) WDE Review

S&MA completed its review of the 717 ISS waivers, deviations, and exceptions and their findings were integrated. In support of this Continuing Flight Team action response, the Phase 2 WDE team reconvened primarily to review and coordinate the S&MA findings. The S&MA community concurred on the majority of the Phase 2 findings and ultimately did not identify any Category 3 items. Category 2 items, as denoted by S&MA, include the four identified in Phase 2. One of these items was reassigned as Category 2 based on S&MA input. In addition, S&MA is coordinating rationale for the categorization for a few remaining items. This is considered minor in nature and no technical issues are anticipated.

S&MA periodic reassessments of certain waivers will be worked as normal business.

Problem Reporting and Corrective Actions

The S&MA community reviewed all PRACAs excluded from Phase 2 because there were no associated WDE.

The findings were reported to the ISS S&MA Office and Vehicle Office for consideration.

In addition, ISS Continuous Improvement Action ISS-5 specifically addresses the need to review the ISS In-flight Investigation (IFI) and PRACA databases to determine whether waivers were appropriately generated when restoration of functionality and compliance was not achieved. A review of the IFI process by the Vehicle Office, system teams, and S&MA determined that no IFI can result in a waiver without first becoming a PRACA. The PRACA database was reviewed and some did result in waiving conditions that were not documented on a waiver form. The initial determination from the ongoing S&MA assessment is that none of these items would precipitate a change in the ISS risk acceptance profile.

Further study is in process to determine whether any of these items should be transferred to a waiver form. An early result of the study led the ISS Program to direct the use of the waiver form and to develop work instructions to assure requirements are waived using the official waiver process. To assure completeness, all waivers are discussed and the rationale approved in the appropriate ISS control boards.

Based on these findings, the Space Station Program Control Board (SSPCB) approved closure of the Phase 2 WDE review.

Process Improvements

Based on Phase 2 and team feedback, Configuration Management received Program direction to implement SSPCB-approved generic process improvements to facilitate WDE definition and management:

1. WDE forms will list the requirement waived, technical rationale, and assessed alternatives (rationales for many WDE were only found in presentation charts and not in the WDE database).
2. Future change requests for WDE approval will be stand-alone (many WDE were incorporated in other requirements changes and are difficult to track).
3. For clarity and consistency, handling and definition of "WDE-like" areas will be recorded in Program documentation (WDE database, GGR&C, SPN, PRACA, CIL, FIAR, NCR, etc.).

Due to the Program's complexity, the ISS Program Manager has a control board and panel structure in place to facilitate management of the NASA-controlled Program baseline. The top board, chaired by the ISS Program Manager, approves the Program baseline and dispositions any changes, waivers, or deviations.

The Program's hierarchy of boards and panels reviews cost, technical, and schedule issues and elevates issues to the next tier where appropriate. The ISS boards and panels structure is documented in the Station Program Implementation Plan Volume 1: Station Program Management Plan, Annex A: ISSP Management Overview. Delegation of authority to individual boards/panels (including review of waivers, deviations, and exceptions) is documented via ISS Program Directive; Management Directive, Joint Program Directive, or Partner Program Directive. The directives can be found in the Electronic Data Management System.

ISS Program board memberships have been updated via a formal Program Manager Letter to representatives of the NASA Engineering and Safety Center (NESC). The NESC may be petitioned to assess waivers and deviations on an as-needed basis. A Memorandum of Agreement is being established with the recently formed JSC Technical Authority (TA) to document the TA role in the ISS waivers and deviation process. It is expected that the JSC TA will review and approve all new ISS waivers/deviations and any changes or updates to existing WDE. For more details, refer to the response to CAIB Recommendation R7.5-1.

Changes to the ISS waiver, deviation, and exception process are under way to support transition from the development phase to a sustaining engineering and operations phase. The changes represent a significant shift in the ISS Program's historic waiver/deviation process and include:

- Differentiating between minor and major deviations and waivers to allow certain decision authority to be delegated below the ISS Program board level
- Deletion of the ISS Exception category, which was replaced with deviations and waivers consistent with standard industry practices
- Consolidation of the Safety NCR and ISS deviation/waiver processes
- Clarification of how deviations and waivers are to be implemented contractually
- Integration and consistency with ISS Quality Assurance and anomaly tracking processes

- Clarification and expansion of authority granted to an authorized Materials Review Board
- Implementation of a “retirement” process for ISS waivers (i.e., Category 4)

Revisions to the existing waiver and deviation requirements were released to the ISS Program in December 2004 after an extensive Program-wide review.

Changes within the CoFR process are being documented in the update to SSP 50108, “Certification of Flight Readiness Process Document,” and each organization’s CoFR plans (refer to ISS-3 in Section 2.1). Configuration Management reports to ISS Program management any applicable waiver/deviation from requirements documented for each SORR and Flight Readiness Review. As denoted by the SLSD example cited previously, CoFR exceptions are documented when a Program organization is unable to meet its CoFR endorsements. This condition may represent a waiverable condition pending approval or open work that is behind schedule. The CoFR exception does not document a deviation from Program requirements. However, closure of a CoFR exception can be accomplished with approval of a Program waiver or deviation.

FORWARD WORK

As part of normal work, the ISS Program will standardize the waiver/deviation process across ISS organizations. In addition to near-term standardization of terminology and processes, integration of databases is a longer-term objective. Integrating Program databases that contain different types of noncompliances ultimately could improve assessment of cumulative ISS risk.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Dec 03 (Complete)	Phase 1 review of waivers, deviations, and exemptions
ISS Program	Mar 04 (Complete)	Phase 2 review of WDE
ISS Program	Aug 04 (Complete)	MIOCB Action 1380 (MORD)-Waiver/Deviation Process Improvement
ISS Program	Sep 04 (Complete)	ISS Program Manager approval
ISS Program	Ongoing	Continue standardizing databases terminology and waiver deviation process
ISS Program	Ongoing	Continue reviewing status and closure of applicable WDE and SPNs at SORRs

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 2

The International Space Station Program will review all hazard report non-compliances, regardless of classification, to review rationale for acceptance of these "accepted risks."

Note: The International Space Station (ISS) response to Continuous Improvement Action ISS-2 was approved by the ISS Safety and Mission Assurance Panel (S&MAP) on September 30, 2004. All actions related to assuring implementation are the responsibility of the S&MAP.

BACKGROUND

ISS safety analysis is accomplished by performing a top-down assessment of hazards and identifying the events that could lead to those hazards. The results of these analyses are captured in hazard reports. The ISS Program has established safety requirements designed to provide the necessary control of hazards. For environmental or operationally induced risks, hazard reports are prepared. When a safety requirement is not met and the ISS Safety Review Panel (SRP) feels that the risk is adequately controlled, a noncompliance report (NCR) to the hazard report is generated to justify and accept the risk.

SRP assessments of ISS hazards and controls are continual and well supported. SRP membership is diverse and representative of the whole ISS Program. It meets frequently and includes representatives from Kennedy Space Center Safety, Marshall Space Flight Center, Johnson Space Center (JSC) Safety, Headquarters' Office of Safety and Mission Assurance, JSC Engineering, JSC Mission Operations, JSC Life Sciences, the ISS Program Office, the Astronaut Office, and the International Partners. The communication of SRP plans and results are communicated via Web site: http://www. jsc. nasa. gov/srp/index. html.

There are system-level fault tolerance requirements in ISS functionality tables that are addressed by reliability assessments in failure modes and effects analysis (FMEAs); and there are safety fault-tolerance requirements to preclude hazardous events. The system-level fault tolerances for safety are addressed in integrated safety assessments conducted by the ISS integration contractor and are documented in ISS integrated hazard reports. These integrated hazard reports are reviewed by the SRP via the Safety Review Process document (SSP 30599).

The ISS integration contractor uses standard analysis techniques that are recommended by the ISS Program and defined in the Safety Analysis Requirements document (SSP 30309). This assessment includes review of all input hazard reports prepared by hardware providers and assesses unique interfaces between elements to determine the existence of interface and integrated hazards.

The focus of ISS hazard reviews is to ensure the design is compliant with safety requirements without NCRs. If an NCR is necessary, each is assessed individually focusing on why the requirement cannot be met and its unique rationale for acceptance. When the noncompliant condition relates to failure tolerance to a hazardous consequence, it is the SRP's general policy not to accept less than single failure tolerance to preclude catastrophic consequences.

ISS PROGRAM IMPLEMENTATION

As a result of the *Columbia* accident, the ISS SRP conducted a review of each NCR to determine whether the ISS Program should revisit the associated accepted safety risks. This activity reviewed assumptions and ground rules used when the NCR was accepted to assess whether they were still valid. Many steps were taken to provide a level of confidence on how the original NCRs compare to the current ISS conditions and operations.

As part of the review, the ISS SRP identified several potential sources of ISS changes that could have impacted the NCR assumptions. These areas included how the current ISS environment compares to the assumed environment when the NCR was approved; how the current ISS operations compare to the operations assumed when the NCR was approved; additional data that would question the validity of the rationale on the NCR; how ground test or on-orbit anomalies may have weakened the assumptions of the strength of some of retention rationale features; and any changes in failure detection that could contribute to the hazard manifesting itself since the NCR was originally approved. These criteria were used to assess each existing ISS NCR.

Ground rules were established to limit the review of NCRs to those carrying the greatest amount of Program risk and affected by anomalous performance. NCRs addressing the control of touch temperatures, protrusions, pinch points and sharp edges were not reassessed because the associated risks have not changed since original acceptance and are well managed with operational controls. On-orbit anomalies with safety implications were reviewed to see if they had any impact on NCRs. The decision to limit the review of anomalies to on-orbit anomalies was based on the fact that most ground test failures result in restoration of function or design back to compliance with the specifications and drawings.

NCRs impacted by the defined criteria were categorized as follows:

1. No Significant Impact – No changes/action required
2. Minor Impact – Recommend NCR update and subsequent SRP NCR re-approval/signature
3. Major Impact with Acceptable Risk Mitigation – Recommend rewrite of NCR with subsequent full panel review and re-approval
4. Major Impact with Potentially Unacceptable Risk – Reopen NCR and go to full SRP for proper action assignments to resolve

STATUS

In response to the changed risk posture identified by this completed review, the ISS Program has taken the following actions to mitigate risks. Of the approximately 270 NCRs that exist, only one required any appreciable new action. All other NCRs were either acceptable as is or only in need of minor cleanup.

The SRP determined that one NCR had "Major Impact with Potentially Unacceptable Risk." The NCR addressed a Space Shuttle failure mode that could affect the ISS. Specifically, the Space Shuttle Reaction Jet Driver (RJD) does not have adequate failure tolerance to control against an inadvertent Space Shuttle Orbiter primary jet firing. The ISS SRP determined that the hazard exposure was greater than was considered at the time of acceptance of the NCR and asked that the Space Shuttle and ISS Programs revisit this issue. Options for modifications were discussed that included changes to software, wiring, avionics, and operational procedures. To control this thruster firing risk for the first two Shuttle flights, a software change will be in place to automatically and rapidly close an affected thruster propellant manifold. In addition, to avoid the risk of thruster plumes upon ISS solar arrays during Shuttle docking and undocking, thruster firing keep out zones will be implemented. Operational changes include minimizing RJD activation time while docked, RJD avionics health checks prior to activation, and rescheduling of first-time Shuttle equipment power up outside of the ISS mated period.

The results of the SRP review and position on the RJD issue are a focus of attention and discussion by the ISS Mission Management Team, the NASA Engineering and Safety Center (NESC), and the Space Flight Leadership Council (SFLC). Given the near-term solutions being implemented, longer term solutions are now of most interest. The NESC recommends replacing RJD wire, conducting Darlington electrical characterization tests and destructive physical analysis, and adding pre-flight leakage current tests no later than STS-115/12A. After evaluating those data, NESC will deliver a recommendation on the RJD box redesign. By the time ISS assembly adds an additional truss and solar array with mission 12A, additional risk controls will be in place. The selection and implementation of specific new controls will be determined jointly between the ISS and Space Shuttle Programs.

Not specifically covered by an NCR, yet considered very important by the ISS SRP, is the ISS External Thermal Control System robustness. In response to this concern, the ISS Program approved and authorized development of electrical power jumpers that remove the risks associated with certain external thermal system failures. Consideration was given to the need for an on-orbit spare pump and an independent peer review of the pump design.

Four NCRs had "Major Impact with Acceptable Risk Mitigation." These included three Russian Segment micrometeoroid and orbital debris NCRs associated with implementing enhanced protection have occurred. Together with our Russian Partners, the ISS Program took steps to mitigate these risks as reported in the response to Recommendation R4.2-4. The fourth NCR was modified to address a system issue that has since been resolved. In this case, the characteristics of an expected internal thermal control system line pressure was redefined using real flight data to correct a deficiency in pre-flight data. The four NCRs were reviewed by the SRP and re-accepted by the Program.

As a generic process improvement, the critical items list (CIL)/hazard report (HR) process for Program approval was streamlined to specifically approve Criticality 1 CILs with catastrophic hazardous effects in conjunction with the corresponding HR/NCR, per Revision F of the FMEA and CIL Requirements for Space Station (SSP 30234). Also, traceability is provided with the CILs referenced in the HR and the HR is referenced in the CIL.

FORWARD WORK

Based upon the Shuttle Program Requirements Control Board's (PRCB's) review of the recommendations by the NESC in its recent assessment report, the wiring and avionics modification options were taken to the Joint PRCB for consideration. Final decision by the Joint PRCB is pending regarding the long-term approach. The ISS Program identifies the RJD issue as a formal risk with forward work being tracked in the Integrated Risk Management Application system.

In general, the SRP will continue HR review and approval using the existing established safety review process (SSP 30599). The NESC will have a new ongoing role in these ISS hazard reviews and continue to conduct independent assessments, such as were conducted on the RJD issue.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Sep 03 (Complete)	Completed NCR Review
SFLC	Sep 04 (Complete)	Review status of NESC study regarding RJD issue
NESC	Sep 04 (Complete)	Provide results of RJD study to Shuttle PRCB
ISS and Shuttle Programs	Nov 04 (Complete)	Agree on risk mitigation plan for Shuttle RJD hazard via Joint PRCB for first two flights
ISS and Shuttle Programs	Ongoing	Agree on risk mitigation plan for Shuttle RJD hazard via Joint PRCB beyond first two flights
ISS SRP	Ongoing	Continue hazard assessments per SSP 30599
ISS SRP	Ongoing	Interface with NESC in independent assessments of ISS Hazard Reviews

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 3

ISS will review its Certification of Flight Readiness (CoFR) process and identify areas for improvement.

Note: The International Space Station (ISS) response to Continuous Improvement Action ISS-3 was approved by the ISS Mission Integration and Operations Control Board (MIOCB) on September 23, 2004. All responsibility for continuous improvement and ongoing management was assigned to the MIOCB.

BACKGROUND

The ISS Certification of Flight Readiness (CoFR) process enables certification of the safety and operational readiness of ISS Program hardware, software, facilities, and personnel that support launch, return, assembly, maintenance, and scientific utilization of the ISS. Additionally, the CoFR process assesses and certifies completion of activities required for mission success. Certifying organizations (ISS Program contractors, International Partners and Participants, ISS Program organization managers, and other NASA institutional managers) use the CoFR process to endorse their commitments to launch and continued ISS operations.

ISS PROGRAM IMPLEMENTATION

The ISS Program formed a team to assess the adequacy of its CoFR process and to make recommendations for improving the review and acceptance of risks when committing to flight and continued operation of the ISS. This assessment included a process review, a documentation review, and an audit of the key processes used by certifying organizations in making their endorsement decisions. In addition, the ISS Program requested that a representative of the Independent Assessment Office (IAO) work with the CoFR Review Team to provide an independent assessment of the CoFR process and the team's recommendations.

STATUS

ISS Program management received initial recommendations from the CoFR team in September 2003. This early release of important findings allowed the ISS Program to implement several improvements in time for the Stage Operations Readiness Review (SORR) and Flight Readiness Review (FRR) conducted before the launch of the Expedition 8 crew on ISS flight 7Soyuz. Specific changes included guidance on the content of CoFR review presentations, with an increased focus on the risks associated with operations and hardware. This process was successfully executed during the 7Soyuz SORR and FRR as all Program elements fully discussed concerns surrounding the ISS environmental monitoring capability. When concerns with the adequacy of ISS environmental monitoring were brought to the SORR, these concerns were openly discussed and all possible risk mitigation actions were enacted. These concerns and mitigating actions were fully discussed at the FRR, where NASA management decided to proceed with the launch of the Expedition 8 crew.

The NASA IAO completed two separate studies of the ISS CoFR process in 2003 and 2004 that can be found at http://sma.jsc.nasa.gov/srqa/nq/assessments/ in reports JS-3005 and JKM-3002. The initial report was consistent with the observations of the CoFR Review Team.

The CoFR Review Team provided their formal report in November 2003 and it is available at http://iss-www.jsc.nasa.gov/ss/issapt/cofr/cofrindex.html. In mid-January 2004, the Space Station Program Control Board (SSPCB) approved the following phased plan for additional changes to the ISS CoFR Process Document (SSP 50108:

- Phase 1 – Update CoFR board membership to incorporate the roles of three new contractors, revisions to reflect organizational realignments of existing support groups, and terminology definitions for risk and standard/forward work.

- Phase 2 – Resolve IAO CoFR process concerns, refine and clarify processes, and include updates to implementation plans of support organizations.

- Phase 3 – Address and resolve CoFR management and logistic processes and resources (e.g., control of implementation plans of support organizations, CoFR staff support).

The ISS Program assigned the ISS Mission Integration and Operations Office the task of responding to each of the recommendations. Weekly team meetings discuss findings, recommendations, process improvements, and resulting document changes.

Phase 1 was completed prior to the SORR for ISS flight 13Progress. Improvements were implemented to ensure full and open discussions, disclosure, and resolution of issues with all support organizations. These improvements include the standard inclusion of special topic reviews initiated by people other than management. Additionally, special CoFR reviews will be performed such as the delta FRR for the first two-person extravehicular activity.

Phase 2 is planned to be complete before the first mission of Shuttle return to flight on ISS-LF1 (STS-114). The Phase 2 changes to SSP 50108 are currently under review for formal approval. This change request was initiated in September 2004. Updates include matching International Partner CoFR processes with NASA current practices, definitions for terms (e.g., "mission success"), and clarifying the waiver/deviation process. As an example of attention to Columbia Accident Investigation Board findings, a representative of the NASA Engineering and Safety Center has been added as a supporting participant in each SORR and FRR. As hardware certification processes are evaluated, resulting recommended changes will be considered for implementation in the CoFR process. The current CoFR requirements document, pending changes, and the CoFR charter can be found at http://iss-www.jsc.nasa.gov/ss/issapt/cofr/index.html.

FORWARD WORK

The ISS Program will continue to review and implement the recommendations of the IAO and its own CoFR review team. It will also assess the conclusions and changes of the Space Shuttle Program for potential ISS applicability.

To complete Phase 2 and 3 improvements, following approval of Revision C to SSP 50108, the implementation plans of support organizations and the International Partners will be updated. This future change to SSP 50108 will also incorporate the European Automated Transfer Vehicle into the CoFR processes.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Sep 03 (Complete)	Initial recommendations
ISS Program	Oct 03 (Complete)	IAO Phase 1 Report
ISS Program	Nov 03 (Complete)	Program Review Team Phase 1 Report
ISS Program	Jan 04 (Complete)	SSPCB approved SSP 50108 updates to support 13Progress SORR
ISS Program	Feb 04 (Complete)	SSPCB disposition Program Review Team and IAO recommendations
ISS Program	Sep 04 (Complete)	Initiate change request for Rev. C of SSP 50108
ISS Program	Feb 05	Approve SSP 50108, Rev. C
ISS Program	May 05	Update SSP 50108 for International Partner process improvements (complete Phase 2 and 3 improvements)
ISS Program	Ongoing	Review of Shuttle CoFR changes for ISS applicability

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 4

The International Space Station (ISS) Program has initiated a review of its critical items lists (CIL) and the failure modes and effects analyses (FMEA) associated with the CIL to revalidate acceptance rationale based on experience gained in operating a crewed ISS for almost 3 years.

Note: The International Space Station (ISS) response to Continuous Improvement Action ISS-4 was approved by the ISS Safety and Mission Assurance Panel (S&MAP) on September 30, 2004. All actions related to assuring implementation are the responsibility of the S&MAP.

BACKGROUND

The failure modes and effects analysis/critical items list (FMEA/CIL) is used to identify potential hardware failure modes and their credible causes and to assess their worst-case effect on ISS operations and crew/ISS survival. A subset of the hardware analyzed in the FMEA is categorized as a "critical item" based on the inherent risk of failure. For critical items, acceptance rationale that minimizes the failure probability and/or precludes the failure effect is documented in the FMEA/CIL.

As part of the ISS design process, the ISS Program performed the following steps:

1. Developed an FMEA on all ISS hardware to identify critical items.
2. Identified essential manufacturing inspection and test processes for critical items to eliminate or further reduce the risk. Consideration is given to enhancing the hardware design by focusing on design specification, qualification, and acceptance requirements.
3. Formulated operational and maintenance procedures for critical items to eliminate or minimize the likelihood of occurrence and the effect associated with each failure mode.
4. Formally documented the acceptance rationale identified for each failure mode in the CIL and provided assurance that the critical item controls are effectively implemented.

The critical items/hazard report (HR) process was improved per SSP 30234, FMEA/CIL Requirements for ISS, Revision F, to specifically link Program approval of Criticality 1 critical items with catastrophic hazardous effects to the corresponding HR/nonconformance report. Where applicable, traceability is provided with the critical item referenced in the HR and the HR referenced in the FMEA/CIL worksheet. The FMEA/CIL development and verification process was audited by independent agencies with satisfactory results. Future planned audits of the Reliability and Maintainability (R&M) Panel process and FMEA/CIL dispositions will be identified and scheduled through the Safety and Mission Assurance (S&MA) Panel.

ISS PROGRAM IMPLEMENTATION

The ISS Program R&M Panel review was established to revalidate all ISS critical items using the following process:

1. Review criticality assignments for accuracy and consistency with current use and environment.
2. Validate the retention rationale associated with each critical item to ensure that the level of risk initially accepted by the ISS Program has not changed.
3. Establish new or modify existing retention rationale, as required.
4. Capture any on-orbit or ground processing experience that impacts the CIL retention rationale.
5. Develop or revise FMEA/CIL worksheets to include updates.
6. Submit updated FMEA/CIL worksheets and newly identified critical items to the R&M Panel for approval.
7. Submit newly identified critical items for Program approval to the S&MA Panel and, if required, the Space Shuttle Program Control Board (SSPCB).

The R&M Panel categorized its findings into three types: High, Medium, and Low. High represents technical issues and open work to the retention rationale. Medium represents minor documentation issues. Low represents no impact to the critical item. The ISS Program subsystem teams participated in this effort by reviewing findings with the R&M team. The ISS R&M Panel served as the responsible forum for managing completion of these tasks.

STATUS

Each ISS critical item was reviewed by the S&MA subsystem engineers (SSEs). The S&MA SSEs generated numerous comments. Of the High Category comments submitted, two resulted in critical items. One is the U.S. on-orbit segment (USOS) hatch, and the other is the USOS Node 1 smoke detector. The hatch was identified as a critical item for the failure mode of “fails to open” in a newly defined operations scenario involving emergency access. Failure analysis documentation will be revised accordingly. Reassessment of the failure concluded possible “loss of mission” (Criticality 2) if the crew is unable to open a hatch closed during an emergency. The Node 1 smoke detector was identified as a critical item (Criticality 1S) as the smoke detector could fail without crew notification such that a fire event could go undetected. The Command and Data Handling Team is currently pursuing a software change that would perform a system status check more frequently. If the Program accepts the change, the smoke detector will not be assessed a critical item.

Over 340 Medium Category comments were submitted. Most comments addressed the need to update retention rationale to reflect failures experienced subsequent to approval of the critical item. Examples include the Remote Power Control Module, USOS smoke detector, and quick disconnects. The Low Category included over 330 comments. All technical comments were reviewed and approved by the ISS Program subsystem teams.

FORWARD WORK

As described in the response to *Columbia* Accident Investigation Board recommendations R7.5-1, R7.5-2 and R9.1-1, the Headquarters Office of Safety and Mission Assurance shall continue to own FMEA/CIL and Hazards Analysis processes. The new Technical Authority will participate in these processes. The ISS R&M Panel will ensure that a process is in place to review and update any ISS FMEA/CIL worksheets as the need arises through the life of the ISS. Revised FMEA/CIL worksheets and critical item presentations will be completed and presented to the R&M Panel for review and approval. Critical items will be brought to the S&MA Panel and the SSPCB for approval, as required.

In addition, the R&M Panel has the responsibility to assess findings from the Shuttle Return-to-Flight Implementation Plan Action SSP-9, regarding Shuttle FMEA/CILS for applicability and lessons learned that can be applied to ISS. Any findings that can be applied to ISS will be dispositioned through the R&M Panel process.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS R&M Panel	Nov 03 (Complete)	Status Report to Program Manager
ISS R&M Panel	Nov 03 (Complete)	S&MA SSE Critical Item Review
ISS R&M Panel	Feb 04 (Complete)	ISS Subsystem Team Review
ISS R&M Panel	Mar 04 (Complete)	Approval of revised FMEA/CIL documentation for Medium and Low Category comments
ISS R&M Panel	Feb 05	Approval of revised FMEA/CIL documentation for High Category comments
ISS Program Manager	Mar 05	Assess the SSP-9 response for applicability to ISS
ISS R&M Panel	Ongoing	Continue process of review and approval of FMEA/CILs per SSP 30234

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 5

Review ISS anomaly resolution processes to ensure that proper requirements are in place and anomaly resolution processes are operating effectively.

Note: International Space Station (ISS) Continuous Improvement Action ISS-5 was approved by the ISS Vehicle Control Board (VCB) on September 13, 2004. All forward actions will be tracked by the VCB or, in the case of the Problem Reporting and Corrective Action (PRACA) actions, by the Safety and Mission Assurance/Program Risk (S&MA/PR) Office, with oversight by the Program Risk Advisory Board (PRAB).

BACKGROUND

An "anomaly" is any unexpected performance characteristic or condition that requires further investigation. A "nonconformance" is any anomaly where one or more characteristics do not conform to requirements specified in a contract, bilateral agreement, drawings, specifications, etc. The proper identification, investigation, resolution, reporting, trending, and documenting of ISS hardware, software, and operations anomalies, whether they occur on the ground or on orbit, is essential to ensuring successful activation and operation of ISS systems. The integration of numerous International Partner, NASA, and contractor systems and organizations, coupled with the fact that it may not always be feasible to return anomalous hardware to the ground for investigation or repair, are some of the primary reasons that anomaly investigation and resolution is one of the most critical, complex, and challenging ISS Program processes.

Throughout the design, development, testing, and delivery of its systems, the ISS Program requires that all NASA ISS contractors and hardware/software providers establish formal processes for identifying, investigating, resolving, and documenting nonconformances in accordance with *Space Station Quality Assurance Requirements* (SSP 41173). Further, *Problem Reporting and Corrective Action Requirements for Space Station Program* (SSP 30223) defines which nonconformances must be elevated from a provider's reporting system to the ISS Program and, once elevated, how the ISS Program is to investigate and disposition those nonconformances. System Problem Resolution Teams (SPRTs) consisting of engineering, S&MA/PR, operations, and other organizations have been established for each system to investigate and resolve those reportable nonconformances.

As the ISS Program began to transition from designing, building, testing, and delivering systems to launching, activating, operating, and sustaining systems, it also evolved its anomaly resolution processes. SSP 41173 was modified to better define expectations of government and contractor reporting, investigation, and Material Review Board (MRB) disposition of anomalies that occur on the ground during the development and testing of ISS systems, hardware, and software. SSP 30223 was updated to require that the ISS PRACA process and associated database become the on-orbit hardware nonconformance reporting system and that all on-orbit nonconformances be treated in the same manner as those ground nonconformances that are elevated to an SPRT by a contractor or hardware provider. The ISS Mission Evaluation Room (MER) also created the Item for Investigation (IFI) process and database to track all on-orbit anomalies until they could be confirmed as reportable nonconformances and documented in the appropriate PRACA database. SSP 41173 establishes standards for handling PRACA entries so they are uniform across the ISS, no matter where or how the anomaly is discovered.

In addition, work instruction MGT-OA-019, *On-Orbit Anomaly Resolution Process*, was released to formally define the implementation process for reporting, investigating, and dispositioning on-orbit system anomalies, as well as non-system anomalies with potential system or crew safety impacts (e.g., payloads).

While MGT-OA-019 recognized that the ISS Flight Director was responsible for taking any immediate actions required to protect the ISS and its crew, it also established the ISS MER as the primary organization responsible for investigating on-orbit system anomalies and identifying appropriate corrective actions to allow safe and extended operations until the anomaly could be fully resolved. The work instruction also established criteria and guidelines for transitioning responsibility for continuing the root cause investigation and implementation of long-term corrective actions and recurrence controls from the ISS MER to the SPRTs once the "real-time" and "near-real-time" risks were mitigated.

Similar to the system community's efforts to evolve the on-orbit anomaly reporting and disposition process, the ISS Payloads Office established comparable processes for the investigation and functional disposition of on-orbit anomalies involving NASA payloads and scientific research. Those processes established the Payload Operation Integration Center (POIC) and its Payload Operations Director as the primary organization responsible for initially investigating and resolving on-orbit payload anomalies and for assuring that any anomalies that could potentially result in interface or integration impacts upon other NASA or Partner systems were communicated to and worked with the Flight Control Team, ISS MER, and SPRTs, as appropriate.

Figure ISS-5.1 illustrates the complexity of the integrated ground and on-orbit anomaly resolution process.

ISS PROGRAM IMPLEMENTATION

In January 2003, the ISS Program established a process improvement team to evaluate the overall effectiveness of the ISS on-orbit anomaly resolution processes, as well as the integration of those processes with other critical ISS processes (e.g., waivers, change requests). The team was also asked to recommend process improvements to determine where improvements could be made by integrating different anomaly resolution processes and/or tools (e.g., systems and payloads; ISS and Shuttle), and to monitor the effectiveness of any implemented actions.

Following the STS-107 accident in February 2003, the team also increased its level of participation and coordination with the Space Shuttle Program return to flight team assessing the Shuttle Program's anomaly resolution process.

It was decided to initially focus the team's evaluation on the NASA's process for evaluating and dispositioning all on-orbit hardware anomalies, as well as those ground anomalies that could not be dispositioned within the scope of the MRB processes used by the various ISS contractors.

Deferring assessment of the effectiveness of the various contractor quality assurance processes was considered appropriate since audits of these processes are performed when a contractor is selected. In addition, the S&MA/ PR Office has contracted with the Defense Contractor Management Agency to provide quality assurance oversight at the various contractors. The S&MA/PR Office will also determine the need to make changes in its formal contractor surveillance audit process.

The team's evaluation identified several strengths and improvement opportunities to ISS Program management via the Systems Working Group (SWG) between February and May 2003. SWG is a multi-organizational forum where integrated system and process issues may be discussed.

As a result of the SWG discussions, ISS Program management approved several actions and their associated implementation schedule. These same strengths and areas for improvement were also reported to the Space Station Program Control Board in September 2003, with periodic updates being presented as certain milestones are achieved or changed. The reported strengths, areas for improvement, and ongoing corrective actions and improvements are described below.

Strengths

The seven anomaly resolution process strengths identified by the continuous process improvement team are as follows:

- The on-orbit portion of the anomaly resolution process for ISS systems, including the interfaces between and roles and responsibilities of the ISS MER, flight control team, SPRTs, and other ISS Program organizations, is well defined within ISS Program-level work instructions.

- On-orbit anomaly information is immediately and consistently disseminated and frequently presented to all levels of ISS Program management, with requirements for dissemination clearly established within ISS Program-level work instructions.

  For example, all anomalies that occurred within the previous 24 hours are reported to the ISS Mission Management Team (IMMT), to the ISS Vehicle Office and system managers, to ISS and Headquarters S&MA personnel via the daily ISS MER S&MA Console's Daily Shift Report; to the operations community via the flight control teams Daily Spacecraft Analysis report; and throughout the ISS and Headquarters community via the daily Increment Management Center report.

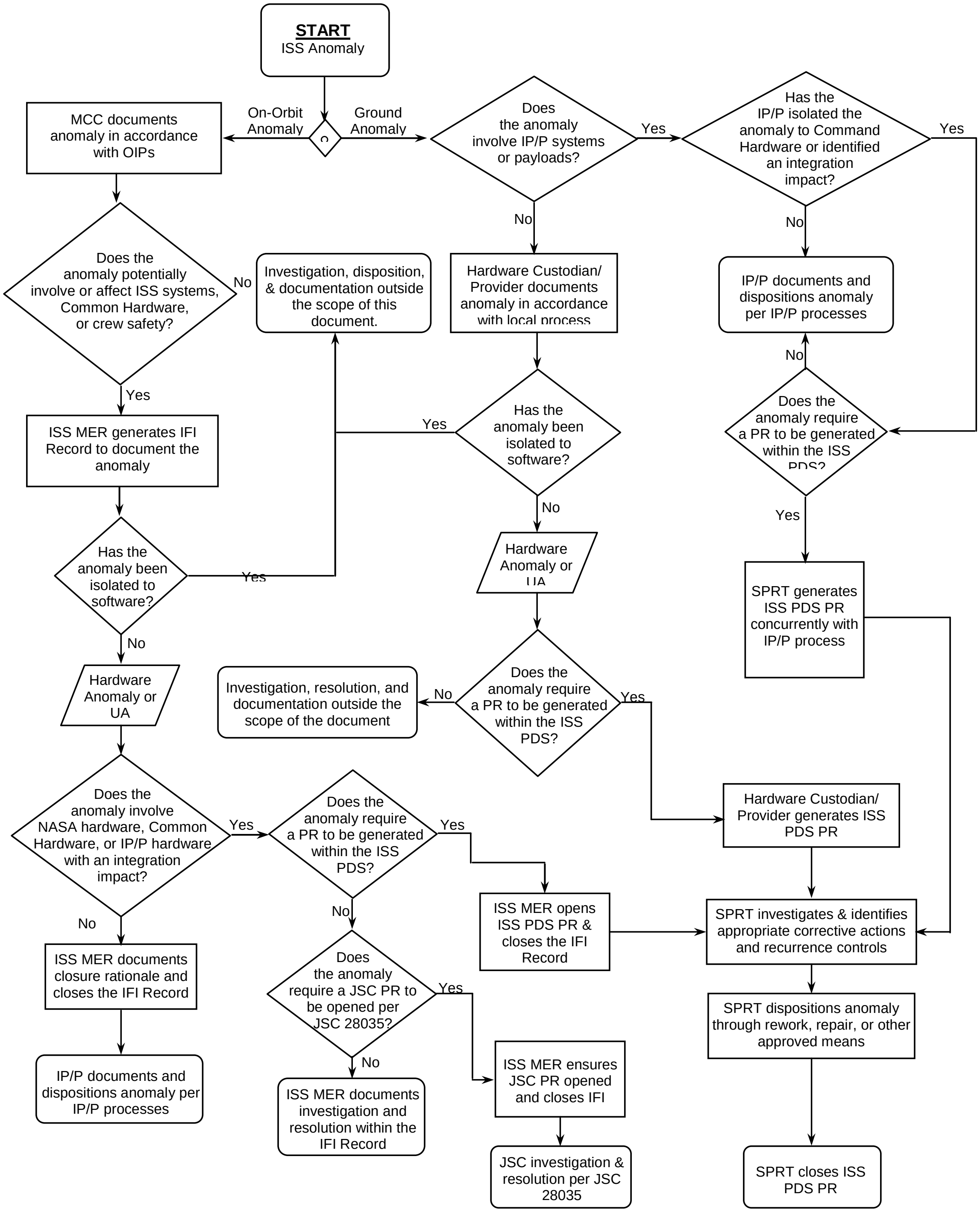


Figure ISS-5.1. Anomaly resolution process.

- Information related to active on-orbit anomaly investigation activities is readily available and accessible via the ISS MER Web site.

  For example, information regarding anomaly resolution team meeting information, minutes, and supporting analysis can be obtained from file folders available from the ISS MER Web site. In addition, hyperlinks allow quick and direct access to anomaly reports documented within the ISS MER's IFI database and other applicable ISS PRACA databases.

- Criteria are clearly established above and beyond the authority granted to the ISS Flight Director during real-time operations for determining what levels of management approval are required for implementing on-orbit troubleshooting and anomaly response actions.

  For example, MGT-OA-019 establishes clear criteria defining when anomaly resolution activities may be approved at the ISS MER Manager and Flight Director level and when such activities must be elevated to the IMMT and governing ISS Program Boards for approval.

- Criteria are clearly defined to be used by anomaly resolution teams in determining the impacts and risks associated with an on-orbit anomaly and potential response actions.

  For example, MGT-OA-019 provides a detailed checklist to be used by all anomaly resolution teams to support investigation efforts, development of fault trees, comparison of risks, etc.

- Overall, the established on-orbit anomaly resolution process ensures thorough, timely, and meaningful response to all on-orbit anomalies and assurance that appropriate steps are taken to understand, document, communicate, and mitigate real-time and near-real-time risks.

- The SPRTs are effective in resolving specific anomalies and in updating operations procedures when required to support the anomaly resolution.

Areas for Improvement

The seven areas for improvement were identified as follows:

- Many of the existing requirements documents, bilateral/multilateral agreements, and work instructions governing the anomaly resolution process were in need of revision. In addition, there were inconsistencies within and between existing ISS requirements documents, agreements, and work instructions associated with the anomaly resolution process and other ISS processes.

- There was a lack of meaningful metrics, consistent Program management oversight, and adequate quality assurance participation to monitor overall ISS MER and SPRT performance and the effectiveness of the anomaly resolution process.

- Trending of ISS system performance and recurring anomalies was inconsistent and non-standardized, with inadequate definition of trending requirements, guidelines, and expectations.

- Several of the existing anomaly reporting databases and other tools (e.g., Web sites) that support the anomaly resolution process were not efficient in supporting current ISS Program needs and long-term sustaining of the ISS.

- Training for individuals who participate in and oversee the anomaly resolution process was infrequent, inconsistent with requirements and processes, and at such a high level that it had not contributed meaningfully to overall process improvement or compliance.

- Several organizations were not implementing current portions of the anomaly resolution process requirements and/or work instructions, mostly due to conflicting or outdated requirements.

- The quality of the historic anomaly reports stored within the various ISS anomaly reporting databases was inconsistent and often poor, due in significant part to inadequately qualified and trained quality assurance personnel who support and oversee the anomaly resolution process. Delays in initiating and maintaining the records of known new anomalies were similarly caused by staffing deficiencies.

Process Improvements

The process improvement team recommended the following Process Improvement (PI) actions to ISS Program management between February and November 2003:

PI-1. Update existing requirements documents, bilateral/multilateral agreements, and work instructions, with priority being given to requirements and documents governing hardware that is already on orbit.

PI-2. Identify, establish, and implement meaningful anomaly resolution process metrics, as well as a Quarterly Management Review where ISS Program Management evaluates open anomalies, assesses how well teams are managing/mitigating risks, evaluates aggregate risk associated with multiple anomalies, assesses/resolves process issues, etc. (i.e., a "top-down" individual and aggregate system review).

PI-3. Clarify and, where appropriate, expand trending requirements and establish a formal process for trending ISS system performance and anomaly history. *(Ref. ISS-6)*

PI-4. Update the ISS anomaly reporting databases and associated tools to support long-term sustaining of the ISS. Coordinate with the Shuttle Program, Johnson Space Center (JSC), and other NASA and commercial organizations to identify lessons learned, available systems and tools, and additional areas of improvement.

PI-5. Establish an internal audit/oversight process for the ISS anomaly resolution process to assure improvements are continued.

PI-6. Expedite negotiations with the International Partners, both on a one-on-one basis and in multilateral forums, to establish and document an overall ISS anomaly resolution process that governs all aspects of ISS anomaly resolution activities.

PI-7. Update and, where necessary, generate new generic and specific discipline training for all personnel involved in the anomaly resolution processes, pursue the option of establishing a Web-based mandatory retraining program, and determine the need for a formalized anomaly resolution process training and certification program.

PI-8. Consider conducting a detailed, independent assessment of the software anomaly resolution process, including ongoing improvements, to determine the effectiveness of requirements and their implementation.

PI-9. Given that the Space Shuttle Program and JSC are also considering significant anomaly resolution process improvements independent of each other and the ISS Program, develop rationale to form a JSC- and/or Agency-level team to determine the feasibility of combining the improvement efforts and key portions of these processes.

PI-10. Perform a quality review of currently closed and open records within the ISS IFI and PRACA databases to determine whether any of those records were closed without resulting in a waiver being generated when restoration of full functionality and compliance was not accomplished. Where waivers should have been generated, provide the anomaly record information to the team established to review all open waivers, deviations, and exceptions as part of ISS Continuous Improvement Action ISS-1.

STATUS

Process Improvement 1

For PI-1, which addresses existing requirements and process documentation, NASA has:

- Completed the update of MGT-OA-019, *On-Orbit Anomaly Resolution Process,* to incorporate lessons learned from the *Columbia* Accident Investigation Board findings regarding the reporting and dissemination of anomaly information to the IMMT. This document provides instructions on handling on-orbit anomalies. The updates are being used during real-time operations as well as during Mission Control Center (MCC) simulations involving joint ISS/Shuttle operations to ensure their effectiveness.

- Completed the update of SSP 41170, *Configuration Management Requirements*, to formally authorize use of a minor versus a major waiver process and to define clear lines of responsibility regarding who must review and approve such waivers.

- Completed the update of SSP 41173, *Space Station Quality Assurance Requirements,* to incorporate the major and minor waiver business practices currently being used by the ISS Program and to bring the high-level nonconformance processing requirements more in line with MIL-STD-1520C, *Corrective Action and Disposition System for Nonconforming Material* (i.e., Department of Defense nonconformance process requirements).

- Released a significant revision of SSP 30223, *Problem Reporting and Corrective Action Requirements for Space Station Program,* for review within NASA The revised document incorporates lessons learned from five years of on-orbit operations. It includes a detailed description of what anomalies are to be included in the PRACA database. Discussions are occurring with ground processing facilities to ensure that PRACA requirements are sufficient for the ISS operations team.

- Released revised MCC Operations Integration Procedures (OIP) incorporating initial NASA and Partner review comments. The OIP integrates and expands upon various aspects of MCC operations previously defined in separate documents. The OIP includes processes for real-time communication of anomaly information between the various NASA and Partner engineering, operations, and support teams, as well as the transition of anomaly resolution activities from real time to engineering support.

Process Improvement 2

For PI-2, which addresses the need to establish process metrics and a "top-down" individual and aggregate system review, NASA has:

- Drafted process metrics that measure how effective the SPRTs and ISS MER are in performing their anomaly resolution activities and complying with ISS Program requirements and processes. These metrics are being reviewed against the new revisions to SSP 30223, SSP 41173, SSP 41170, and MGT-OA-019.

- Implemented changes to the ISS Program management forums that evaluate ISS risks and various aspects of system manager performance to review the systems and their process effectiveness. Initial metrics were defined and formal quarterly reporting has begun. It is expected, however, that these metrics may be modified as their usefulness is determined and SSP 30223 requirements are finalized.

Process Improvement 3

PI-3, which involves clarification and expansion of trending requirements, is addressed separately under ISS Continuous Improvement Action ISS-6.

Process Improvement 4

PI-4 actions, which involve the update of ISS anomaly reporting databases and associated tools, are still ongoing. The ISS S&MA/PR Office, with participation from the anomaly resolution process improvement team, has:

- Drafted requirements for an integrated ISS anomaly reporting system that can be used to govern the upgrade or replacement of the existing ISS IFI and PRACA Data System (PDS) databases. As part of this effort, S&MA has identified potential areas in which to standardize processes, including areas in which integrating processes between ISS and other programs might be warranted. Three likely database candidates are being evaluated for cost and benefit.

- Made significant progress in improving and adding to the tools used to disseminate anomaly-related information. For example:

  1. The SPRT Web site was restructured to enable SPRTs to manage their own sections of the Web site. This has resulted in more timely and consistent dissemination of SPRT meeting information, minutes, actions, etc. It has also resulted in higher confidence that the information presented on the Web site is current and up to date.

  2. The flight control team has created and implemented an MCC Anomaly Tool to augment the existing IFI and PDS databases. The MCC Anomaly Tool documents all on-orbit anomalies as soon as they occur. When the ISS MER is notified of the anomaly and generates the appropriate IFI, the MCC Anomaly Tool is updated to reference the IFI and is then closed. This has significantly reduced the likelihood that the MER is not informed about an anomaly that occurs during periods when the MER is not providing flight support. In addition, responsibility for creating PRACA reports has been clearly defined. This has assured that IFIs or PRs that should be entered as PRACAs are completed

within five days. Metrics to ensure timeliness are tracked and reported. The MCC Anomaly Tool is also being used to track the investigation and disposition of anomalies that are related to operations, but that do not directly involve and/or affect ISS hardware or software, such as operator errors.

3. The POIC's Payload Anomaly Report (PAR) system was modified to require that each payload anomaly is assessed for potential impacts on ISS systems and crew safety and health. ISS MER Managers S&MA personnel have access to the PAR system and perform independent reviews of these payload anomalies. The POIC and ISS MER now conduct daily teleconferences during which system and payload anomalies as well as upcoming plans are discussed to ensure that existing anomalies will not adversely affect the activities that are being planned.

Process Improvement 5

PI-5, which establishes and implements an internal audit/oversight process for the ISS anomaly resolution process, is addressed separately under ISS Continuous Improvement Action ISS-12.

Process Improvement 6

For PI-6, which addresses the need to expedite negotiations with the Partners to better integrate them into an overall ISS anomaly resolution process, NASA has:

- Held process discussions with all of the Partners. Although individual collaborations will continue, multilateral discussions are scheduled to finalize agreements with all of the Partners. Feedback from these discussions and any agreements reached are being flowed back into the various requirements, bilateral/multilateral agreements, and work instruction updates.

- Directed the ISS MER to work with the flight control team and various Partners to improve the integration of the Partners within the various process tools (e.g., action request chits, IFI Database, PRACA databases). As improvements are identified, activities to test those improvements are being implemented. For example, efforts to incorporate the European Space Agency into the ISS chit process for current real-time operations were simulated recently with excellent results. Coordination in preparation for real-time operations will continue.

Process Improvement 7

Efforts to implement PI-7, which addresses training and certification of personnel involved in the anomaly resolution process, are under way. For example:

- Personnel who work in and support the MCC are currently going through flight simulations to train them on the process changes that have been made. Development of detailed anomaly resolution training beyond that already incorporated into existing flight controller and ISS MER certification programs is complete and personnel are being trained.

Process Improvement 8

For PI-8, which addresses improvements to the software anomaly resolution process, the ISS Program has made and continues to pursue many improvements in its generic problem reporting and tracking processes. These improvements in problem reporting requirements, trending, and quality assurance audit capabilities are described in the separate responses to other ISS continuous improvement actions (i.e., ISS-5, ISS-6, and ISS-12). In parallel, specific improvements in ISS software problem resolution have been addressed as stated in the response to ISS-10. Given these generic and specific improvements, the ISS Program has found no need for additional near-term reviews of its software anomaly process. Future reviews will be addressed as normal business by ISS quality assurance processes.

Process Improvement 9

For PI-9, which addresses the potential for combining anomaly resolution processes with other programs, NASA assessed the advantages and disadvantages of such an effort and found that:

- Attempts to combine processes at this time would not be productive. Each program has been assessing its own processes and is taking appropriate action to shore up any deficiencies and make its process thorough and complete. The complications that would be introduced by merging with another program make the task unwieldy and unproductive.

Process Improvement 10

PI-10 addresses the need to review the ISS IFI and PRACA databases to determine whether waivers were appropriately generated when restoration of functionality and compliance was not achieved. The assessment determined that:

- No IFI ever resulted in a waiver without first becoming a PRACA. The PRACA database was reviewed and some did result in waiving conditions that were not documented on a waiver form, although none of these would change the ISS risk acceptance profile. A further study is in process to determine whether any of these items should be transferred to waiver forms. As a result of the study, the ISS Program has delineated the use of the waiver form and is setting in place work instructions to ensure that all requirements are waived using the official waiver process. To ensure completeness, all waivers are discussed and the wording is approved in the appropriate ISS Control Board.

FORWARD WORK

Most actions to implement the recommendations from the process improvement team and to monitor their effectiveness have been implemented. Work remains, however, to complete the approval of the PRACA requirements document. In addition, final agreements of the anomaly process and the interface with the International Partners must be completed. Completion of the PRACA requirements will be tracked by the Safety and Mission Assurance Panel. All other future items will be tracked by the VCB. The ISS Program reviews the status of these improvements at each PRAB, which meets every six weeks.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Oct 03 (Complete)	Develop corrective action/ improvement schedule
ISS Program	Nov 03 (Complete)	Update ISS Quality Assurance requirements
ISS Program	Dec 03 (Complete)	Upgrade SPRT Web site
ISS Program	Dec 03 (Complete)	Implement MCC Anomaly Tracking Tool
ISS Program	Jan 04 (Complete)	Update ISS Configuration Management requirements
ISS Program	Apr 04 (Complete)	Update of On-Orbit Anomaly Process Work Instruction, MGT-OA-019
ISS Program	Apr 04 (Complete)	Complete MER/MER Manager and generic IFI/ PRACA/SPRT training for NASA
ISS Program	May 04 (Complete)	Complete technical evaluation of update/ replacement options for ISS PRACA and IFI databases
ISS Program	Jun 05	Update ISS PRACA requirements document
ISS Program	In negotiation	Develop multilateral agreement that covers entire ISS Program anomaly resolution process
ISS Program	Ongoing	Complete update of NASA/Partner bilateral/ multilateral agreements associated with anomaly resolution
ISS Program	Ongoing	Review status of improvements at each PRAB

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 6

Review ISS system performance trending requirements and implementation status and make recommendations for improvement.

Note: International Space Station (ISS) Continuous Improvement Action ISS-6 was approved by the ISS Vehicle Control Board (VCB) on September 13, 2004. All forward actions will be tracked by the VCB and by the Safety and Mission Assurance Panel, with oversight by the Program Risk Advisory Board (PRAB).

BACKGROUND

Trending of ISS system performance and recurring anomalies is essential in assuring the successful assessment and management of risk to support the long-term operation of the ISS. The importance of adequate trending increases as ISS systems and operations become more complex through assembly activities and as ISS systems age. The grounding of the Shuttle fleet and the resulting impacts upon ISS systems with preventive maintenance and calibration requirements, as well as impacts to the resupply capability, have reemphasized the importance of trending.

In January 2003, the ISS Program began a reassessment of its ISS system trending processes. The goal was to identify potential weaknesses and areas of improvement in the Program's ability to detect and respond to adverse trends or recurring events before they lead to an eventual failure that significantly impacts crew safety or mission objectives or that lead to a catastrophic failure. NASA recognized that improvements in trending should also lead to better decision-making regarding logistics, spares provisioning, reliability predictions, and resource management.

It is worth noting that ISS performance metrics reported at the Agency level do not include targets for on-orbit anomalies. This exclusion is deliberate and is done to promote accurate and complete reporting of the true technical status within the ISS Program. Because of this choice, there is no perception of inappropriate pressure and no motivation for unwarranted complexity in the terminology of tracked issues. An example is the site that displays items for investigation, available at http://jsc-issprd01.jsc.nasa.gov/IFI/.

ISS PROGRAM IMPLEMENTATION

The ISS Program divided its efforts to assess and improve the overall trending process into three key areas, each discussed separately below:

1. System performance trending
2. Anomaly recurrence trending
3. Process trending

System Performance Trending

System performance trending is needed to indicate how well ISS systems are performing over time and to provide insight into any adverse or unexpected trends that, while not yet a problem, could result in system failures or additional anomalies if preventive actions are not taken.

While all data for onboard systems are kept in an online database accessible to flight controllers and engineers for immediate and trending enquires, an evaluation of system performance trending within the ISS Program confirmed that detailed trending requirements and expectations had not been clearly defined and documented. As a result, the trending that was performed varied significantly from system team to system team, contractor to contractor, etc. In addition, the level of trending that was performed also varied significantly across systems, from little trending for some systems to an extensive amount of trending for other systems. Where teams were performing trending assessments for their particular systems, the results of such assessments are not always effectively communicated outside of the team.

The ISS Program has initiated several efforts to establish a more consistent and meaningful system performance trending process.

The Statement of Work within the ISS Vehicle Sustaining Engineering contractor has been modified to clarify that system performance trending is a requirement of the contractor.

The ISS Vehicle Office and Vehicle Integrated Performance and Resources (VIPeR) team, with support from the NASA and ISS Vehicle Sustaining Engineering contractor Chief Engineers, has initiated efforts to assist the various system teams in establishing system-by-system trending plans. It is intended that the trending plan developed for each system will define what parameters and performance characteristics need to be trended, how those performance trends will be analyzed and used by the system manager, how those trends will be evaluated across multiple systems, and how and when those trending analysis results will be disseminated throughout the ISS Program and reported to ISS Program management.

The ISS Program is comparing actual data of on-orbit hardware performance to its respective predictive data. Comparisons of predicted and actual failure rates, maintenance actions, crew time, and availability give insight into the hardware performance to date. Trending these comparisons has begun to indicate how the hardware may be expected to perform in the future. The data for these analyses are updated as events occur on orbit, and analyses are updated and assessed quarterly.

An evaluation continues as to how to improve databases and tools can be used to support effective and efficient trending of system performance. The objective of the evaluation was to determine where changes to the existing databases and tools are needed and whether new databases and tools should be acquired to help improve overall trending activities. The evaluation determined that the current tools can meet the requirements but are not the most efficient. Additional requirements for future tools have been established, and currently the Program is developing cost estimates for candidate databases. Once completed, the ISS management will consider the cost and the potential benefits in deciding whether the efficiency improvement should be approved.

Anomaly Recurrence Trending

Trending of recurring anomalies is needed for several reasons. First, such trending is needed to identify areas where an investigation team may not have adequately identified and implemented sufficient corrective actions and recurrence controls, as well as whether the root cause of the anomaly may not have been accurately identified. Second, anomaly recurrence trending needs to be performed to identify areas where the ISS Program may have previously accepted the risks associated with a rare, an infrequent, or an unexplained anomaly but now may need to revisit that risk acceptance decision to ensure that the decision rationale is still valid. Third, trending of anomalies plays a direct role in validating and adjusting system hardware life predictions, maintenance and calibration frequencies, reliability calculations, sparing planning, and other logistics and maintenance activities.

The ISS Problem Reporting and Corrective Action (PRACA) Data System (PDS) is the database used to document the investigation and disposition ISS hardware nonconformances that must be elevated to an ISS Program System Problem Resolution Team (SPRT) or Program board for approval. Hardware nonconformances that do not require elevation to an ISS SPRT or Program board are tracked within the hardware provider's nonconformance system.

The PDS incorporates several features that allow a user to trend recurring nonconformances. These features are currently being used by the ISS Reliability and Maintainability organization in support of the system managers and their SPRTs to determine whether certain hardware items are exhibiting problems that warrant a change in the predicted life of the hardware, which in turn could lead to potential changes in logistics and sparing planning, as well as potential changes in system design and operation.

In addition, the search and query functions built into the ISS PDS allow the system managers and their SPRTs established for the various ISS systems to determine whether a newly reported nonconformance has previously occurred and, if it has, how often it has occurred, any unique factors associated with previous occurrences, etc.

The ISS Program Professional Version Control System (PVCS) is the primary database used by the ISS Program to document the investigation and disposition of ISS software nonconformances, including those Software Program Notes that are written to address software anomalies that might recur because the Program has elected to defer or waive implementation of resolution activities. PVCS has similar features allowing queries in the software areas.

To help ensure that SPRTs are doing an adequate job of trending recurring anomalies and that they are equipped with the proper tools to perform such trending, the ISS Program has initiated some process improvement actions.

NASA and its ISS Vehicle Sustaining Engineering contractor, Boeing, have initiated periodic systematic reviews of "recurring events" being experienced at the integrated stage, element, system, subsystem, hardware, software, and component levels. The objective of these reviews is to ensure that the ISS Program has adequately identified the root cause of those events and that any corrective actions and recurrence controls implemented are still sufficient. In addition, the reviews are intended to identify any differences in the anomalies, ISS configuration, or other factors that would warrant the need to modify previous decisions to accept the risks associated with those anomalies and the previously implemented corrective actions and recurrence controls.

NASA has initiated efforts to update the existing ISS anomaly and nonconformance reporting databases as part of ongoing anomaly resolution process improvement efforts. As part of these upgrade efforts, consideration is being given to how anomalies and nonconformances are categorized so that the tools can be configured to improve automated trending of recurring anomalies. The cost estimating for improved tools and databases is being done jointly with the effort defined above, and the benefits of any new products are being assessed in an effort to provide the most cost-effective result for NASA.

Process Trending

Process trending is intended to uncover inefficient and ineffective areas within the various ISS processes as well as to identify where organizations and personnel may not be fully compliant with or knowledgeable in the process requirements.

In the area of anomaly resolution, the ISS Program has identified the need to establish metrics that can be used to measure how effectively the various anomaly resolution teams (e.g., ISS Mission Evaluation Room (MER), SPRTs) are implementing and complying with the ISS anomaly resolution process. The metrics that teams will collect have been established, and the first such metrics are being reviewed by vehicle management. As the usefulness of these metrics is determined, the data to be collected and reported are modified. This will ensure that anomalies receive proper attention and the teams working them are being effective.

To determine the effectiveness of other ISS Program processes and how well the various ISS Program organizations are complying with those processes, as well as any adverse trends in those processes, consideration is being given to the establishment of an internal audit/surveillance function that resides within the ISS Safety and Mission Assurance organization independent from the engineering and configuration disciplines. Additional information regarding ISS Program consideration of an internal audit/surveillance function is provided separately under ISS Continuous Improvement Action ISS-12.

STATUS

The Statement of Work has been modified to clarify that system performance trending is a requirement of the ISS Vehicle Sustaining Engineering contractor. Although it was determined that each system manager was performing system trending to some extent, the change to the contract has been communicated to NASA and the contractor system managers to ensure that they understand their role and responsibility for system trending activities.

The ISS Vehicle Office and Boeing VIPeR team have obtained detailed reports from the system teams that describe the various parameters being evaluated and trended by those teams, where those teams report their trending information, and how those teams use the trending data to support decision-making activities. With the information received from each subsystem team, the VIPeR team has initiated efforts to formalize the trending process to improve consistency between how the various teams are performing, documenting, and disseminating their trending information. The first set of metrics was collected based on these analyses. Currently quarterly reviews are being done and analyses are being assessed.

Another effort of the ISS Program is comparing actual data of on-orbit hardware performance to its respective predictive data. Comparisons of predicted and actual failure rates, maintenance actions, crew time and availability give insight into the hardware performance to date. Trending these comparisons begins to indicate how the hardware may be expected to perform in the future. The data for these analyses are updated as events occur on orbit, and analyses are updated and assessed quarterly.

The trending efforts have already been useful on several occasions. For example, batteries are monitored for power changes that could indicate an impending hardware failure. This has been very beneficial. Trends are used to review maintenance schedules for equipment to try to optimize timing for preventative maintenance tasks. All ISS data are kept in a database that is easily accessible to the flight controllers and engineers. These data were reviewed to find a way to detect small leaks aboard the ISS. Measuring gas content directly did not provide the correct information as it was too reliant on actual activities of the astronauts. After much work, the partial pressure of nitrogen was found to correlate closely with small leaks on the ISS. This trending metric is now routinely examined. As the usefulness of metrics and the frequency of their need are determined, it is expected that the metrics being collected will be modified to continually improve their quality and relevance.

Evaluation of the various databases and tools used to support effective and efficient trending of system performance is continuing. A Task Order was issued to authorize the ISS Program Integration contractor to evaluate options for upgrading/replacing the ISS PDS to not only improve anomaly reporting and documentation activities, but also to determine what changes should be made to improve anomaly and process trending. The ISS MER Item for Investigation Database used to initially document on-orbit anomalies, the JSC GFE PRACA Database, and several other databases are also within the scope of the review that will be performed under this Task Order.

FORWARD WORK

Much work has been done to ensure that overall trending and metrics reporting is being completed more uniformly across the ISS Program. More importantly, periodic reviews of the data have been institutionalized, ensuring that the information will continue to be gathered and receive management attention. As the ISS Program reviews the data and determines that additional data will be useful or relevant, it will continue efforts to improve the trending of system performance, recurring anomalies, and process effectiveness and compliance.

Periodic systematic reviews of "recurring events" will continue for each system, with the frequency of each system review being based on the number of anomalies associated with the system, the number of recurring anomalies, schedules for implementing corrective actions and recurrence controls, and other appropriate factors. Trending of certain parameters within each system will continue to be refined to locate potential problems or watch areas allowing teams to improve operation of the ISS by catching and fixing small problems earlier. Summaries of overall predicted versus actual system performance will continue to be generated and reviewed quarterly.

A cost/benefit analysis of a new database tool will be completed to determine whether changes would improve efficiency and provide better service.

All forward actions associated with system performance and anomaly recurrence trending will be tracked by the VCB. All forward actions associated with process trending will be tracked by the Safety and Mission Assurance Panel. The ISS Program reviews the status of these improvements at each PRAB, which meets every six weeks

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Dec 03 (Complete)	Vehicle Sustaining Engineering contract change
ISS Program	Jan 04 (Complete)	Issue Task Order for Program Integration Contract to review tools and databases
ISS Program	Apr 04 (Complete)	Complete current trending process evaluations
ISS Program	Apr 04 (Complete)	Complete review of ISS Program trending tools/databases
ISS Program	Ongoing	Identify/implement additional trending tool training
ISS Program	Ongoing	Perform periodic system reviews of trends, performance, recurring events, and metrics
ISS Program	Ongoing	Review status of improvements at each PRAB

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 7

The ISS Program will assess its hardware (ground and on-orbit) to verify that they are within the hardware qualification and certification limits, in light of the grounding of the Space Shuttle fleet. Where life limits are approaching, take appropriate action.

Note: The International Space Station (ISS) response to Continuous Improvement Action ISS-7 was approved by the ISS Vehicle Control Board (VCB) on September 27, 2004. All actions related to assuring implementation were closed and responsibility for ongoing management was assigned to the VCB.

BACKGROUND

Flight hardware is designed to a set of specifications that identifies the lifetime of that hardware, any maintenance, and the verification to validate the condition of the hardware that will provide assurance of the ability to achieve this lifetime. The ISS is composed of three general lifetime categories of hardware. These categories are (1) hardware designed to remain on orbit without maintenance for the life of the ISS, (2) hardware designed for periodic replacement and/or maintenance, and (3) flight hardware on the ground that must be launched within a specified time period or be recertified.

There is a fundamental difference between the design and certification approaches of the ISS and the Space Shuttle. While the Shuttle is accessible for ground maintenance, major ISS structures like truss and module shells have had to be qualified for long on-orbit life without any human intervention (up to 15 years). To ensure that the prolonged effects of atomic oxygen, thermal cycles, vacuum and other conditions continue to be well understood over time, material exposure experiments are conducted by NASA and our International Partners that are then studied in detail by ground experts. As reported elsewhere in this report, telemetry data, trending, and periodic visual surveys help maintain awareness of hardware performance health.

Since the ISS Program development was authorized in 1984, the approach to hardware and software integration and validation has evolved. Because of the phased availability of each element to be assembled, all of ISS could not be fully integrated and tested on the ground prior to launch. To improve confidence that the many components to be assembled would function when initially activated on orbit, innovative and multifaceted testing was instituted. For example, critical hardware parts to be manually assembled by suited crewmembers are proven in human thermal vacuum chamber tests at Johnson Space Center. ISS computer software and avionics hardware are validated in the software development and integration lab (SDIL). Software at SDIL is developed in the Prime Software Production Facility, then verified in the Software Verification Facility, and finally integrated with the hardware in the ISS Systems Integration Laboratory. Multi-element integration tests performed at Kennedy Space Center (KSC) assess the functionality of several major elements so that problems are identified and resolved prior to launch. In combination, these capabilities and other tests and analyses help ensure that ISS Elements will continue to work properly together.

ISS PROGRAM IMPLEMENTATION

With respect to Service Life Extension, the ISS Program's planned life is to 2016. Service life requirements are currently in place but, in some cases, do not fully support a 2016 service life. The ISS Program intent is to recertify those items before the end of their certified life in the most cost, schedule, and technically effective manner.

With the grounding of the Space Shuttle fleet, the ISS Program systematically reviewed on-orbit hardware certification limits and took appropriate actions. With the exception of the limited-life certification hardware, the ISS currently has significant margin remaining in its certified design life. As the certified design lifetime is approached, recertification will be examined if use of the ISS is intended to extend beyond its original certification period. As an example, the ISS Program is currently expanding its capability to capture structural load data by scarring the outboard truss segments for an External Wireless Instrumentation System. This will augment the existing on-board sensors to capture data to compare the load cases used during the "design to actual" loads to enable the ISS Program to assess extending structural life. Additionally, a team recently visited our Russian Partners to better understand how the Russians certified life for the Functional Cargo Block (FGB) module. The FGB life needs to be extended from 2013 to 2016. Understanding the dynamic test article, facilities, and methods used in the original certification, as well as existing and future on-orbit data, will enable the ISS Program and our International Partners to develop plans to meet ISS Program life.

A limited set of hardware is designed for periodic replacement and, therefore, carries certification limits that limit useful life.

Within weeks of the *Columbia* tragedy, all on-orbit hardware was reviewed for compliance with certification limit requirements. Where additional testing or analyses could be done to extend these certification limits, this testing and analysis was approved and performed. Where this was not possible, strategies and justification were developed to allow continued use of these items in an acceptable manner. In the case of the Environmental Control and Life Support System, the team had already gathered data to extend the life of certain items to reduce the logistics upmass. Using these data, eight items had their life extended; five items from contractor-provided equipment, and three items of government-furnished equipment. The Trace Contaminant Control System's Charcoal Bed Assembly's life was extended from one year to four and a half years for a crew of three.

Launch delays due to the *Columbia* accident have also driven the ISS Program to assess and define the preventive maintenance requirements for hardware waiting for launch. The ISS Program has established preventive maintenance requirements for spare hardware still on the ground, but has no such requirements for hardware that is integrated into larger elements, such as truss sections. Additionally, some ISS hardware now awaiting launch at KSC has a limited storage life, such as the electrical power system batteries and solar array wings. The original rationale was that such hardware would fly, be in use, and not need this kind of maintenance. Since this is no longer the case, systematic reviews were completed by each ISS subsystem to determine needs for ground preventive maintenance, battery boost charging, reconditioning of batteries, and additional checkouts due to launch delays. The reviews involved an item-by-item and flight-by-flight reevaluation of ISS hardware relative to these areas and identified recommendations for new requirements, storage life extensions, and confidence checks. The Space Station Program Control Board has approved actions to meet these new requirements.

STATUS

The ISS Program reviewed all systems and expanded on the original preventive maintenance requirements to also address recommendations for confidence tests due to launch delays. For hardware integrated into carriers, the ISS Program de-integrated the hardware, is performing the maintenance per nominal logistics processes, and has established reintegration milestones to occur once launch dates are identified. Based on these assessments, a new set of preflight confidence tests was added to the Program.

The ISS Program assessed the impacts to electrical power system batteries for various storage options, and is implementing procedures to minimize degradation. The planned approach is to conduct monthly boost-charging and ambient reconditioning every six months. The ISS Program is assessing additional cold reconditioning and orbital rate capacitance testing based on results obtained over time.

To mitigate risks associated with long-term stowage of solar array blankets in their launch configuration, the right and left solar array blanket boxes of flight wing number 5 were de-integrated from the launch configuration and data were collected on panel stiction during solar array blanket deployment. Based on the test results and analysis, the ISS Program extended the acceptable storage limit to 63 months. Prior to this effort, each solar array wing was certified for 48 months of storage. The current limit is due to a foam pad that provides preload but compresses over time. Options are currently being pursued to extend storage limit to 82 months. Preload will be reduced and restored on each solar array wing in its current configuration, at prescribed intervals, prior to launch.

The ISS was originally certified by element and stage configurations. However, the vehicle is being sustained at the system level. The ISS Program authorized change 7938 Rev C, Orbital Replacement Unit (ORU) Certification Baseline data, for the sustaining and operations phase of the ISS Program. The certified baseline of each component will serve as the basis for ORU operational management throughout the ISS life cycle. The Certification Baseline document, SSP 50699, will consist of three volumes:

1. SSP 50699-01, Volume 1, will describe the certified performance of ISS ORUs. This performance will be identified in the associated verification

data Acceptance Test Procedure per Data Requirement Description F-PM-10.

2. SSP 50699-02, Volume 2, will describe the agreements to operate ORUs outside of accepted certified limits as identified in Volume 1.
3. SSP 50699-03, Volume 3, will describe the latest approved flight attitude tables used as part of each element's Certification of Flight Readiness. Volume 3 is future work.

It is the ISS Program's intent to process an additional change (early 2005) requesting the contractor to map the ORUs into end-to-end systems and characterize each system/subsystem to define its performance characteristics. Updates to the Certification Baseline will follow standard configuration management practices for the ISS Program and will include life extensions.

FORWARD WORK

The ISS Program has completed all special assessments associated with this response to the *Columbia* Accident Investigation Board. All ground and on-orbit life limits associated with issues due to launch delays were reviewed and updated as appropriate and preventive maintenance actions are in place. Current plans for maintenance due to truss launch delays are summarized in Table 7.1. Additional work to extend the ground storage life of solar array wings and batteries is under way. Continuing activity to assess that the hardware is within its qualification and certification limits is part of the normal sustaining activity of the ISS Program. The Certification Baseline document, SSP 50699, will be completed and additional ORU and system characterization will be documented. Specific implementation activities and schedules may change as continuing needs dictate.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Mar 03 (Complete)	Review certification limits of on-orbit hardware
ISS Program	Jun 03 (Complete)	Define/review certification limits of flight hardware on the ground
ISS Program	Jun 03 (Complete)	Wing 5 Solar Array Deployment Test
ISS Program	Jun 05	Complete SSP 50669 for ORU operational management
ISS Program	Dec 05	Extend FGB life
ISS Program	Ongoing	Perform preventive maintenance to ensure ISS hardware awaiting launch will function properly on orbit
ISS Program	Ongoing	Continue characterization of on-orbit environment with material exposure experiments and instrumentation

Table 7.1 Current Plans for Maintenance Due to Truss Launch Delays

Truss Delays Item	Plan	ECD	Flight Effectivity						
			LF-1	ULF1.1	12A	12A.1	13A	13A.1	15A
Utility Transfer Assembly Spare	Deintegrate and conduct annual cycling preventative maintenance (last completed 10/7/03)	Annual	X						
Trundle Bearing Assembly Spare	Deintegrate and conduct annual cycling preventative maintenance (last completed 10/6/03)	Annual	X						
Flex Hose Rotary Coupler Spare	Deintegrate and conduct annual cycling preventative maintenance (last completed 10/7/03)	Annual	X						
External Television Camera Group	Moved from LF-1 to 12A.1 - Communication and Tracking Subsystem re-evaluating preventative maintenance due to longer delay	10/04				X			
Control Moment Gyro	Deintegrate and conduct preventative maintenance (spin up every 2 years and gimbal rotation annually)	8/04	X						
Lightweight Multipurpose Carrier	Deintegrate and conduct inspections and bolt replacements	9/04	X						
Corrosion Inspections	Perform inspections every 3 months on all hardware - disposition, document, clean and protect where required.	3 month cycle	X	X	X	X	X	X	X
Pump Module Spare	Perform functional checkout within 2 years of launch (last completed 9/03)	Complete		X					
Solar Array Wing	Perform tests and analyses on solar array to extend storage life to 63 months (completed 11/03) - develop and demonstrate solar array preload relaxation method to extend storage life to 82 months (completed 7/04) - perform preload relaxation on flight elements	L-6 months			X		X		X
Ammonia Mass Check	Conduct pre-flight confidence test (PFCT) to check ammonia mass	L-120d			X		X		X
Pump Flow Control Subassembly Valve	Conduct pre-flight confidence test (PFCT) to verify flow control valve functionality before flight	L-120d			X		X		X
Pump operation	Conduct pre-flight confidence test (PFCT) to verify pump functionality before flight	L-120d			X		X		X
Photovoltaic active thermal control system sensors check	Conduct pre-flight confidence test (PFCT) to verify sensors before flight	L-120d			X		X		X
Drive Lock Assemblies	Conduct preventative maintenance in place on Solar Alpha Rotary Joint Drive Lock Assemblies	12A 11/04 13A 12/04			X		X		

		Flight Effectivity							
Truss Delays Item	**Plan**	**ECD**	**LF-1**	**ULF1.1**	**12A**	**12A.1**	**13A**	**13A.1**	**15A**
Battery Boost Charging	Conduct battery boost charging on each photovoltaic module	Monthly			X		X		X
Battery Rebalancing	Conduct battery rebalancing at least every 13 months	Every 13 months			X		X		X
Electric Power System ORUs Electrically Erasable Programable Read Only Memory (EEPROM)	Perform EEPROM pre-fresh on Electric Power System ORUs concurrent with a battery rebalancing or boost charge event	Every 3 years			X		X		X
Battery Orbital Rate Capacitance Test	Perform Orbital Rate Capacitance Tests on photovoltaic module batteries 1 time prior to launch (12A complete 5/04)	12A done 13A 7/05 15A 12/05			X		X		X

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 8

Review lessons learned from ISS operations and identify any enhancements to ISS hardware or software that significantly mitigate risk to crew safety and mission success. Survey ISS system teams to identify any further modifications to hardware or software that reduce risk.

Note: The International Space Station (ISS) response to Continuous Improvement Action ISS-8 was approved by the ISS Vehicle Control Board (VCB) on September 27, 2004. Follow-on actions will be tracked by the ISS VCB and the Avionics and Software Control Board (ASCB). ISS enhancements will be addressed during annual planning processes and the Integrated Space Operations Summit (ISOS).

BACKGROUND

Enhancements to the ISS design go beyond the minimums required to meet ISS Program requirements and significantly mitigate risk to crew safety and mission success. To identify improvement candidates, the ISS Program conducted a bottom-up review and selected several proposals for implementation. Also, the ISS Program worked with several different forums to develop new materials and technologies to enhance performance, such as the Internal Active Thermal Control System coolant and biocide studies and Requests for Information to seek inputs for new exercise equipment, environmental monitoring hardware, and battery technology development.

ISS PROGRAM IMPLEMENTATION

The ISS Program conducted the review to compile near-term enhancements options in two phases. The first phase consisted of an independent review by ISS operations, engineering, and safety personnel of system design deficiencies and operational techniques that represent significant risk to the crew or to the vehicle. Potential hardware or software modifications that would mitigate the risk were identified. These potential modifications, called ISS enhancements, were intended to reduce risks to crew safety and mission success. Flight controllers from the Mission Operations Directorate and engineers in the Mission Evaluation Room in the Mission Control Center reviewed on-orbit system performance, known software deficiencies, and lessons learned from on-orbit operations to identify ISS enhancements. Safety engineers reviewed hazard reports and nonconformance reports to identify ISS enhancements. Inputs from each organization were compiled, and the results were reviewed and grouped in three categories. These categories are enhancements that:

1. Should be assessed by the Program immediately due to the potential for significant risk reduction.
2. Are covered by ongoing work.
3. Have potential benefits but do not merit immediate Program action.

Enhancements recommended for immediate Program review were presented to the Space Station Program Control Board (SSPCB). These included enhancements to External Active Thermal Control System (EATCS) redundancy and to the oxygen system on board the ISS. The SSPCB directed further study of the technical solution and estimated cost of each recommended enhancement. Enhancements covered by ongoing work will be worked through normal processes.

Phase 2 of the ISS enhancements review entailed soliciting recommendations from each system team to review risks and bring forward suggested ISS enhancements to mitigate these risks. These included additional infrared sensing equipment for internal and external use on board the ISS, additional EATCS redundancy, and enhancements to the oxygen system. The SSPCB directed further study of the technical solution and estimated cost of each recommended enhancement.

This Phase 2 activity was supplemental to the normal robust system planning that occurs to identify potential areas to improve hardware reliability or reduce preventive maintenance impacts. As a result, a system strategic plan through program end-of-life was developed for each team and will be updated as part of the annual program operating plan (POP) budget cycle.

The development cycle of approved enhancements is dependent on the complexity of the change. For example, the trade studies for the fail-safe heat exchanger design took nine months to complete. The electrical power jumpers were designed, developed, and scheduled for delivery in approximately a year. The urgency of the change also impacts the design cycle.

Examples of hardware modifications that have been implemented through normal program processes are the Schwinn resistive exercise device, carbon dioxide removal assembly filter modifications, and photovoltaic battery reconditioning for the P6 truss. In addition, maintenance requirements were reevaluated on the trace contaminant control system's charcoal bed and catalytic oxidizer assemblies as well as numerous other internal life support components to reduce the amount of crew time involved in their operation. Similar ongoing improvements are discussed in this document under the ISS response to Recommendations R3.6-1, R4.4-4, and R6.4-1 and Continuous Improvement Action ISS-10.

As a source of enhancement options, lessons learned from every ISS increment are formally reviewed and documented. These lessons are available at http://mod.jsc.nasa.gov/dt/HTML/ECWGWeb/postflight/uspostflight.html for use by ISS personnel and decision-makers as well as by those involved with future exploration development. In addition, the flight crews perform out-briefs that provide the system teams and operational personnel with key insight into on-orbit conditions and help generate ideas for improvement.

As another improvement opportunity, the International Partners participating in our system forums and control boards have insight into any system improvements NASA is making and can use these forums for suggesting hardware or process improvements.

STATUS

Several ISS enhancements were approved for implementation, and detailed design and development work has begun. The detailed implementation of other enhancements has yet to be approved.

The approved and proposed enhancements resulting from this assessment are:

1. Electrical power jumpers to increase robustness in the case of certain failures were approved for delivery in fiscal year (FY) 2005.
2. Software modifications to facilitate recovery from a lockup of the thermal rotary joint were approved and will be implemented as part of the launch packages of the S3 and P3 truss elements.
3. An oxygen system outlet hose that includes a check valve to reduce the risk that contamination could cause a problem with the ISS oxygen system was approved for delivery in FY 2005.
4. Conceptual design of infrared cameras for internal and external use on the ISS is in work by the ASCB. A formal change request remains to be developed and approved.
5. Development of the fail-safe heat exchanger was approved for delivery in FY 2006.

FORWARD WORK

The ISS Program will continue to investigate methods of improving operations and reliability of the hardware as part of its day-to-day management of the on-orbit vehicle. ISS will use all resources, internal and external, available to gain knowledge of the systems, develop options for improvement, and leverage ISS capability for new strategic initiatives.

The ISS Program will also use its annual system strategic planning and POP cycle to further identify and implement system and hardware enhancements. These enhancement options will be dispositioned as part of the ISOS process led by the NASA Deputy Associate Administrator for Space Station and Space Shuttle Programs. An ISS specific panel of ISOS is compiling enhancement proposals from all ISS personnel as part of an action for post-2010 vehicle operations and maintenance.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Sep 03 (Complete)	Enhancement concepts approved by SSPCB
ISS Program	Ongoing	Complete design and approval for infrared cameras
ISS Program	Ongoing	Implementation of approved enhancements
ISS Program	Ongoing	Collection of ISS enhancement options during annual system strategic planning and POP budget processes
ISS Program	Ongoing	Disposition enhancement proposals in the ISOS process

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 9

Review program, project, and supporting organization contingency action plans and update them based on *Columbia* mishap lessons learned.

Note: The International Space Station (ISS) response to Continuous Improvement Action ISS-9 was approved by the ISS Mission Integration and Operations Control Board (MIOCB) on September 23, 2004. All actions related to assuring implementation and continual improvement are the responsibility of the MIOCB.

BACKGROUND

The ISS Program Contingency Action Plan documents the actions to be taken in the event an ISS contingency is declared. It defines the ISS Program's responsibilities in the areas of mishap reporting and the investigation process. The ISS Program has reviewed and updated the ISS Program Contingency Action Plan and the implementation plans that will be used by the investigation teams in support of the Board of Investigation.

The ISS Program reviews its Contingency Action Plan at least yearly and updates the document accordingly to ensure that it is current. At a minimum, the Technical Action Center and working group membership lists are updated at the start of each crew Increment.

ISS PROGRAM IMPLEMENTATION

The ISS Program performed an extensive review of the ISS Contingency Action Plan during the March – July 2003 timeframe to reflect the lessons learned from the *Columbia* mishap and to convert the original Johnson Space Center (JSC) ISS Lead Center Plan to an ISS Program Contingency Action Plan. The revised ISS Program Contingency Action Plan defines the lines of authority within the ISS Program Office for notifying NASA Headquarters of a potential ISS contingency and the responsible ISS officials who will lead a mishap investigation pending the establishment of a formal Board of Investigation. ISS Program Office and ISS support personnel participated in the review and the update of this Plan.

During this time, investigation teams supporting the ISS Technical Action Center prepared and/or reviewed their team's implementation plan. The ISS Technical Action Center leads technical activities associated with understanding contingencies and managing all associated technical actions.

The ISS Contingency Action Plan and its appendices, which contain contact information for NASA senior management, ISS Program, and JSC management personnel, are updated and posted on an internal ISS server. The appendices also contain contact information for the chairpersons and alternates of the ISS Technical Action Center's investigation teams. Access to this information and the implementation plan for the ISS Technical Action Center and its investigation team are available on the Increment Management Center Management Coordination Web site at http://iss-www.jsc.nasa.gov/ss/issapt/mio/IMC.html.

STATUS

The ISS Program Manager approved the updated ISS Program Contingency Action Plan, SSP 50190, in July 2003. Using this updated plan, a simulation of an off-nominal Soyuz landing was completed in October 2003. Call lists were again updated in September 2004. The ISS Program conducted a review of the Contingency Action Plan appendices in April 2004 in preparation for the launch of the Expedition 9 crew and in October 2004 reviewed planning for the Expedition 10 crew.

The most recent update of the NASA Headquarters produced Agency Contingency Action Plan for Space Operations was completed in December 2004 and is available at http://nasa-mis.nasa.gov/.

ISS Program management participated in several joint Mission Management Team simulations with the Shuttle Program, NASA Headquarters, and other field centers. The simulations supported have been Shuttle stand-alone and also combined with ISS and Shuttle. ISS Program Managers, Launch Package Managers, Mission Evaluation Room personnel, and flight control teams participated in the simulations. Contingency plans are exercised whenever a major malfunction is simulated requiring activation of the Technical Action Center.

The ISS Program has proactively created a formal contingency plan that records the conditions for de-crewing and re-crewing the ISS vehicle if consumables or systems issues warrant. This plan clearly defines the number of days of remaining provisions that will initiate de-crewing preparations and how many days of provisions must be preserved to support re-crewing. This plan also defines the decision processes and safe vehicle conditions to minimize the risks of an unattended vehicle.

Lower-level work instructions were completed for the Technical Action Center's investigation teams. The ISS Program will continue providing assistance to the ISS supporting centers and their directorates in the development of their organizational Contingency Action Plans.

FORWARD WORK

The ISS Program will update, with its International Partners, the de-crew/re-crew requirements that ensure the safe least risk crewless ISS configuration and will maintain the ability to safely and successfully restore ISS crew habitation.

ISS personnel will continue to participate in contingency simulations for both ground and on-orbit events, including activation of the Mishap Investigation Teams (MIT). The MIT is a small group of specialists activated to quickly provide or supplement emergency functions, such as administrative, computer/database, and anomaly management support.

ISS will review all updates to the Shuttle Contingency Action Plan and will update the ISS Contingency Action Plan accordingly.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Jul 03 (Complete)	Revise ISS Contingency Action Plan
ISS Program	Oct 03 (Complete)	Conduct contingency simulation to exercise Contingency Action Plan response
ISS Program	Mar 04 (Complete)	Develop initial draft of de-crew/re-crew plan
Office of Space Operations	Dec 04 (Complete)	Revise Headquarters Contingency Action Plan
ISS Program	Early 2005	Integrate International Partners into the ISS Contingency Action Plan
ISS Program	Ongoing	Participate in contingency simulations. Review Space Shuttle Program Contingency Action Plan. Update ISS Contingency Action Plan

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 10

The ISS Program's avionics and software management organization will continue to evolve software development and integration processes to provide high fidelity flight software suites with higher productivity. In addition, ISS software uplink and long term sustaining processes will be updated to reflect lessons learned from ongoing ISS software upgrade activities.

Note: The International Space Station (ISS) response to Continuous Improvement Action ISS-10 was approved by the ISS Avionics and Software Control Board (ASCB) on September 15, 2004. All actions resulting from this assessment are the responsibility of the ASCB for ongoing management.

BACKGROUND

The ISS is comprised of elements provided by the space agencies of many nations. Operation of these diverse elements is integrated into a single spacecraft via the on-board software suite.

The U.S. portion of the ISS is controlled by computers both inside and outside the pressurized modules using 20 different sets of software with over 2 million source lines of flight code. In aggregate the Russians, Canadians, European, and Japanese partners are providing computing capability of roughly equivalent size and complexity for a total ISS on-board software suite of 4 million source lines of code. The system architecture is a three-tier federated system managed as functional control zones. Due to the size and complexity of the software suite and the incremental development strategy, it is imperative that all development be highly structured to avoid on-orbit problems. Facilities in Houston replicate the significant aspects of each ISS configuration for overall software integration prior to uplink of the required functionality for that specific configuration.

Even though the initial ISS software has been on orbit for five years providing excellent operational performance, we have instituted a continuous improvement program to continue the effort to provide the same high-fidelity software with even higher organizational productivity.

ISS PROGRAM IMPLEMENTATION

Development Process

Software for the ISS is developed per the Mil-Standard 2167A process. The ISS uses the Software Engineering Institute (SEI), Capability Maturity Model (CMM) as the "measuring stick" to document the maturity of each developer's processes. The industry-accepted norm for a cost-effective, repeatable software developer is a CMM rating of Level 3. A newer standard, termed Capability Maturity Model Integration (CMMI), is replacing the CMM. Both CMM and CMMI provide a framework to structure software development, testing, and configuration management processes. The framework has a series of steps that involves progressively more structured and improved processes. By tightening the process and their documentation, most day-to-day effort by the team can be focused on developing and testing products rather than lost in wasted effort resolving jurisdictional disputes and process ambiguities. The top level of the process, Level 5, is defined as achieved when the process is fully documented, performance is characterized by metrics, and further improvements can be assessed in terms of their improvement in the metrics. The closed-loop process of metrics collection, product improvement, and measurement of the impact of the improvements creates a self-optimizing organization. Achieving each level in the SEI CMM process involves an assessment by knowledgeable individuals of the candidate organizations' policies, procedures, and performance data.

The CMM and CMMI processes build on the framework of ISO 9000 compliance by ISS software developers.

The ISS development process has the Independent Verification and Validation (IV&V) organization embedded in it. IV&V provides individuals who support the analysis and resolution of all software change requests. They provide an independent test of selected software using testing and instrumentation approaches different from that used by the software development team. They may examine the inner working of the code, in some cases monitoring operations within the Computer Software Code Item at a low level. IV&V then reports its findings as Software Change Requests to be reviewed by other participants in the process. In addition IV&V assesses each software transition reporting out through the software board structure.

Integrated testing

The Software Development and Integration Laboratory (SDIL) in Houston is used for the formal integration and certification of the flight software suite. It has a combination of flight-equivalent and actual flight hardware computers used in appropriate combinations to replicate the on-orbit spacecraft, enabling in-depth evaluation and certification of the entire software suite.

Sustaining Approach

A block release approach is used to plan and produce the sustaining software necessary to operate and maintain the spacecraft. The plan will produce three blocks of needed software sets per year in the near term and taper to one per year as operational experience is gained. Once the software has completed certification, it is uplinked to replace the initial or previous block code. In addition, the management of ISS software anomalies is provided as support to the flight operations team and anomaly resolution process.

STATUS

Development Process

NASA is encouraged that the Prime contractor achieved the infrastructure to support a CMM Level 5 rating in Houston in December 2003. The goal is for all of Boeing Space Station software development to be CMMI Level 5 by the end of 2005.

To date, over 2 million source lines of code have been developed and flown by NASA with minimal problems.

Sustaining

Due to the incremental assembly of the ISS, over 1.5 million lines of ISS code have been developed and replaced on ISS using the sustaining process. Lessons learned from these operations have been studied, and ISS software development and uplink processes have been improved as a result.

One of the primary lessons learned is that a process is needed to ensure that the best ideas for spacecraft operability enhancements receive priority for competing resources. Our approach is to use the existing Program Software Change Request system to develop a comprehensive, coordinated, and structured list of proposed software product improvements (SPI) from all stakeholders (i.e., crew, operations, engineering, and safety). All ISS systems and other ISS stakeholders were solicited to submit product improvements to supplement the list that has flowed out of the ongoing development in the first of what is anticipated to be an annual cycle of solicitations. The list, which was prioritized to optimize the core software system for safety, speed, robustness, usability, and maintainability, was used for a coordinated content determination for each sustaining Computer Software Configuration Item release to implement the highest-priority software product improvements. It will be a living document, with each new proposed change being evaluated against the existing priorities for placement of its relative priority. As of July 2004, there were 1128 SPIs being tracked with 334 having been fully implemented. The remainder are in work or are candidates for subsequent revision of the software in question. Virtually all of the product improvements increase the robustness of the Command and Data Handling system and its human-machine interface, the Personal Computer System. Collectively, these improvements simplify procedures, reduce the chances for error, and enhance the safety of the vehicle. In addition, three of the 1128 SPIs have been identified specifically as safety related by assigning them Severity Code 1P. Of these three, one was deployed on orbit in May 2004. The other two are in work and are intended to improve the robustness of processes that already meet safety and fault-tolerance requirements.

With each cycle of software upgrades, code is made to operate more efficiently, decreasing central processing and memory utilization. These improvements eliminate or reduce the significance of Program waivers written to document the lack of margin specified in Program requirements. Upgrade of the Space Integrated Global Positioning System (GPS) Inertial Measurement System (SIGI) software upgrades added the capability to use precise time from GPS satellites and thus remove a Program waiver for the lack of GPS time on ISS.

The ISS Program takes advantage of the fact that software anomalies can generally be very well characterized by review of cyclic telemetry and special selected downloads of blocks of computer memory (data dumps). The interface between the software development organization and the flight control team is the Mission Engineering Room (MER). As an on-orbit issue is identified, it is documented in the MER and software support is brought in as necessary. In a typical anomaly resolution cycle, the MER team compiles the telemetry and requests data dumps as appropriate. The hardware/software integration team then attempts to duplicate the problem in the lab and compares the results of the test with the telemetry and data dumps. In parallel, the significance of the anomaly is assessed and documented in the software configuration management tool as a Software Change Request (SCR). In the typical flow, a near-term workaround is identified and fed back to the flight control team as an action request (chit). Since most anomalies have minimal near-term impact, the SCR is then reviewed technically and resolution is scheduled by a structured set of boards and panels, each with membership of software engineering, operations, flight crew, and safety.

The ISS software development process can quickly deliver a fully tested and certified fix to software in a few days and associated data in a day. The process is a logical extension of the engineering support and anomaly resolution provided to flight operations. If analysis and hardware/software testing determines that a quick software or data change may be warranted, the standard review panels and boards are convened in special sessions. In a matter of hours; this session assesses the change, its impact on the software development and testing groups, and any downstream impact to the normal flow of development and testing. Two recent examples of the quick-turnaround process are changes in External Control Zone heater set point data (termed pre-positioned loads or PPLs) and multiple small software changes to the Guidance Navigation and Control software to handle ”walk-off” in the attitude calculations. Software simulations and other tools play a critical role in the development and testing of flight software. Within the overall framework of process improvement, the simulations and tool groups have a board to review issues, defects, and recommended product improvements. This process is in line with the normal flight software processes. A series of periodic updates has been defined, and a content review process identical to that used for flight software has been instituted to prioritize defect fixes and product improvements.

Changes have been made to improve communication with flight controllers relative to Software Program Note (SPN) elimination status, rationale for schedule, and retirement strategy. Since October 2003, the flight director's office has led a weekly review of the agendas and issues of ISS boards and panels so that flight controllers and their meeting representatives are adequately coordinated. To further aid communication between all parties involved with flight software, the ASCB weekly reviews all safety-critical SCRs (characterized by Severity Codes 1, 1N, or 1P) under review or in work.

Integrated Testing

The ISS is just completing Phase 1 of an enhancement project to enable the inclusion of additional flight computers and firmware controllers into the SDIL. Phase 1 expanded the laboratory floor space and control rooms, and replaced several flight-equivalent computers with flight prototypes for the ISS Systems Integration Laboratory of the SDIL. Phase 2 will continue to expand the software/hardware integration capability with additional flight computers and firmware controllers.

FORWARD WORK

Continue to rigorously pursue process improvements and laboratory enhancements.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
Mission Ops Directorate	Oct 03 (Complete)	Initiate weekly reviews of ISS board agendas
ISS Program	Dec 03 (Complete)	Houston software developers attain quality process CMM Level 5
ISS Program	Jan 04 (Complete)	Implement SPI process
ISS Program	Dec 05	Houston and Huntsville software developers attain CMMI Level 5
ISS Program	Mar 06	Phase 2 enhancements to SDIL
ISS Program	Ongoing annual releases	Identify and implement software product improvements

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 11

The International Space Station (ISS) has implemented some initiatives to facilitate the reporting of occupational and on-orbit safety concerns by its employees.

Note: The ISS response to Continuous Improvement Action ISS-11 was approved by the ISS Safety and Mission Assurance Panel (S&MAP) on November 18, 2004. All actions related to assuring implementation were closed and responsibility for continuous improvement was assigned to the S&MAP for ongoing management.

BACKGROUND

Safety is paramount in the minds of NASA personnel. Each ISS Program individual contributes to the safe operation of the ISS through execution of their assigned responsibilities. Each person is also trained and encouraged to communicate safety concerns to their supervisor or team members. The purpose of a safety reporting system is to ensure direct, effective communication of all safety concerns. These concerns may be with flight hardware, software, or flight and ground operations and procedures.

To complement the formal ground and on-orbit anomaly reporting processes described under Continuous Improvement Action ISS-5, the ISS Program has implemented an effort to increase awareness of established NASA safety reporting systems. The goal is to ensure that personnel are encouraged to report any safety concerns and to ensure that they are aware of the NASA Safety Reporting System (NSRS) program.

ISS PROGRAM IMPLEMENTATION

As recommended by the Agencywide Action Team headed by the Director of the Goddard Space Flight Center, NASA has established an Ombuds Program that is empowered to listen to and act on the concerns of Agency personnel related to safety, organizational performance, and mission success. The Ombuds who have been named at each NASA center serve as a safety valve when employees feel regular channels for raising issues and concerns are not working effectively. Each Ombuds serves as an unbiased resource to ensure NASA becomes fully accountable and results-oriented from a safety perspective. When an issue is brought to the Ombuds, they may conduct an informal inquiry and seek to promote a mutually satisfactory resolution of the issue or concern. Each Ombuds has the authority to raise issues directly with Center Directors and, at NASA Headquarters, with the Deputy Administrator. The Ombuds are empowered to perform their duties independently and in a diligent and timely manner. They will maintain confidentiality at all times, unless the person providing information requests or approves otherwise.

The ISS Program also actively participated in the Agencywide Safety and Mission Success (SMS) Week during November 17–21, 2003. At each staff meeting and all board and panel meetings during this period, all NASA and contractor employees were encouraged to review the *Columbia* Accident Investigation Board Report and openly discuss any cultural or technical issues that should be brought to the Program's attention. Results and implementation of these ideas are being handled independently both at the Agency and Program level by various organizations using normal processes

As a further improvement, the ISS Program has implemented links from the ISS homepage and other ISS office homepages for ISS Safety Reporting options. The ISS Safety Reporting Web site clearly defines the steps that should be taken if a safety concern exists. These steps include to:

1. Correct the situation yourself, if possible.
2. Report the situation to your supervisor.

If an employee feels that the situation has not been or cannot be addressed adequately at this level, or if they feel that further management visibility is warranted, they should contact the:

1. ISS Safety and Mission Assurance Manager.
2. ISS Program Manager.
3. Center Safety and Mission Assurance Director.

4. Center Ombuds.

If an employee has reported the concern and has seen no action, is not satisfied with the response, or fears reprisal, that employee has the option to submit an NSRS report. A link to the NSRS is provided on the ISS Safety Reporting Web site.

Additionally, NASA has modified the Close-Call reporting system to accommodate anonymous reports related to the ISS.

All personnel in the ISS Program were notified of their rights under The Whistleblower Protection Act of 1989. This act provides the right of every employee to make whistle-blowing disclosures and ensures protection from reprisal. Any NASA employee who has reason to believe that there has been misconduct, fraud, waste, or abuse is encouraged to report these matters. See Whistle Blower Information at http://www.osc.gov/documents/pubs/post_wbr.htm.

To ensure that all NASA personnel are aware of and understand the prohibited practices and whistleblower protections, employees are encouraged to read "Your Rights as a Federal Employee" on the Office of Special Counsel's Web site at http://www.osc.gov/documents/pubs/rights.htm.

STATUS

An ISS safety reporting homepage that reflects the above process has been developed and is available to ISS Program personnel at http://www. jsc. nasa. gov/ ss/ issapt/ smaprm/ safe_report. html.

The ISS-specific results of the SMS Week were assessed for any suggested improvements to the safety of the ISS Program. No changes or deficiencies in the ISS safety reporting system were noted.

The NASA Ombuds Program was announced by the NASA Administrator on January 27, 2004. The Agency distributed Ombuds contact information in a Message from the Administrator issued on May 12, 2004, to all employees to facilitate this method of safety reporting when other avenues are not working.

FORWARD WORK

The ISS Program will continue to improve and implement programs that make its personnel aware of their safety reporting responsibilities and the methods available to report their concerns.

Additionally, the ISS Program has evaluated options for placing proper emphasis on minority dissenting opinion, such as requiring that minority dissenting opinions be captured in meeting minutes as a standard practice, but has not formally required any new changes at this point in time.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
NASA HQ	Jan 04 (Complete)	NASA Ombuds Program announced
ISS Program	Nov 04 (Complete)	Complete review of ISS results of SMS Week
ISS Program	Ongoing	Safety awareness activities

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 12

The International Space Station (ISS) has initiated action to make recommendations for improvements in quality assurance aspects of ISS development and operations.

Note: The ISS response to Continuous Improvement Action ISS-12 was approved by the ISS Safety and Mission Assurance Panel (S&MAP) on October 13, 2004. All actions related to assuring implementation were closed and responsibility for continuous improvement was assigned to the S&MAP and Quality Product/Process Assurance Panel (QPAP) for ongoing management.

BACKGROUND

The purpose of the ISS Quality Assurance (QA) program is to ensure successful activation and operation of ISS systems, overall mission success, crew safety, and effective operations and sustaining engineering. To accomplish this goal, quality processes must be established with assurances that those processes are being followed from the development and delivery of flight hardware and software to the successful performance on orbit. When failures of quality-built hardware or software or failure of personnel to follow the quality processes do occur, they must be identified, analyzed, and dispositioned to ensure that proper corrective action and reoccurrence control is implemented.

ISS PROGRAM IMPLEMENTATION

The ISS Program initiated several continuous improvement activities related to this action and embarked on a far-reaching improvement plan to strengthen its QA program. Foremost, the Program identified the need to strengthen the QA role in management and implementation of its anomaly resolution processes. Specific actions are now in place to accomplish these high-priority improvements, including philosophical and organizational changes that will have a positive impact for quality in all aspects of the ISS QA program.

The ISS Program also developed action plans to address other areas of continuous improvement related to problem tracking and anomaly resolution processes, system performance and process trending requirements, hardware processing and operations for hardware qualification and certification limits, and software process improvements. This need for quality process improvements is the underlying requirement expressed in several other continuous improvement actions, most notably ISS-5 (problem tracking and in-flight anomalies) and ISS-6 (performance trending). With respect to ISS-5, QA will perform audit/surveillance to assure adherence to quality requirements. With respect to ISS-6, QA will audit the systems engineering anomaly resolution-trending process and verify compliance with quality objectives. The system managers remain accountable for ensuring that recurrence trending is performed.

The goal is to strengthen ISS QA activities while embracing the following concepts:

1. A strong quality discipline within the ISS Program to accomplish nominal ISS QA and support anomaly resolution activities.
2. Adherence to requirements and process is maintained within the ISS Program by all ISS Program organizations and personnel.
3. A knowledgeable and authoritative QA organization to assist all elements of the ISS Program.

First, SSP 30223, *Problem Reporting and Corrective Action (PRACA) Process for the International Space Statio*n requirements defining NASA QA roles and responsibilities, will be expanded to:

1. Enforce criteria for initiating and closing problem reports.
2. Ensure rigor in problem investigations.
3. Enforce documentation requirements.
4. Monitor the process for conformance to requirements.

Second, System Problem Resolution Teams (SPRTs) will be staffed with dedicated QA representatives to fulfill new responsibilities. The ISS Program will train/certify QA representatives and other SPRT members on requirements and processes and develop process and product quality metrics. Quality expectations will be standardized and integrated across all program participants. QA will manage the Mission Evaluation Room In-flight Investigation (IFI) processes and database to ensure maximum utilization of PRACA and IFI data.

Additional QA Improvements

The following new ISS QA tasks will be defined and implemented:

- Training and certification requirements for ISS-critical processes
- Process and product quality metrics
- Anomaly recurrence trending process
- Formal contractor audit and surveillance program
- ISS internal process audit program
- Charter a QPAP

The following current QA tasks will have increasing emphasis or changing scope:

- ISS commercial-off-the-shelf/government furnished equipment procurement QA reviews
- On-orbit QA
- Acceptance Data Package maintenance

STATUS

NASA has developed prioritized plans to implement the QA improvement strategy. The first priority was to staff the SPRTs with qualified QA personnel, form and staff an audit/surveillance group, hire an ISS Quality Manager, charter a quality panel, and provide training and certification for QA personnel. All new priorities have been completed except for the training and certification plans for QA personnel, which should be completed by March 2005.

Using the new available personnel and practices, the ISS Program is performing the following tasks to strengthen the anomaly resolution functions:

- Ensure proper initiation of nonconformance reports or PRACA records
- Ensure the anomaly records are assigned to the appropriate SPRT for analysis and resolution
- Ensure on-orbit nonconforming articles are properly identified and/or tracked
- Support the SPRTs with proper documentation of dispositions
- Support the SPRTs with root cause analysis and documentation of corrective and preventive action
- Ensure all nonconformance records are reviewed for PRACA reportability in a timely manner and ensure the quality of anomaly records
- Ensure anomaly records are complete and adequately support closure

Further, the following enhancements to the audit-surveillance tasks are being developed:

- Develop an audit and surveillance plan; perform audits and surveillance
- Develop metrics and integrate Defense Contract Management Agency metrics at the Program level
- Develop and implement an ISS Corrective Action Request system

Plans are being developed to perform training and certification at three levels of personnel involvement commensurate with ISS Program needs. These plans will include initial and recurring training and certification.

FORWARD WORK

The ISS Safety and Mission Assurance (S&MA) Office is currently implementing the organizational responsibilities proposed above.

A Change Request (CR) was initiated to revise SSP 30223, the Problem Reporting and Corrective Action (PRACA) requirements document, to improve QA roles and responsibilities. This CR is under review and no issues are expected.

The training and certification plans, the implementation, and the development of audit/surveillance metrics are on track to be completed as noted below.

Unfinished improvements will be managed by the S&MAP and the QPAP as appropriate. The S&MAP and QPAP will also continue to assess QA processes and personnel improvements through the life of the ISS Program.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Sep 03 (Complete)	Initial approval for QA improvements
ISS S&MA	Jun 04 (Complete)	Staff SPRTs with contractor QA personnel
ISS S&MA	Jul 04 (Complete)	Hired 5 Quality Engineers for ISS Audit and Surveillance Team
ISS S&MA	Oct 04 (Complete)	Hired ISS Quality Manager
ISS S&MA	Nov 04 (Complete)	Space Station Program Quality Control Board approval of Charter for Quality and Process Assurance Panel
ISS S&MA	Mar 05	Complete training and certification plans
ISS S&MA	Apr 05	Update SSP 30223, PRACA, to define NASA and contractor QA responsibilities
ISS S&MA	Jun 05	Implement process and product quality metrics
ISS S&MA	Ongoing	Continuous improvement of QA processes and personnel

ISS Continuous Improvement Actions

ISS Continuous Improvement Action 13

The ISS Program will assess its process for tracking Top Program Risks via the existing ISS risk management tool, specifically the Integrated Risk Management Application (IRMA), and recommend improvements where necessary.

Note: The International Space Station (ISS) response to Continuous Improvement Action ISS-13 was approved by the ISS Safety and Mission Assurance Panel (S&MAP) on January 14, 2005. All actions related to assuring implementation were closed and responsibility for ongoing management was assigned to the S&MAP.

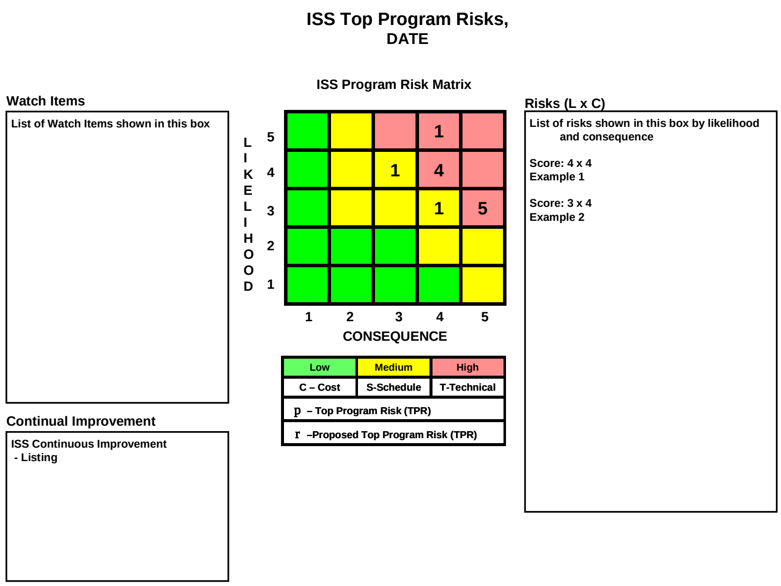
BACKGROUND

The purpose of risk management is to identify risks throughout the life of a program so that appropriate mitigation plans can be put into place to effectively reduce or eliminate the risk. The risk management process provides systematic methods for identifying, analyzing, tracking, controlling, communicating, and documenting risks. The ISS forum for accomplishing these functions if the Program Risk Advisory Board (PRAB), which is chaired by the ISS Program Manager.

PRAB assessments of ISS risks are continual and well supported by a diverse and representative membership of all ISS Program organizations. The PRAB meets frequently and includes representatives from Kennedy Space Center (KSC), Marshall Space Flight Center (MSFC), Johnson Space Center (JSC) Safety, JSC Engineering, JSC Mission Operations, JSC Life Sciences, the ISS Program Office, the Astronaut Office, and the International Partners. PRAB activities are communicated to the internal ISS Program team at this Web site: http://iss-www.jsc.nasa.gov/ss/issapt/prab/prab.htm.

ISS PROGRAM IMPLEMENTATION

Every ISS organization is involved in risk management. These organizations use the ISS risk database ISS Risk Management Application (IRMA) to manage and communicate risk data. A characterization of each risk, its likelihood/consequence scoring, cost, and mitigation tasks are entered into this database. The individual risks are plotted on a risk matrix to provide a visual representation of the relative importance of each risk so that the responsible organizations and ISS Program management can readily determine where intervention or resources are required. The overall top risks of the ISS Program are captured in the Top Program Risk (TPR) matrix that is presented at all PRAB reviews (see sample TPR matrix below).



The TPR matrix accumulates the current major issues being managed by the ISS Program. TPRs are risks that significantly affect the safety of flight, ISS Program budget, schedule, crew health, integrity of the ISS hardware/software, or mission success. TPRs generally require significant ISS Program resources and attention to resolve. The TPRs are evaluated at each PRAB meeting where all top risks are discussed, integrated, and allocated appropriate resources to mitigate the risk. The PRAB is held approximately every six weeks.

The PRAB and responsible organizations review plans to mitigate these TPRs and other risks. These mitigation plans are entered into the ISS risk database. Independent NASA organizations, such as the Technical Authority and NASA Engineering and Safety Center, provide an ongoing role in the ISS risk review process by participating in pre-PRAB and PRAB meetings.

The aggregate risk of all the TPRs is reviewed at the PRAB using a metric that tracks the cumulative score of all current TPRs. This metric, revised for every PRAB, is a function of the number of TPRs and their scores and produces a cumulative projection (i.e., workforce or burn-down chart) representing the current plans of when the TPRs will be mitigated.

The responsible organization continues the mitigation process for the TPRs and other risks they manage with periodic updates. This process continues until ISS Program management closes, accepts, or mitigates each risk to an acceptable level through the continual risk management process. This risk process is also conducted at the organizational and sub-organizational levels within the ISS Program for their own risks.

When the risk is eliminated or mitigated to an acceptable level, it is formally closed. The responsible organization documents this action in the IRMA database.

The PRAB may also accept a risk. Accepting a risk means that mitigation may be technically impractical or resource prohibitive. The PRAB and/or the Program Manager are the only authorities that can accept a risk.

As part of the Certification of Flight Readiness (CoFR) process, risks are reviewed for the appropriate flight effectivity. Risk records applicable to a specific flight are either closed or accepted prior to that flight. Risks are reviewed and verified to ensure that adequate controls are in place and safety concerns are addressed.

Space Shuttle and ISS risks are reviewed in joint forums and processes to identify any shared risks. Hardware issue alert processes such as Government Industry Data Exchange Program are used to widely transmit the issues. Risks are worked collaboratively with the appropriate risk owners and internal or external organizations.

Risk metrics are reported as one of the Key Program Performance Indicators in NASA's Management Information System that are reviewed at the ISS Monthly Program Review. For more details, reference Recommendation R6.2-1 in Part 1 of this document.

International Partners and other NASA centers such as KSC and MSFC are integrated by the appropriate ISS organization that manages and integrates their functions into the Program.

Probabilistic Risk Assessment (PRA) is one of the many tools used to further define and quantify risks to the ISS Program. PRA is a required risk management tool on the ISS Program and is implemented in accordance with NASA Program Requirement 8705. Major risks to the ISS and crew modeled by the ISS PRA model include: micrometeoroid/orbital debris strikes, loss of cooling, loss of power, and failure of the life support system. In support of operational decisions following the *Columbia* accident, ISS conducted PRAs looking at zero- versus two- versus three-person crews as well as conducting extravehicular activity with two crewmembers.

There are other ISS processes, however, that document accepted Program risks that are not currently in the IRMA. Other safety and mission assurance processes that capture accepted risk include the approval of noncompliance reports (NCRs), the approval of waivers, deviations, and exceptions (WDE), and the approval of critical items documented on the critical items list (CIL). NASA conducted a review of these items to determine which of these should be documented in IRMA for increased visibility and to ensure that they are periodically reviewed.

STATUS

NASA reviewed all accepted, mitigated, and closed risks in the safety, quality, and reliability areas to determine where significant risks were accepted and whether these items should be reexamined further and brought into the existing ISS continuous risk management process for increased visibility. The status of one risk was changed from closed to accepted to elevate programmatic awareness of an already well-understood anomalous condition with field effect transistors. Now, this risk will be assessed on a yearly basis for further mitigation opportunities.

The ISS Program completed its review of CILs (ref. ISS-4), NCRs (ref. ISS-2), and WDEs (ref. ISS-1).

As a risk management process improvement, the rules for reviewing, closing, and accepting risks were reassessed. ISS updated its process documentation to capture these changes.

FORWARD WORK

Accepted risks that carry significant consequences will continue to be captured in the ISS risk management process to ensure that they are regularly reviewed. As the ISS Program identifies new NCRs, CIL items, and waivers, the Program will evaluate those items for incorporation into the risk management process as well.

Additionally, as part of the CoFR process, all risks will be either closed or accepted, and will be presented to the ISS Program Manager prior to flight at the Launch Package Review or Stage Operation Readiness Review for approval. These risks include risks previously accepted that affect the flight in question.

The ISS Program will continue to ensure that Program risks are identified, reviewed, and mitigated/closed throughout the ISS life cycle in accordance with SSP 50175, the ISS Risk Management Plan.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Jan 04 (Complete)	Space Shuttle Program Control Board approved plan for regular review of closed top risks
ISS Program	Jan 04 (Complete)	CoFR risk review process update
ISS Program	Aug 04 (Complete)	Complete review of closed top risks
ISS Program	Oct 04 (Complete)	Update ISS Risk Management Plan, SSP 50175
ISS Program	Jan 05 (Complete)	CIL, NCR, and WDE applicability to IRMA review
ISS Program PRAB	Ongoing	Continue reviews of risks at PRAB and launch readiness reviews

Part 2.2
Formal Observations of the *Columbia* Accident Investigation Board

The observations contained in Chapter 10 of the Columbia *Accident Investigation Board (CAIB) Report expand upon the CAIB recommendations, touching on the critical areas of public safety, crew escape and survival, vehicle aging and maintenance, quality assurance, test equipment, and the need for a professional training program for NASA managers and personnel. NASA is committed to examining these observations and has made significant progress in determining the appropriate corrective measures.*

Part 2.2 analyzes the underlying intent of the CAIB observations regarding the Space Shuttle Program for applicability to the ISS Program. Details are provided that demonstrate NASA's intent to take steps to improve our identification and management of risk for crew safety and mission success.

Columbia Accident Investigation Board

Observation 10.1-1

NASA should develop and implement a public risk acceptability policy for launch and re-entry of space vehicles and unmanned aircraft.

International Space Station (ISS) Corollary: ISS will support the development and application of Agency public risk policies.

Note: The ISS response to Observation O10.1-1 was approved by the ISS Program Integration Control Board (PICB) on September 1, 2004. All actions related to assuring implementation were closed and responsibility for ongoing management was assigned to the PICB.

BACKGROUND

The primary intent of this *Columbia* Accident Investigation Board observation was to cover the launch and entry, either from aborted launch/ascent or normal end of mission, of the Space Shuttle. The ISS, however, relies upon crew and cargo spacecraft that may be subject to different requirements and policies established regarding risk to the public.

ISS PROGRAM IMPLEMENTATION

The NASA Headquarters Office of Safety and Mission Assurance (HQ/OS&MA) has established a risk policy working group to develop and coordinate the NASA risk acceptance policy for launch and entry of space vehicles, including future NASA vehicles associated with the ISS. This activity is described in greater detail in Volume 1, the Shuttle Return to Flight Plan (ref. Part 2.2, Observation O10.1-1). The working group will define standards, requirements, risk criteria, and a risk management process for all NASA programs to follow. This effort has resulted in a revised draft NASA Procedures and Requirements (NPR) 8715.XX, which was assessed for applicability by the ISS Program.

STATUS

Public risk applies to the risk of human injury or property damage to parties outside of the ISS and Shuttle Programs. These risks are currently identified as only those resulting from the launch and landing of crew/cargo vehicles and the de-orbit of the ISS (controlled or unintentional).

For ISS purposes, the new policy in NPR 8715.XX only applies to Shuttle operations and future domestically developed and commercially procured crew and cargo vehicles. Given the Shuttle Program's approved plans to continue using Kennedy Space Center as its primary landing site, there is no impact to existing ISS ground support services or flight operations for alternate landing sites. As part of the new exploration vision and as noted in the President's fiscal year 2005 budget, resources were identified for the future purchase of crew and cargo transportation to ISS other than the Shuttle. Per the "ISS Cargo/Crew Services Report" provided to Congress in late August 2004, it is the ISS Program's intent to solicit, evaluate, and award all domestic commercial transportation services in concert with the new public risk policy.

NPR 8715.XX does not, however, apply to ISS crew and cargo vehicles provided by its International Partners. By international agreement, the ISS Program's jurisdiction over International Partner visiting vehicle design and operations exists only within the on-orbit 2-km approach ellipse. Therefore, new U.S. public risk requirements may not be levied on the international fleet without renegotiation of existing agreements.

As written, the draft NPR 8715.XX also does not apply to end-of-mission de-orbit of spacecraft conducted for the purpose of disposal (as opposed to the intentional recovery of any portion of spacecraft). The applicable risk management strategy for ISS end-of-life disposal is defined in chapter 7 of NASA Safety Standard (NSS) 1740.14 as called out by NPR 8710.3B (NASA policy for limiting orbital debris generation). The plan for implementing ISS controlled de-orbit uses a design for minimum risk approach and is documented in the May 1996 *Final Tier-2 Environmental Impact Statement for International Space Station*. In this publicly disseminated plan, which is further discussed in the ISS response to Observations 10.1-2 and 10.1-3, NASA identified controlled de-orbit of the ISS over uninhabited ocean as the minimum risk to the population, with the chance of any individual injury at less than one in 10,000. The risk of unintentional de-orbit (orbital decay) of the ISS is managed through the use of visiting vehicle propellant reserves, altitude margin, and engine failure tolerance.

As described in detail by the ISS response to Recommendation R3.2-1, the public is further protected by new ISS policies managing the intentional jettison of items during extravehicular activities.

Under all other on-orbit assembly and operating conditions, the ISS vehicle has been determined not to be a source of public risk.

FORWARD WORK

At the appropriate time in the NPR review cycle, the recommended policies, standards, and requirements will be assessed by the ISS Program for potential impacts and implementation. Initial document review cycles for the new public risk policy are complete. ISS will remain cognizant of updates to applicable standards and procedural requirements.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
HQ-OS&MA	Feb 04 (Complete)	Review initial draft of NPR
ISS Program	Aug 04 (Complete)	Assess draft NPR
ISS Program	Ongoing	Continue to assess and apply updates to NASA public risk policies

Columbia Accident Investigation Board

Observation 10.1-2 and 10.1-3

O10.1-2 NASA should develop and implement a plan to mitigate the risk that Shuttle flights pose to the general public

O10.1-3 NASA should study the debris recovered from *Columbia* to facilitate realistic estimates of the risk to the public during Orbiter re-entry.

International Space Station (ISS) Corollary: ISS end-of-life disposal plans and update requirements based on knowledge gained from similar large vehicle entries.

Note: The ISS response to Observations O10.1-2 and O10.1-3 was approved by the ISS Program Integration Control Board (PICB) on September 1, 2004. All actions related to assuring implementation were closed and responsibility for ongoing management was assigned to the PICB.

BACKGROUND

NASA's approach to the risks posed by Space Shuttle flights (which are closely integrated with the ISS Program) is addressed in Part 2.2 of the Volume 1 *NASA's Implementation Plan for Space Shuttle Return to Flight and Beyond.*

With the exception of the Space Shuttle Orbiter and the descent module of the Russian Soyuz spacecraft, every part of the ISS on-orbit vehicle and its visiting vehicles is designed to ultimately be disposed of within the Earth's atmosphere by a controlled entry. Such entries, if not controlled, present a risk to the general public. The ISS International Partners each control the entries of their respective visiting vehicles, i.e., Roscosmos controls Soyuz and Progress, the European Space Agency (ESA) will control the Automated Transfer Vehicle (ATV) and the Japanese Aerospace Exploration Agency will control the H-II Transfer Vehicle (HTV). NASA's responsibility is the entry of the ISS vehicle itself, although this event will be implemented with Partner assets (ATV or Progress).

NASA trajectory specialists who study ballistics and entry profiles are the same organization in the Mission Control Center for the Space Shuttle and the ISS. All trajectory data derived from the *Columbia* accident are entered into the same databases used in these analyses.

ISS PROGRAM IMPLEMENTATION

In May 1996, NASA completed the Final Tier-2 Environmental Impact Statement for International Space Station. This document explicitly addresses the ISS end-of-life disposal as part of the verification of the ISS United States On-orbit Segment (USOS) requirement in the USOS Segment Specification SSP 41162, which reads:

3.3.15 "End-of-life decommissioning and disposal. The Space Station shall allow for safe disposal of the orbital Space Station at the end of its useful life."

To assure enough total impulse to transfer the ISS from a stable orbit to a guaranteed, targeted ocean impact within one-half orbit, the ISS Program assessed and verified the propulsive capabilities of the Russian segment and of the ESA ATV as being independently capable of delivering adequate impulse for a safe and controlled de-orbit of the Assembly Complete configuration of the ISS.

The non-U.S. components of the ISS visiting vehicle fleet and its boosters are under the control of the International Partners. All ISS visiting cargo vehicles are intentionally de-orbited into unpopulated regions of the ocean. The Soyuz descent module lands in a remote area of Kazakhstan.

NASA has identified six candidate entry zones on the Earth's surf ace for a large spacecraft in a 51.6-degree orbit with shallow entry angle. These zones are comprised of completely unpopulated ocean entry corridors extending for thousands of kilometers, and are wide enough to handle conservative lateral dispersion of debris with high-energy release at altitude. These zones are routinely used by Russians in their military and human Spaceflight programs, and will be used by the

Japanese and European visiting vehicles once they begin flight operations.

Unlike the Shuttle, there are no constraints on ISS that would require entry before all Partners are ready for and committed to the event and all system prepared. The redundancy and time-to-criticality of the ISS systems allow the ISS Program to plan the optimum time and place for safe entry.

STATUS

During assembly, the ISS altitude is managed using fault-tolerant reboost systems to provide a minimum of three months of orbital duration (usually more) before the potential of atmospheric entry. The ISS hovers above this three-month limit and is allowed to drift close to it just prior to a Shuttle launch, to maximize the cargo lift capability of the Shuttle fleet. (Following the *Columbia* accident, the ISS was maneuvered to a high altitude to extend orbital life duration to nearly a year).

The altitude strategy is a minimization of programmatic risk, balancing small risks to survival of the ISS at low altitudes versus growing risks associated with increased launch traffic to meet higher cargo mass demands at higher altitudes. Following Assembly Complete, the altitude strategy requires a minimum of one year of orbital duration before orbit decay. In addition to this altitude strategy, at all stages of assembly reserve propellant is maintained to cover an additional year's worth of reboost and nominal propulsive attitude operations. The decay time (and, therefore, the effective propellant margin) can be extended by drag-reduction techniques at the expense of power margin. The ISS Service Module and all visiting vehicles (except the HTV and Soyuz are capable of reboosting the ISS, providing multiple fault tolerance against random entry, even in the unlikenly ocurrence of multiple failures of the on-board propulsion system or in groundings of one or more types of visiting vehicle.

Dress Rehearsals

The *Mir* space station was de-orbited March 23, 2001, into one of the candidate zones for ISS disposal. NASA worked closely with Roscosmos and RSC-Energia Corporation to understand the details of the operation of this record large spacecraft entry, and to gather lessons learned for the ultimate de-orbit of the ISS. U.S. assets were employed to confirm NASA's technical models of the entry debris survivability and dispersion. Due to an unexpectedly large propellant reserve, which was fully used in the de-orbit burn, several data-gathering opportunities were marginal due to the difference in the expected up-range splash point. Within the data available, the *Mir* behaved qualitatively as predicted, lending credibility to the analytical process for ISS breakup prediction. The *Mir* breakup was essentially a two-stage event, with structural failure of the overall architecture at predicted altitude leading to separation of the major modules (module count corresponded to that predicted for structural failure at the expected weak points), followed by aerodynamic splintering of the individual modules sometime later at more typical spacecraft rupture altitudes. A similar process is expected for ISS.

In addition, NASA conducted one planned controlled entry of one of its own large spacecraft—the 17-ton Compton Gamma Ray Observatory—in June 2000, also supported by data gathering with national assets. Better data were collected on this entry, and again provided strong support for the ability of the analysts to predict altitude and mechanism of breakup, with subsequent debris dispersion well within the predicted limits.

Contingency plans were prepared for both entries, especially focusing on communications to affected parties in the event of impending de-orbit outside of the designated safe zone. A similar document will be compiled for the ISS a minimum of one year before its planned entry. This work will be carried out under the provisions of NASA Safety Standard 1740.14: Guidelines and Assessment Procedures for limiting Orbital Debris.

The debris field of the *Columbia* was consistent with NASA's debris survivability and dispersion models. The mechanism of the *Columbia* accident, however, was sufficiently different from typical spacecraft breakups (which occur higher, on weaker, lower ballistic number structures, without thermal shielding) that the details of the accident provide only minimal additional validation of the model's predictive capability of the ISS de-orbit. Due to the differences in altitude and other contributing factors in the *Columbia* accident, there is limited forensic data from its debris that could reshape ISS plans to de-orbit the ISS intact over the Pacific Ocean into the minimum possible debris footprint.

FORWARD WORK

NASA maintains proficiency in its de-orbit operations planning through exercises with the limited number of crewless spacecraft that can be so maneuvered. The Tropical Rainfall Measuring Mission presents NASA's next opportunity for a controlled de-orbit. In addition, if the new Gamma Ray Large Area Space Telescope is ultimately equipped with a proposed de-orbit module, NASA will also conduct de-orbit operations for that spacecraft sometime before the planned ISS de-orbit. Over 400 tons of logistics vehicles will be intentionally de-orbited by the International Partners during the ISS Program before the de-orbit of the ISS itself. Within the limits of technology transfer and U.S. export controls, NASA will work closely with its International Partners to gather experience and lessons learned in planned destructive de-orbits in preparation for NASA's role in coordinating the final end-of-life de-orbit of the ISS.

As the ISS end-of-life risk is periodically updated, a Probabilistic Risk Assessment (PRA), governed by the requirements of NASA Procedures and Requirements 8705, will be employed to refine the existing PRA. The recommendations of the National Research Council ("Engineering Challenges in the Long-Term Operations of the International Space Station," National Academies Press 2000, pp 28-30) will be incorporated to include the consequences of engine malfunction, human error due to stress, etc. Although the revised PRA will not alter the primary decision to maintain reserves of altitude, propellant, and engine fault tolerance for a controlled de-orbit of the ISS to an uninhabited expanse of ocean, the integrated de-orbit risk may be better quantified as a result. Details of this plan are not due until end-of-life minus one year. The ISS Strategic Planning and Requirements Office is responsible for planning this activity, with support from the Vehicle Integrated Performance and Resources team.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Ongoing	Monitor ISS attitude/altitudes, and monitor all known entries of large spacecraft
ISS Program	One Year Before ISS end-of-life	Update ISS end-of-life contingency plans and risk assessment

Columbia Accident Investigation Board

Observation 10.2-1

Future crewed-vehicle requirements should incorporate the knowledge gained from the *Challenger* and *Columbia* accidents in assessing the feasibility of vehicles that could ensure crew survival even if the vehicle is destroyed.

International Space Station (ISS) Corollary: Ensure that future vehicle developments use lessons learned from ISS development and operations to enhance crew survivability options.

Note: The ISS response to Observation O10.2-1 was approved by the ISS Program Integration Control Board (PICB) on September 1, 2004. All actions related to assuring implementation were closed and responsibility for continuous improvement was assigned to the PICB for ongoing management.

BACKGROUND

Since its inception, the ISS Program has sought to provide capabilities for crew escape and survival during all flight phases, as noted in Section 10.2 of the *Columbia* Accident Investigation Board Report. ISS capabilities to ensure crew survivability are extensive and are derived from lessons learned during all crewed space vehicles to date, including those of our Russian partners. At all times while a crew is on board ISS, they have immediate access to an escape vehicle. This includes visiting Space Shuttle crewmembers (using the Space Shuttle) as well as ISS expedition crewmembers (using the Soyuz). If a portion of the ISS pressurized modules were to be disabled or isolated by an atmospheric leak, fire, or contamination, an orderly evacuation can be effected.

ISS PROGRAM IMPLEMENTATION

Most near-term efforts to assess and implement this observation are being carried out by the Space Shuttle Program and are described in *NASA'' Implementation Plan for Space Shuttle Return to Flight and Beyond* (ref. Part 2, Observation O10.2-1). NASA's long-term efforts to develop a new crewed vehicle are being guided by NASA Procedures and Guidelines (NPG) 8705.2, *Human Rating Requirements and Guidelines,* released in July 2003. In addition to NPG 8705.2, the ISS Program is working with the office charged with developing future crewed vehicles to provide detailed requirements for crew and cargo needs by the ISS Program. The ISS Program continues to work side-by-side with this office and has established a dedicated interface function. In parallel, the ISS Program continues to coordinate with its International Partners to maintain the safety of the ISS crews. Nominal activities and contingency capabilities are continually assessed to maximize performance. Though Russia is formally responsible for Soyuz crew safety, since Increment 7 NASA has provided backup evacuation and medical support during the landing of the crews in Kazakhstan. In addition, a portable satellite telephone and global positioning system receiver are now available to help establish contact and location assistance in the event of off-range landings.

STATUS

The status of ongoing crew survivability studies related to Shuttle and future crewed vehicles is reported in the Return to Flight (RTF) Implementation Plan. The safety of ISS crew activities is continuously monitored and managed by many methods and forums. ISS personnel are supporting many of the Shuttle RTF activities. Further, International Partner cooperation in RTF is also proceeding through participation in selective Shuttle RTF tests, technical interchange on specific RTF development technologies, and a more integrated safety assessment supporting ISS participating in flight readiness forums.

Employees with ISS experience are heavily involved in numerous exploration activities, including requirement development, technology maturation, and proposal activities. ISS operational experience is also being provided via numerous lessons learned papers and discussion forums. For example, as solicited by the Exploration Systems Mission Directorate at NASA Headquarters, ISS lessons have been supplied to http://65.168.55.83/portal/site/codet.

FORWARD WORK

The ISS Program will exercise continued diligence in crew survivability support activities and will provide assistance to the Shuttle and to future crewed vehicle programs through joint forums, standards and specifications updates, and lessons learned.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Sep 04 (Complete)	Disposition closure status of ISS response
ISS Program	Ongoing	Maintain support to Shuttle and future exploration programs

Columbia Accident Investigation Board

Observation 10.4-1

Perform an independently led, bottom-up review of the KSC Quality Planning Requirements Document to address the entire quality assurance program and its administration. This review should include development of a responsive system to add or delete government mandatory inspections.

International Space Station (ISS) Corollary: Same as Space Shuttle Program.

Note: The ISS response to this Columbia Accident Investigation Board Observation was approved by the ISS Safety and Mission Assurance Panel (S&MAP) on September 23, 2004. All actions related to assuring implementation and continual improvement are the responsibility of the S&MAP.

BACKGROUND

The ISS Program requirements document, SSP 41173, *Space Station Quality Assurance Requirements*, states that critical characteristics derived from drawings, specifications, and Program-accepted risks shall be designated as inspection points that must be verified by Quality Assurance (QA) personnel during hardware fabrication, buildup, test, use, closeout for launch, and maintenance. These requirements are satisfied by using inspection points implemented by contractor and NASA inspectors.

In compliance with Program requirements, the Kennedy Space Center (KSC) International Space Station/Payload Processing Safety and Mission Assurance organization established a NASA Quality Planning Requirements Document (QPRD) governing the NASA Government Mandatory Inspection Points (GMIP) process. The goal of Government Quality witness/verification is to assure the critical characteristics of processes and/or products satisfy NASA, program, contract, and design requirements. The goal of the QPRD is to define and control the GMIP process. The NASA QPRD is approved by the NASA Chief, Safety and Mission Assurance (S&MA) Division, and establishes a minimum set of GMIPs. Additional inspection points, based on changing requirements or negative trends, can be incorporated in the QPRD at the S&MA Division level. Also, GMIP deletion is requested and approved via a deviation/waiver process at the S&MA Division level.

The ISS/Payload Processing Directorate contractor, Boeing, with inputs from NASA, developed a contractor QPRD that defines their quality mandatory inspection processes. This document is approved by the Boeing KSC Senior Manager of Mission Assurance and the Boeing KSC Site Manager. This QPRD satisfies Program and contract requirements.

NASA QA, at their discretion, may choose to inspect characteristics that do not require mandatory inspection points. These inspection points are designated as government surveillance inspection points (SIPs). NASA QA applies a SIP stamp to the work authorization document (WAD) steps for which surveillance inspection is desired. NASA SIPs are treated identically to NASA GMIPs during WAD performance.

The response to this Observation is linked with ISS-5, ISS-6, ISS-12, and R7.5-2 activities but does not overlap them.

ISS PROGRAM IMPLEMENTATION

The NASA and contractor QPRDs were updated to require an annual review and provide a change status to the initiator/requester for a change to the QPRD. They also established an appeal route for unapproved change requests. Anyone can propose changes to the QPRD and the changes are configuration controlled. The NASA Quality Surveillance system, including the associated electronic database [known as the Record, Assessment, Inspection, Surveillance and Evaluation (RAISE) System], was updated to collect and trend data resulting from NASA Quality inspections, surveillances, and system assessments of KSC ground processing activities. NASA Quality, as part of their inspections, surveillances, and system assessments, evaluates compliance to the QPRD, including GMIP implementation. Data analysis is used to determine the hardware readiness to proceed to the next phase, support contractor performance evaluation, and identify process deficiencies. Noted deficiencies are managed through the NASA Corrective Action Request system. This system was also updated to provide an enhanced closed-loop process for requesting root cause, preventive/corrective actions and to verify effective implementation of these corrective/preventive actions.

The ISS Safety and Mission Assurance/Program Risk Office at Johnson Space Center (JSC) performed an audit of the NASA-KSC ISS Program quality planning process and technical implementation. This audit included an evaluation of the NASA QPRD to determine the effectiveness of GMIP criteria in assuring verification of critical functions and implementation of these criteria. The audit also included a review of the mandatory inspection process change process and discrepancy identification and closure process. The team used various inputs to develop the audit plan including applicable sections from the NASA Shuttle GMIP Independent Assessment team report.

STATUS

The NASA QPRD and the contractor QPRD were updated to require annual reviews and a formal change process.

The audit team met twice at KSC in March and April 2004 for familiarization and collection of process documentation. The team's initial visit included tours of applicable facilities, interviews of NASA and contractor personnel, and reviews of relevant process documentation. The actual audit occurred twice in June and July 2004. The topics audited included human resources, training, metrology/calibrations, work instructions, mandatory inspection points, and general quality. In particular, the team assessed implementation of the programmatic requirements contained in SSP 41173, *Space Station Quality Assurance Requirements*, Revision C. The audit also referred to the following documents:

- SAE-AS9100: Quality Systems – Aerospace – Model for Quality Assurance in Design, Development, Production, Installation and Servicing
- ISO-9001: 2000 – Quality Management Systems – Aerospace – Requirements
- NASA and Boeing QPRD requirements
- Internal and external requirements of inputs, outputs, and process measurements
- Shuttle GMIP Independent Assessment team report

At this time, the on-site audit activities are complete and a report of the audit results is in development. A draft report is under review at JSC and KSC.

Daily KSC QA activities are documented in the evolving KSC quality control assessment tool database (RAISE System). Metrics are generated and trend analyses are performed to assess hardware processing and maintenance depot activities including contractor performance.

FORWARD WORK

The audit team will complete their report in early 2005. KSC will respond to audit findings, observations, and recommendations and develop plans for corrective actions. As part of normal business, the ISS Safety and Mission Assurance Panel will ensure that corrective actions are appropriately implemented.

There are additional proposed audits such as reviewing Marshall Space Flight Center and JSC ISS Program quality planning activities and a review of the KSC nonconformance report system. ISS S&MA will oversee these audits.

QA groups will be retrained formally on changes to procedures and processes and this effort is described in QA training (ref. Observation 10.4-3).

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
NASA KSC	Jan 04 (Complete)	KSC QA RAISE System initiated
NASA KSC	Mar 04 (Complete)	Update NASA QPRD
Boeing KSC	Apr 04 (Complete)	Update Checkout, Assembly, and Payload Processing Services QPRD
ISS Program S&MA	Jul 04 (Complete)	Perform audit
ISS Program S&MA	Sep 04 (Complete)	Initial draft of audit report out for review by JSC and KSC
ISS Program S&MA	Feb 05	Audit report completed and dispositioned by ISS S&MAP

Responsibility	Due Date	Activity/Deliverable
NASA ISS Program-JSC	Feb 05	Report out to the Space Station Program Control Board
NASA KSC	Mar 05	Respond to audit findings/observations/ recommendations
NASA KSC	Sep 05	Implementation of audit findings/ observations/ recommendations
ISS Program S&MA	Oct 05	Acceptance of the audit response implementation
ISS Program S&MA	Ongoing	Monitor the health of S&MA at other NASA centers implementing ISS Program requirements and implement continuous improvements
NASA KSC	Ongoing	Evaluate potential continuous improvement candidates

Columbia Accident Investigation Board

Observation 10.4-2

Kennedy Space Center's Quality Assurance programs should be consolidated under one Mission Assurance office, which reports to the Center Director.

International Space Station (ISS) Corollary: Assess the organizational structure of quality assurance groups at the three primary ISS support centers.

Note: The ISS response to this Columbia Accident Investigation Board (CAIB) Observation was approved by the ISS Safety and Mission Assurance Panel (S&MAP) on January 14, 2005. All actions related to assuring implementation were closed and responsibility for monitoring continuous improvement was assigned to the S&MAP for ongoing management.

BACKGROUND

In the year 2000, a major reorganization of Kennedy Space Center (KSC) was implemented. As part of this effort, which is known as *KSC 2000*, separate safety and mission assurance (S&MA) offices were formed in each appropriate directorate at KSC. This was done to provide direct S&MA support to each of the directorates, including ISS support.

ISS PROGRAM IMPLEMENTATION

The ISS Program's response to this Observation was to assess the S&MA organizational structures at its three primary support centers.

In close coordination with the effort led by the Associate Administrator for Safety and Mission Assurance (AA/S&MA) in responding to CAIB Recommendation R7.5-2, KSC established a center-level team to assess the KSC S&MA organizational structure.

STATUS

For an overview of the status of ISS related S&MA and Technical Authority (TA) organizational attributes, refer to this document's responses to Observation O10.4-1 and to Recommendations R7.5-1, R7.5-2, and R9.1-1.

In response to this Observation, the ISS Program found the quality assurance groups at the Johnson Space Center (JSC) and the Marshall Space Center to be adequately organized and consolidated, but did recognize the need to strengthen quality assurance capabilities at JSC. The results of this activity are described more fully in Section 2.1, ISS Continuous Improvement Action ISS-12.

Regarding the KSC specific aspects of this Observation, a team was formed from each KSC directorate with S&MA organizations. KSC's Safety, Health, and Independent Assessment Directorate worked with the NASA Headquarters AA/S&MA to determine the optimal organizational structure to support the Space Shuttle, the ISS Program, and other programs at KSC. Based on the results of this review, in May 2004, KSC consolidated all S&MA efforts into a centralized S&MA organization reporting to the KSC Center Director. This new organization structure is illustrated by figure O10.4-2-1. The latest overall organization structure for KSC, including the TA activity, can be found at http://ba.ksc.nasa.gov/execteam.htm.

As a final assurance of the validity of this response to CAIB, funding for the S&MA and TA efforts at each center is now independent of the ISS Program and is provided through NASA Headquarters.

FORWARD WORK

The S&MA organizations at each center will continually assess opportunities for organizational improvements.

For more details regarding TA forward work, refer to the ISS response to Recommendations R7.5-1, R7.5-2, and R9.1-1 in Part 1 of this document. For further discussion of S&MA forward improvements, please see the ISS responses in Part 2 of this document for Continuous Improvement Action ISS-12, Observations O10.4-1 and O10.4-3 and General Deal Recommendations D.a-4 and D.a-15.

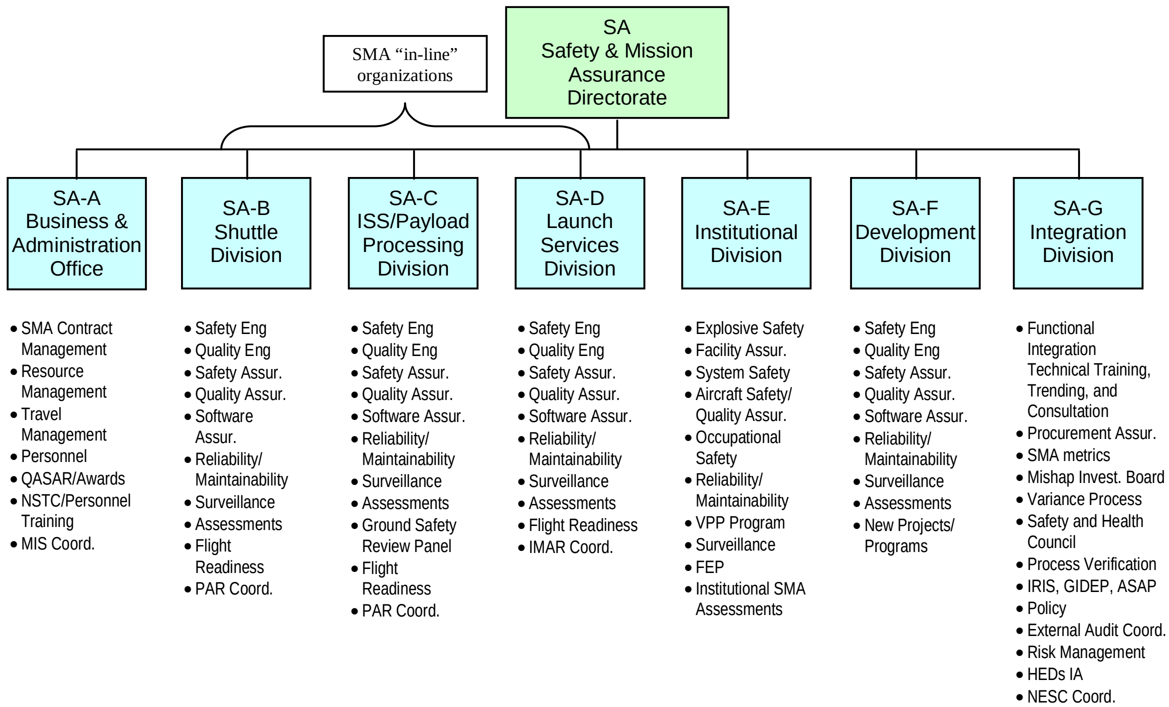


Figure 10.4-2-1. Consolidated S&MA

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
KSC Safety, Health, and Assessment Directorate and AA/S&MA	Dec 03 (Complete)	Recommendations to KSC Center Director
KSC Safety, Health, and Assessment Directorate and AA/S&MA	Jan 04 (Complete)	Initiate S&MA reorganization activities
NASA KSC	May 04 (Complete)	Complete KSC S&MA Reorganization
ISS Support Centers	Ongoing	Continuous improvement assessment as part of normal management

Columbia Accident Investigation Board

Observation 10.4-3

KSC quality assurance management must work with NASA and perhaps the DOD to develop training programs for its personnel.

International Space Station (ISS) Corollary: Assess the training of quality assurance groups at the three primary ISS support centers.

Note: The ISS response to this Columbia Accident Investigation Board (CAIB) Observation was approved by the ISS Safety and Mission Assurance Panel (S&MAP) on January 14, 2005. All actions related to assuring implementation and Program-wide continuous improvements were assigned to the S&MAP.

BACKGROUND

The CAIB reported that most of the training for Quality Engineers, Process Analysts, and Quality Assurance Specialists was on-the-job training (OJT) rather than formal training. In general, NASA Quality Assurance personnel supporting the ISS Program and Space Shuttle payload programs are trained per a formal training plan. This plan includes formal classroom training for specific process and product tasks (e.g., nonconformance reporting, crimping, wire bonding, etc.) as well as OJT.

At the Kennedy Space Center (KSC), Boeing, the ISS/Payload Processing Directorate's contractor, has a mature training program that encompasses all functions by skill for payload processing. The program includes training criteria standards that have the requirements for each major function (i.e., OJT packages, certifications, physicals, and training courses). These data reside in a Boeing database that is located on a Boeing Web site. Each major function has a training administrator or coordinator that monitors the training requirements for each particular department. In addition, the Boeing Quality Organization participates in training provided by the local American Quality Society chapter and the annual Florida Governor Sterling Award Seminar that is focused on process excellence and trending/analysis.

ISS PROGRAM IMPLEMENTATION

The ISS Program's response to this Observation was to assess possible improvements to the Safety and Mission Assurance (S&MA) training at its three primary support centers. While NASA and its contractors both plan and conduct training for their quality personnel, it is acknowledged that improvements can and will be made.

At KSC, the ISS/Payload Processing Directorate participated with the Shuttle Processing Directorate's benchmarking of the Department of Defense (DoD) and Defense Contract Management Agency (DCMA) assurance training programs. The current training plan was expanded by the new KSC consolidated S&MA Directorate to include additional philosophy, basic principles, and technical courses. The revised training plan also contains a training schedule and includes refresher requirements. All seven of the DCMA core classes are incorporated in the S&MA training plan. Additionally, this training plan includes formal and technical training requirements for nondestructive equipment and tests such as boroscope use.

A joint KSC ISS and Space Shuttle Quality Assurance Training Team was chartered to develop the process and tools for training of new and current Quality Assurance personnel. Specifically, the team developed a training plan that provides increased instruction in basic Quality skills. DCMA training processes and requirements are used as an initial model for this training. The following are examples of required training classes:

- American Society for Nondestructive Testing recognized course:
  - A visual testing course is being developed for certification.
- DCMA QA training courses:
  - Fundamentals of Quality Assurance
  - Measuring Techniques
  - Calibration System Requirements
  - Statistical Sampling
  - Drawings, Dimensions, and Tolerances

- Specifications and Standards
- Data Collection and Analysis

Contractor personnel who control critical work processes or perform critical operations on products must have satisfactory completion of an approved, written, and/or practical examination. Certification cards and licenses are available at the job site as evidence that personnel are certified to perform a specific task. The task leader is responsible for ensuring that assigned personnel are qualified to perform the task and quality personnel verify that certifications are current by reviewing licenses and training records.

STATUS

The joint KSC-ISS and Space Shuttle Quality Assurance Training Team finalized the enhanced training plan and documenting requirements through KSC's Business Systems organization. The revised plan includes training philosophy, basic principles, additional technical courses, and the rate of retraining. This plan, KSC-UG-2801, S&MA Directorate Development Training Curriculum, was approved in October 2004 by the KSC Director of Safety and Mission Assurance. This plan is now being implemented across KSC for all S&MA disciplines.

The ISS Program Office at the Johnson Space Center also completed its assessment with the recognized need to strengthen local Quality Assurance training. The results of this activity established three levels of training that are further described in the ISS response to Continuous Improvement Action ISS-12.

The ISS Program also assessed the ISS quality training programs at Marshall Space Flight Center and found them to be adequate.

FORWARD WORK

Actual training of KSC S&MA personnel is ongoing, using the enhanced training plan, KSC-UG-2801, S&MA Directorate Development Training Curriculum.

The ISS Program and the S&MA organizations at each center will continually assess opportunities for training improvements.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
KSC ISS/Payload Processing Directorate	Apr 04 (Complete)	Benchmark DoD and DCMA training programs
KSC S&MA Directorate	Aug 04 (Complete)	Develop and document improved training requirements (Draft KSC-UG-2801, S&MA Directorate Development Training Curriculum)
KSC S&MA Directorate	Oct 04 (Complete)	Release Training Plan – KSC-UG-2801, S&MA Directorate Development Training Curriculum
ISS Program and Centers S&MA	Ongoing	Conduct personnel training
ISS Program and Centers S&MA	Ongoing	Continual improvement assessment as part of normal management

Columbia Accident Investigation Board

Observation 10.4-4

Kennedy Space Center should examine which areas of International Organization for Standardization 9000/9001 truly apply to a 20 year old research and development system like the Space Shuttle.

International Space Station (ISS) Corollary: Same as Space Shuttle Program.

Note: The ISS response to this Columbia Accident Investigation Board Observation was approved by the ISS Safety and Mission Assurance Panel (S&MAP) on September 23, 2004, and again on January 13, 2005. All responsibility for monitoring this activity and for ongoing management was assigned to the S&MAP.

BACKGROUND

NASA originally imposed International Organization for Standardization (ISO) 9001 as the primary tool required to implement NASA management systems. Effective April 17, 2003, the NASA Management System Policy (NPD 1280.1) was updated to state that ISO 9001 or AS9100 may be used to satisfy the management system policy, but that "additional approaches may also be acceptable, where approved by the Deputy Administrator." The updated policy includes a set of minimum criteria for management systems. ISO 9001 addresses quality management system requirements and should not be used alone for quality assurance purposes related to mission success of aerospace systems.

ISS PROGRAM IMPLEMENTATION

In December 2003, the ISS Program reevaluated the use of ISO 9001-2000 standards and determined that these standards should continue to be the primary tool and most effective approach to meet NASA quality management system requirements defined in NPD 1280.1. In the new ISS Program contracts negotiated during that same time period, it was specified that contractors supporting the ISS Program must be ISO 9000 certified at a minimum. As a process improvement, contractors are required also to seek AS9100 certification if developing and sustaining hardware for the ISS Program. Service-based contracts are expected to be in compliance with AS9100 standards but are not required to seek certification.

The ISS Program also finds benefit in continuing ISO 9001 practices due to the consistency it provides with management, process and documentation procedures across the Program, and for enhanced working relationships with Johnson Space Center and other NASA centers that also implement ISO 9001 standards. The practice of these standards at NASA has proven to be effective through the usefulness of specific work instructions, the improvements derived from process and performance reviews, and the awareness and corrective action resulting as outcomes from internal and third party audits. The benefits of use of AS9100 include its specific applicability to aerospace applications. As an aid to quality consistency, AS9100 is endorsed and applied by almost all major international companies and government agencies (including most of the ISS International Partners). In addition, using the third-party AS9100 certification process reduces ISS impacts for contract surveillance.

For example, during the Kennedy Space Center (KSC) Checkout, Assembly, and Payload Processing Services (CAPPS) contract competition in 2002, the ISO 9000 family of documents was examined, and it was determined that ISO 9001 required augmentation to ensure a comprehensive quality assurance (QA) program. In compliance with Agency policy and with the concurrence of the NASA Headquarters Safety and Mission Assurance (S&MA) Office and ISS S&MA, the ISS/Payloads Processing Directorate imposed the following requirements on the CAPPS contract to substantiate a sound QA program:

- Q9001-2000, American National Standards Institute/ISO/American Society for Quality
- AS9100, Society of Automotive Engineers Aerospace Standard Quality Management Systems Aerospace – Model for Quality

Assurance in Design Development, Installation, and Servicing

- SSP 41173, Space Station Quality Assurance Requirements (extracts of)

STATUS

The ISS Program at all NASA centers has implemented Agency requirements and required ISS Program contractors also to seek AS9100 certification if they are contracted to develop and sustain hardware for the ISS Program.

As confirmation of the above status, the ISS Program also studied the detailed results of the review of Shuttle operations at KSC (as cited in the Space Shuttle Return to Flight Plan) and found nothing that would change ISS practices.

KSC and the ISS/Payloads Processing Directorate have implemented Agency requirements. These requirements were augmented and imposed on the CAPPS contract to institute a QA program appropriate for ensuring the successful ground processing of ISS elements, components, and payloads at KSC.

FORWARD WORK

The ISS Program, the KSC S&MA Directorate, and the KSC ISS/Payloads Processing Directorate will participate in Agency-wide endeavors to continually improve Agency QA program requirements.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Nov 03 (Complete)	Review of results of Agency/industry review of ISO for Shuttle at KSC
ISS Program	Dec 03 (Complete)	Determination to continue use of ISO 9000/9001 standards with augmentation by AS9100
ISS Program, KSC S&MA Directorate, and KSC ISS/ Payloads Processing Directorate	Ongoing	Participate in Agency efforts to enhance Agency QA program requirements

Columbia Accident Investigation Board

Observations 10.5-1, 10.5-2, 10.5-3

O10.5-1 Quality and Engineering review of work documents for STS-114 should be accomplished using statistical sampling to ensure that a representative sample is evaluated and adequate feedback is communicated to resolve documentation problems.

O10.5-2 NASA should implement United Space Alliance's suggestions for process improvement, which recommended including a statistical sampling of all future paperwork to identify recurring problems and implement corrective actions.

O10.5-3 NASA needs an oversight process to statistically sample the work performed and documented by (United Space) Alliance technicians to ensure process control, compliance, and consistency.

International Space Station (ISS) Corollary: Same as Space Shuttle Program.

Note: The ISS response to Columbia Accident Investigation Board Observation O10.5 was approved by the ISS Safety and Mission Assurance Panel (S&MAP) on January 15, 2005. All actions related to assuring implementation were closed and responsibility for ongoing management was assigned to the S&MAP.

BACKGROUND

Many of the ISS elements and payloads, processed by Kennedy Space Center (KSC) ISS/Payload Processing Directorate NASA personnel, are one-of-a-kind and are processed one time through KSC. Due to the uniqueness of this payload processing environment, NASA personnel have retained signature authority for many procedures, including critical, hazardous, and first-time high-risk procedures. This effort correlates to a 100% sampling of these procedures. In addition, NASA signatures may be added at NASA's discretion for any remaining noncritical procedures as deemed appropriate. Therefore, contract surveillance strategy is implemented differently from the Shuttle Processing Directorate because much of the work consists of unique, non-repetitive activities.

The ISS/Payload Processing Directorate performs surveillance that includes oversight and sampling, of contractor activities. The government's surveillance plan is documented in Attachment J-8 of the Checkout, Assembly, and Payload Processing Services (CAPPS) contract and is titled "Checkout, Assembly and Payload Processing Services Performance Surveillance Plan." It describes the government's plan for providing effective and systematic surveillance and reporting of all aspects of CAPPS contract performance. This surveillance strategy uses a variety of tools including, but not limited to, audit, analysis, observation and inspection, checklist, sampling, metrics, customer feedback, and a variety of management information systems supporting these efforts.

The KSC CAPPS contractor's performance goals are rated using metrics that include objective measures for flight hardware processing effectiveness, safety and mission assurance (S&MA) effectiveness, and other factors. The S&MA effectiveness metrics include quality sampling of documentation and processes in the areas of assurance S&MA, ISS flight hardware, and ground support equipment processing.

NASA KSC Quality Assurance (QA) personnel perform surveillance of real-time operations including reviewing the in-process paperwork to assess compliance with requirements. NASA Process Analysts perform process assessments of paperwork throughout its life cycle to assess compliance with requirements. NASA Quality Engineering also assesses hardware processing paperwork for compliance with requirements. Review and approval of payload processing work documents and hardware nonconformances by NASA Engineering helps ensure the safety, task success, and reliability, operability, and performance of the system. Identified negative performance trends and recurring problems are communicated to the responsible organization's management through the NASA Corrective Action Request System. Any nonconformances involving changes to

ISS flight hardware require review and approval by a senior engineering review board.

In summary, the KSC ISS Payload Processing Program surveillance strategy is very robust, and includes statistical sampling and a well-defined NASA contract management process to assure process control, compliance, and consistency.

The four new ISS Program contracts implemented in 2004 are also managed using contract surveillance plans and employ a variety of tools including, but not limited to, audit, analysis, observation and inspection, checklist, sampling, metrics, customer feedback, and a variety of management information systems supporting these efforts.

ISS PROGRAM IMPLEMENTATION

For ISS cargo processing, the ISS/Payload Processing Directorate continues use of the CAPPS Performance Surveillance Plan while evaluating changes that may impact NASA's surveillance strategy.

NASA conducted a comprehensive engineering and quality review of the STS-107 SPACEHAB integrated payloads ground processing activities and work documents. In addition, KSC extended that detailed review to include the unique, one-of-a-kind Node 2 (STS-120) as well as the STS-114 Multi-Purpose Logistics Module.

As a commercial payload, SPACEHAB (STS-107) retained primary responsibility for payload processing and KSC's involvement was limited to Shuttle integration. Therefore, our review was focused on Shuttle integration documentation that represents only a small percentage of documentation normally used in processing a typical ISS payload such as Node 2, truss, lab module, or a logistics module. In the review of 142 STS-107 KSC documents, 30 minor discrepancies such as clarity of instruction and illegible data were identified.

An Integrated Boeing Quality/Configuration Management Team was established to assess the STS-114 (ISS Logistics Flight-1) work documentation for the initial return to flight mission. The STS-114 documentation was sampled using proven statistical sample methods.

In response to the recent transition to a new payload processing contract, KSC performed a complete review of all governing work procedures and nonconformance processes.

STATUS

The STS-107 review found no instances where technical issues would affect the integrity of the processed payloads; however, instances of noncompliance with documentation processes were noted.

The STS-114 team completed its assessment and is briefing the results to the various teams and management, including recommendations to improve each category of the sample. The team found no instances of technical issues that would affect the integrity of the processed payloads. As with the STS-107 review, instances of noncompliance with documentation processes were noted.

A review and update of procedures and associated processes governing ISS processing, including work documentation and noncompliance processes, has been completed. Employees are being trained on updated processes, and Mission Processing Teams are being briefed on the causes and corrective actions being taken on each issue.

The above reviews were conducted from March 2004 through September 2004 and assessed 310 Work Authorization Documents (WADs) [43 Interim Problem Report/Discrepancy records, 135 Problem Report records, 89 multi-page Operation and Maintenance Instructions, and 43 multi-page Test Preparation Sheet] that resulted in:

- An improvement in the number of missed verification points, legibility, and timeliness of the entry data.
- Improved team training, discipline, and quality of WADs. Continued emphasis will be placed on corrective actions, including discussions concerning quality and performance issues during weekly team meetings, as well as management meetings, to maintain WAD discipline.
- An upgrade of Standard Practice Procedure Q-01, Nonconformance System, and the associated training classes to help communicate requirements to processing team personnel.

Since September 2004, QA members performed a more in-depth review of WADs that were submitted for final closure. This ongoing review included an assessment of 817 WADs. Identified errors were tagged and the WAD was returned to the responsible team for positive feedback and correction. Identified WAD errors were subdivided into categories based upon WAD processing requirements and presented as a Pareto chart. These data, as well as closed paper data, were shared with management and employees.

WAD requirements compliance is discussed during processing team status briefings where employees are presented the results of the WAD reviews and encouraged to suggest solutions to deficiencies including process improvements. Management and each team (Lifting and Handling, Fluids, etc.) are presented a visual picture of where attention should be focused and how they are doing as compared to the overall organization.

A follow-on review of the completed "March through September 2004" WADs was performed to determine whether the corrective actions taken resulting from the 2003 audits of STS-114 and STS-120 WADs eliminated identified discrepancies. The actions taken were found to be effective, and opportunities for improvement were identified. Such audits will now be performed on a monthly basis to provide feedback to the processing teams for their education and action.

A more in-depth review of WADs that are submitted for final closure has been initiated. Identified errors are tagged and the WAD is returned to the responsible team for positive feedback and correction. Data are collected and analyzed to identify areas requiring attention and process improvements.

FORWARD WORK

KSC, Johnson Space Center (JSC), Marshall Space Flight Center (MSFC), and Defense Contract Management Agency (DCMA) will perform a work document review process to ensure compliance with ISS Program and contract requirements. They will identify discrepancies, effect remedial action, trend results, display and analyze metrics, and effect correct actions where required. The S&MA organizations will continually assess for opportunities for process and product sampling improvements.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
KSC ISS/Payload Processing Directorate	Dec 03 (Complete)	Procedure/process updates complete
KSC ISS/Payload Processing Directorate	Jul 04 (Complete)	Training on updated processes complete
KSC ISS/Payload Processing Directorate	Ongoing	Update and maintain the "CAPPS Performance Surveillance Plan''
KSC, JSC, MSFC, DCMA	Ongoing	Perform a work document review process
KSC, JSC, MSFC, DCMA	Ongoing	Review and evaluate potential continual improvement candidates

Columbia Accident Investigation Board

Observations 10.6-1 and 10.6-2

O10.6-1 The Space Shuttle Program Office must make every effort to achieve greater stability, consistency, and predictability in Orbiter Major Modification planning, scheduling, and work standards (particularly in the number of modifications). Endless changes create unnecessary turmoil and can adversely impact quality and safety.

O10.6-2 NASA and United Space Alliance managers must understand workforce and infrastructure requirements, match them against capabilities, and take actions to avoid exceeding thresholds.

International Space Station (ISS) Corollary: Review ISS schedules, associated risks, and available margins for consistency with revised Space Shuttle launch risk considerations. Demonstrate how resources are managed to be consistent with schedules.

The underlying intent of these observations is addressed in Part 1, Recommendation R6.2-1, of this Implementation Plan.

Columbia Accident Investigation Board

Observation 10.6-3 and 10.6-4

O10.6-3 NASA should continue to work with the U.S. Air Force, particularly in areas of program management that deal with aging systems, service life extension, planning and scheduling, workforce management, training and quality assurance.

O10.6-4 The Space Shuttle Program Office must determine how it will effectively meet the challenges of inspecting and maintaining an aging Orbiter fleet before lengthening Orbiter Major Maintenance intervals.

International Space Station (ISS) Corollary: Ensure that aging of ISS systems is factored into ISS inspection and maintenance processes.

Note: The ISS response to Observations O10.6-3 and O10.6-4 was approved by the ISS Vehicle Control Board (VCB) on September 20, 2004. All implementation actions were closed and responsibility for ongoing management was assigned to the VCB.

BACKGROUND

As a long-lived vehicle with systems subject to an array of preflight and on-orbit usage conditions, the ISS Program addresses vehicle aging through its design, verification, operation, and maintenance activities. Experience with the Russian *Mir* space station is also invaluable and directly relevant to ISS performance assurance.

ISS PROGRAM IMPLEMENTATION

The ISS Program either designed its hardware for the intended life of the Program or developed a maintenance plan for hardware where full life was not possible.

STATUS

The ISS vehicle is still well within its current design life, but the Program is continuously assessing any conditions that may change the lifetime estimates developed during the design and development phases. This activity is based upon three major activities that will continue through the life of the Program.

1) Orbital Replacement Unit failure and maintenance rates monitoring

   This is an ongoing activity to collect and maintain maintenance data for the on-orbit and ground hardware. These data are used to assess hardware design issues, adjust sparing levels, and evaluate changes in on-orbit maintenance intervals (e.g., filter change out and cleaning or Trace Contaminant Control System bed replacements). The ISS Program collects a large amount of data due to lessons learned from the Orbiter Project Logistics program and U.S. Air Force methodology. The ISS Logistics and Maintenance Office participates in the Space Shuttle Program's Integrated Logistics Panel and has incorporated several Shuttle lessons learned on vendor availability and data collection into ISS maintenance strategies. In addition, the ISS Logistics and Maintenance Office hired former military logistics experts and maintains contact with Department of Defense Logistics organizations.

2) Hardware Configuration

   The ISS Program continues to document the hardware certification baseline and assess any hardware changes due to ground storage or exposure to the orbital environment. This effort is further detailed in the ISS Continuous Improvement Action ISS-7. Under that effort, the Program reviewed all systems and expanded the preventive maintenance requirements to also address recommendations for confidence tests due to launch delays. In addition, the Program is consolidating the hardware certification data and documenting any changes due to new orbital attitudes or operational uses. As further detailed in ISS Continuous Improvement Action ISS-8, the Program performed an enhancements review that will continue into the future. This will ensure that hardware and software improvements are identified and incorporated through a continuous Program identification and budgeting process. Finally, the Program assesses whether there are hardware items whose current certification life expires prior to the current ISS Program life expiration. Plans are being developed to identify all of these hardware items and define the appropriate timing and method of addressing the limiting life.

3) Hardware Condition Monitoring

The ISS Program maintains tight environmental requirements on the hardware stored at Kennedy Space Center (KSC) in preparation for flight. Even with these controls, the Program continues to monitor hardware on the ground for corrosion and any effects of long-term storage in a one-G environment. A detailed inspection regimen was initiated at KSC in the summer of 2004, and preventive maintenance and preflight testing procedures were adopted. In addition, an extensive evaluation was performed of the impact of having lubricated mechanisms stored dormant on the ground for extended periods of time. Industry experts, ISS Program vendors, and mechanism experts were engaged to evaluate the potential impact of launch delays on the hardware. Testing was performed to determine any impacts upon life due to extended storage. Lessons learned from Space Shuttle Program vendors were incorporated in the ground and on-orbit procedures. The Program Material and Processes experts worked with the U.S. Air Force and the Space Shuttle Program to determine the applicability of their data to the ISS vehicle. The ISS Program also instituted a plan to periodically perform external surveys for hardware configuration verification, assessment of material degradation, and identification of visible anomalies. This provides a historical set of images to assess the long-term degradation and facilitates future problem resolution. On-board assets provide viewing capability for a significant portion of the vehicle's exterior. This is further detailed in the ISS response to Recommendation R6.4-1. In addition, the Program's efforts concerning corrosion and material issues are addressed in Observations O10.7 and O10.8.

FORWARD WORK

The ISS Program recognizes that assessment of the hardware is a continuous process that will occur throughout the life of the ISS vehicle. The Program will continue to learn from external and Agency experts by collecting new information on materials and environmental impacts on the hardware.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Ongoing	Monitoring and control of ISS vehicle performance
ISS Program	Ongoing	Collection of vehicle aging lessons from appropriate NASA, international, and external experts
ISS Program	Ongoing	Identification of ISS enhancement options during the annual strategic planning and budget cycle
ISS Program	Annually (Initially Dec 04)	Disposition of enhancement options by Integrated Space Operations Summit for post-Assembly Complete vehicle operation and maintenance

Columbia Accident Investigation Board

Observations 10.7-1, 10.7-2, 10.7-3, and 10.7-4

O10.7-1 Additional and recurring evaluation of corrosion damage should include non-destructive analysis of the potential impacts on structural integrity.

O10.7-2 Long-term corrosion detection should be a funding priority.

O10.7-3 Develop non-destructive evaluation inspections to find hidden corrosion.

O10.7-4 Inspection requirements for corrosion due to environmental exposure should first establish corrosion rates for Orbiter-specific environments, materials, and structural configurations. Consider applying Air Force corrosion prevention programs to the Orbiter.

International Space Station (ISS) Corollary: Same as Space Shuttle Program.

Note: The ISS response to Observation O10.7 was approved by the ISS Vehicle Control Board (VCB) on September 13, 2004. All future actions resulting from this assessment are the responsibility of the VCB for ongoing management.

BACKGROUND

The ISS is a long-lived vehicle with multiple fluid systems. The ISS Program addresses the hazards of corrosion through design, verification, and maintenance activities. All ISS segments and components are maintained in a controlled environment (temperature, humidity, and particulates) during all phases from manufacturing through launch with specific documented exceptions for brief periods of time. On orbit, only the internal habitable volume has any risk of corrosion. Due to strict controls of environmental and thermal conditions, however, the risk of condensation and consequent corrosion is mitigated in the habitable volume. All materials used in ISS external surfaces have been selected to withstand the continuous low Earth orbit environment (atomic oxygen, radiation, thermal cycling, and vacuum) for the performance life of the vehicle.

ISS PROGRAM IMPLEMENTATION

The ISS Program reassessed corrosion prevention to determine whether additional improvements in current ground and on-orbit practices are needed. Insights from expertise outside the ISS Program were also considered.

Determination of Corrosion Rates

Corrosion control has been a primary consideration in the design of ISS hardware. Material selection and corrosion protection finishes for the majority of ISS hardware were selected from established aerospace guidelines and are expected to significantly exceed ISS performance life requirements. Where exceptions to established corrosion practices were taken, extensive testing was performed to establish the limits to which the system can be operated. An example of testing conducted is on the ISS hatch seal interfaces, where the corrosion finish applied was tested under orbital conditions. This testing showed that the interface assembly could tolerate as many as 14 days of exposure to condensation before pitting would initiate. As a result, ISS operations have always considered this impact on the seal interface when addressing potential thermal conditions that could lead to condensation.

Testing was also conducted to understand the cause and rate of corrosion of nickel-plated quick disconnect (QD) hardware in the External Active Thermal Control System, which uses anhydrous ammonia as the heat transport fluid. It was found that interaction of atmospheric moisture on the ground could lead to rapid corrosion of these QDs. Hence, all ammonia QDs required for ground operations were replaced with a different finish that was established to be compatible in this particular environment.

ISS Materials and Processes (M&P) personnel conducted extensive testing to understand corrosion occurring in the Internal Active Thermal Control System (IATCS). Requirements were established early in the program to take periodic samples of heat transport fluid for the IATCS to monitor whether any corrosion was occurring even though thorough testing of the compatibility of the system materials of construction with the fluid had been conducted. That diligence was justified when an unexpected change in the pH of the IATCS fluid occurred on orbit, followed by the observation of nickel corrosion products in the fluid and some system components. The ISS Program conducted a two-year test to understand the effect of the IATCS fluid pH change on system corrosion and to determine the risks to hardware performance life. The operation of the IATCS is being actively addressed through several test teams to determine the best way to operate the system over the long term to minimize impacts and risks to ISS operations. To avoid any on-orbit issues with the yet-to–be-launched Node 2, there is a plan to lower the pH level of the Node 2 coolant lines and then flush them prior to launch. Other modules awaiting launch may receive similar treatment.

Impacts to Structural Integrity and Risks of Hidden Corrosion

The ISS primary structure is well protected from galvanic corrosion by materials selection and design. Pitting corrosion is prevented by using two coats of chromated epoxy primer on the interior walls of the pressure shell. Materials used in structural applications are all highly resistant to stress corrosion cracking. The ISS Program requires the use of corrosion protection sealants in contacting surfaces to protect against galvanic effects. Furthermore, environmental control systems specialists rigorously monitor water balance, so the risk of significant water condensation leading to corrosion is extremely low.

Long-term Effects and Detection

All of the corrosion evaluations conducted by the ISS M&P team used conservative assessment methods coupled with worst-case operating conditions in ground tests. These evaluations specifically address long-term effects of corrosion on hardware. Since the ISS does not operate in a dynamic structural environment, there are no current plans to develop on-orbit corrosion detection methods.

Implementation of “Lessons Learned” from the Space Shuttle Program

The ISS M&P team monitors all ongoing corrosion investigations and anomalies on Shuttle hardware through periodic technical interchange meetings with Space Shuttle counterparts. ISS and Shuttle M&P subsystem leads are physically collocated and routinely exchange technical information on M&P issues. As an example, the ISS M&P team had detailed technical discussions with Shuttle counterparts to understand the nature and extent of corrosion observed in the Shuttle metal bellows flex hoses in Kennedy Space Center (KSC)-controlled storage facilities. As a response, ISS M&P implemented a sampling inspection plan for ISS metal bellows flex hoses at the Space Station Processing Facility at KSC. The ISS M&P team is also well informed of the recent study conducted by the Shuttle team to define a corrosion control and inspection plan for the structural airframe under Thermal Protection System surfaces, even though this study has no direct applicability to ISS.

Application of Air Force Corrosion Prevention Programs

Because of the different nature of corrosion problems for the ISS, aircraft corrosion prevention programs are generally not directly applicable. However, the ISS M&P team has frequently taken advantage of outside expertise for resolving specific corrosion issues. The Boeing Corporate Laboratories in Seattle, Wash., NASA and Boeing personnel working the Space Shuttle Program, and technical personnel at ISS subcontractors have all made major contributions in this area.

Although not strictly classified as corrosion, atomic oxygen erosion of materials exposed to the ISS external environment is a significant materials issue. The ISS M&P team worked closely with Air Force personnel on development of the Air Force-sponsored Materials International Space Station Experiment passive atomic oxygen exposure flight experiment currently on ISS, and specimens of all critical exposed ISS external materials were included in the experiment.

STATUS

Testing for IATCS corrosion rates was recently completed, and the final report was released in August 2004. Additional IATCS ground test simulations are ongoing with a modified system that began operating at Marshall Space Flight Center in mid-2004. An effort is also under way to return IATCS parts susceptible to biologically induced corrosion to the ground for analysis (flex hose and heat exchanger). Because of this concern, alternatives to the current U.S. biocide are also being pursued and adjustments to the Node 2 coolant are being considered. A coolant quality monitoring kit and an IATCS coolant fluid sample assembly continue to be used to return samples to Earth for detailed analysis. All opportunities for assessment of flight hardware will be used to better understand the long-term performance life of IATCS and assess opportunities for better system performance.

In addition, the IATCS corrosion findings and strategies were reviewed by an independent assessment team and reported in January 2004 as documented in JA-3145.

One ISS component is slated to be replaced earlier than expected due to coolant system related corrosion. A replacement unit for the joint airlock's spacesuit heat exchanger is planned to be manifested on mission 17Progress. Though unlikely, this is a safety issue if coolant leaks into or over-pressurizes the spacesuit. The limited number of properly configured replacement heat exchangers is being addressed to ensure an adequate supply in the future.

As a final example of ISS diligence in this area, recent reviews of ground facilities have identified humidity exposure concerns for some ISS spare parts stored at KSC. A response plan is being enacted to verify initial conclusions that no harm has yet been done to the affected parts and to prevent reoccurrence through improved monitoring and procedures.

FORWARD WORK

Numerous active corrosion control activities are in work. Corrosion-related problems reported by M&P team members at KSC will be technically resolved for each element prior to its launch date. In summary, the ISS M&P team is actively engaged in vehicle operations to ensure that any corrosion anomalies are addressed, with supporting ground tests and return of flight samples if necessary.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Aug 04 (Complete)	Final report on two-year testing of IATCS corrosion rates
ISS Program	17P manifest	Replace suspect airlock spacesuit heat exchanger
ISS Program	Mid 2005	Resolve humidity monitoring issues with ground storage facilities
ISS Program	Prior to launch	Adjust Node 2 coolant pH to flight levels
ISS Program	Per manifesting constraints	Return suspect lab flex hose on LF-1
ISS Program	Ongoing	Additional IATCS ground testing started mid 2004
ISS Program	Ongoing	Investigate generic adjustments to coolant fluid biocide and pH
ISS Program	Ongoing	Continue to support existing external experiments that measure atomic oxygen erosion of materials

Columbia Accident Investigation Board

Observations 10.8-1, 10.8-2, 10.8-3, and 10.8-4

O10.8-1 Teflon (material) and Molybdenum Disulfide (lubricant) should not be used in the carrier panel bolt assembly.

O10.8-2 Galvanic coupling between aluminum and steel alloys must be mitigated.

O10.8-3 The use of Room Temperature Vulcanizing 560 and Koropon should be reviewed.

O10.8-4 Assuring the continued presence of compressive stresses in A-286 bolts should be part of their acceptance and qualification procedures.

International Space Station (ISS) Corollary: Determine whether materials issues exist for ISS and their resolution. Determine whether galvanic coupling exists and requires mitigation and whether Room Temperature Vulcanizing (RTV) 560 or Koropon are used on ISS.

Note: The ISS response to Observation O10.8 was approved by the ISS Vehicle Control Board (VCB) on September 13, 2004. All future surveillance is the responsibility of the VCB for ongoing management.

BACKGROUND

The ISS Program reviews all materials used in the construction of ISS hardware during the design review process and maintains continual review as changes are identified and implemented. Material design standards, requirements, and verification processes were and remain in effect for all ISS hardware. Materials and processes technical issues have been actively managed through the ISS Materials and Processes Team since the inception of the Program.

ISS requirements on this subject are contained in MSFC-SPEC-250, *Protective Finishes For Space Vehicle Structures and Associated Flight Equipment, General Specification* (which is being converted to an Agency standard). This specification is a sub-tier document to SSP 30233, *Space Station Requirements for Materials and Processes*.

The ISS Program originally used MSFC-STD-522 to control stress-corrosion cracking. This document has been replaced by MSFC-STD-3029, which is being converted to an Agency standard.

ISS PROGRAM IMPLEMENTATION

The ISS Program Materials and Processes (M&P) organization assessed these *Columbia* Accident Investigation Board (CAIB) observations for potential present and future hazards. The issues with the use of Teflon and molybdenum disulfide in the carrier panel bolt assembly and the brittle failure of A-286 bolts are unique to the Shuttle Orbiter vehicle configuration and the high temperatures during entry.

ISS M&P requirements have always identified galvanic couples between aluminum and steel alloys as a requirements violation. However, the use of steel fasteners in aluminum structure is commonplace. ISS Program standard practice, where this occurs, is wet installation with the use of Koropon primer to fill and seal any gaps between the aluminum and steel surfaces and to prevent moisture from coming into contact with the surfaces. The same practice is used widely in the commercial and military aerospace industry and completely eliminates any risk of corrosion degradation of the aluminum structure. A few specific cases where wet installation did not occur have been approved by the ISS M&P organization, with the specific rationales documented in materials usage agreements. Although the galvanic couple voltage is unacceptable, corrosion of aluminum in contact with steel fasteners is kinetically very slow, making some noncritical applications acceptable in a benign environment.

The CAIB found that primers and sealants such as RTV 560 silicone and Koropon chromated epoxy primer may accelerate corrosion, particularly in tight crevices, and observed that the use of RTV 560 and Koropon should be reviewed. The ISS Program uses Koropon extensively as a means of preventing corrosion by wet installation (as was mentioned above for stainless-steel fasteners in aluminum structure) and considers that the use of Koropon for sealing, in a proper wet installation, reliably prevents corrosion. When used improperly, these sealants may accelerate corrosion; however, ISS M&P has ensured that such applications are not permitted.

Some designers try to avoid full wet installation because of its permanent nature. Instead, they propose a "fillet seal" in which a seal of RTV or Koropon is placed around the edge of the mating surfaces to prevent moisture intrusion and preclude corrosion. Unfortunately, the fillet seal has to be absolutely perfect or it can be counterproductive – a tiny pinhole in the fillet will have the effect of wicking moisture into the unprotected contact surface and retaining it .The resultant corrosion is significantly worse than it would be with no seal at all. The ISS Program does not allow the fillet seal approach for any application. In all cases, the ISS M&P has required full wet installation, which precludes this problem. Fillet seals have been proposed several times and have always been rejected. Recent issues regarding proposals for Node 3 fillet seal bonding have been resolved to now use wet installation and nickel plating.

An issue that has received visibility is the use of RTV to bond thermal protection system tiles and blankets over damaged Koropon without first repairing the Koropon. The ISS Program does not have a directly equivalent practice, but would not hesitate to use similar procedures if necessary. The use of a Koropon-type chromated epoxy primer is always the first choice in ISS design. Since repairing damaged primer is a difficult operation with some risks to the hardware and uncertain adhesion, the ISS Program considers the application of RTV over damaged Koropon to be a safe option for repair in many situations. The ISS environment is a relatively benign environment from a corrosion standpoint.

The only use of polyurethane and silicone coatings to prevent weld corrosion was on the Mini-pressurized Logistics Modules (MPLMs). These coatings are perfectly adequate for controlling corrosion in the environments to which the MPLMs are exposed. The ISS Program switched to a conventional chromated epoxy primer for Nodes 2–3 and the Columbus module.

The observation that assuring the continued presence of compressive stresses in A-286 bolts should be part of their acceptance and qualification procedures resulted from concerns that the brittle fractures on some Shuttle leading edge carrier panel bolts were caused by stress corrosion. A-286 is susceptible to stress corrosion at elevated temperatures, but numerous tests and a long experience base have shown that it is not susceptible to stress corrosion at ambient temperature. The brittle fractures observed on the *Columbia* fasteners were caused by grain boundary embrittlement at temperatures approaching 2000ºF and above, possibly exacerbated by liquid metal embrittlement from vaporized aluminum. They were not caused by stress corrosion.

Ensuring the presence of compressive stresses in fasteners fabricated from a stress-corrosion-sensitive alloy will assist in mitigating stress corrosion. However, ISS Program standard practice is to select materials for such applications that are not stress-corrosion sensitive. When stress-corrosion-sensitive materials are used (generally not in fastener applications), a materials usage agreement is processed that includes a stress analysis to demonstrate that the tensile stresses imposed on the material in use (including residual stresses from manufacturing) are below the threshold for stress corrosion. ISS requirements on this subject are contained in MSFC-SPEC-522, *Design Criteria for Controlling Stress Corrosion Cracking*, a sub-tier document to SSSP 30233, *Space Station Requirements for Materials and Processes*.

STATUS

The ISS Program completed its review of the M&P used in ISS construction, including a review of specific materials identified by the CAIB. No issues were found.

FORWARD WORK

M&P will continue to be vigilant in ensuring that proper practices are followed for corrosion prevention, especially when potential galvanic couples cannot be avoided.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Ongoing	Surveillance of all M&P issues

Columbia Accident Investigation Board

Observation 10.9-1

NASA should consider a redesign of the system, such as adding a cross-strapping cable, or conduct advanced testing for intermittent failure.

International Space Station (ISS) Corollary: Assess the safety of ISS-related pyrotechnic systems.

Note: The ISS response to Columbia Accident Investigation Board Observation O10.9-1 was approved by the ISS Program in January 2005. Ongoing management of this subject is the responsibility of the Vehicle Control Board and the Safety Review Panel.

BACKGROUND

The ISS Program assessment focuses on the continued implementation of proper requirements, analysis, testing, and operations of safety-critical pyrotechnic systems. For such systems, the ISS Program's risk control philosophy calls for design to minimum risk. This means that associated risks are controlled by adherence to formal detailed design and test characteristics rather than only relying upon general fault tolerance criteria.

Top-level programmatic documents such as SSP-41162 (U.S. Segment Specification) ensure that all relevant requirements are imposed upon ISS hardware suppliers. For example, all domestic pyrotechnic devices and circuits are designed and tested to meet the established requirements stated in NSTS-08060 (Space Shuttle System Pyrotechnic Specification). Firing circuit designs must satisfy MIL-STD-1576 (Electro-explosive Subsystem Safety Requirements and Test Methods for Space Systems). Designs typically include several levels of "inhibits" to physically interrupt power from premature pyrotechnic initiation. The ISS Program prohibits cross-strapping of pyrotechnic electrical firing lines for safety, reliability, and fault tolerance reasons. To ensure reliability and safety, NASA standard initiators are provided as government-furnished equipment for the U.S. segment of the ISS vehicle.

Once these pyrotechnic systems reach orbit, additional operational controls are applied to ensure that they are fired at the appropriate time. In many cases, pyrotechnics are only used as backup release devices in the event that primary mechanisms cannot disengage (e.g., ISS-Orbiter docking system latches). In the event of an off-nominal situation where both primary mechanisms and pyrotechnic redundancy fails, manual intervention techniques exist to ensure safe override (e.g., in-cabin electrical bypass and external releasable bolts for the Orbiter docking system). Flight rules, crew procedures, crew training, and software inhibits help ensure the proper implementation of these operational controls.

ISS PROGRAM IMPLEMENTATION

The ISS relies upon pyrotechnics in six different applications:

- NASA solar array and radiator panel launch restraints
- Shuttle, Soyuz, Progress, and Automated Transfer Vehicle docking systems
- Soyuz re-entry systems (e.g., crew module separation)
- Functional Cargo Block (FGB) and Service Module solar array and antenna launch restraints
- FGB and Service Module propulsion systems (e.g., fuel isolation)
- Solid fuel oxygen generators

Failure of an ISS pyrotechnic component, in each application, is mitigated by design standards, testing, redundancy, and operational controls for these critical functions. In many cases, ISS pyrotechnics actuation is only necessary for mission success (e.g., antenna deployment). In these situations, the only immediate hazard that must be prevented is avoiding the close proximity of extravehicular crewmembers during actuation (one-foot keep-out zone). On-orbit launch restraint pyros have already been fired and are no longer of concern. None of the unfired Service Module propulsion system pyrotechnics are of concern to safety. In all cases, formal hazard reports exist that address NASA and Russian pyrotechnic systems. Although the International Partners are responsible for the safety of their spacecraft, their hazard report documentation is reviewed and approved by NASA-led safety review panels with International Partner participation.

As an example of hazard determination and mitigation, NASA's thermal radiator launch restraints use standard pyrotechnics as part of a radiator cinch mechanism squib firing unit (SFU). For this design, there is a noncompliance report (NCR) for the SFU (NCR-PG1-032) that addresses a violation to MIL-STD–1576. Operational controls are used to mitigate the risk of electrical heaters sharing the same power circuit as the SFUs.

STATUS

A recent concern was raised related to ISS pyrotechnics. It involves the systems used for Russian docking separation and, because these pyrotechnics are used by other ISS cargo and crew vehicles (including backup release of the Shuttle docking mechanism), the impacts and resolution were closely tracked. In September 2004, during ground testing of the Soyuz 9S vehicle at the Baikonur launch site, a single pyrotechnic actuator for a docking separation spring fired prematurely. It was determined that this failure was unique to ground facilities and the associated test panel was modified with additional means to eliminate static electric charges. For additional reliability of this specific vehicle, the complete docking assembly was replaced and retested. The pyrotechnic cartridge testing procedures were also modified to reduce current surges during checkout. While these measures ensured that all subsequent Soyuz operations have been nominal, an additional review of the ISS docking system used by Shuttle is planned. Since similar pyrotechnics are used for contingency release of the Orbiter's docking system from ISS, any possible lessons from this failure are planned to be reviewed at the Joint Program Requirements Control Board (chaired by both managers of the ISS and Shuttle Programs).

Given the above discussion, existing ISS pyrotechnic designs and applications are well understood. Recent issues with ground test equipment have been fully addressed. Though not likely to be an issue, any possible impacts to the ISS docking mechanisms used by the Shuttle will be properly considered. For all other ISS pyrotechnics, no new risks have been identified that are not already adequately mitigated.

FORWARD WORK

Continued diligence in the use of existing design and operational controls.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
Joint Program Requirements Control Board	Early 2005	Review impacts of recent Soyuz pyrotechnic issue upon Shuttle contingency release from ISS
ISS Program	Ongoing	Use of existing design and operational controls to assure pyrotechnic system safety

Columbia Accident Investigation Board

Observation 10.10-1

NASA should reinstate a safety factor of 1.4 for the Attachment Rings—which invalids the use of ring serial numbers 16 and 15 in their present state—and replace all deficient material in the Attachment Rings.

International Space Station (ISS) Corollary: Assess the adequacy of ISS processes and products that ensure that factors of safety are maintained throughout the life cycle.

Note: The ISS response to Observation O10.10-1 was approved by the ISS Vehicle Control Board (VCB) on September 27, 2004. All actions related to assuring implementation were closed and responsibility for continuous improvement was assigned to the VCB for ongoing management.

BACKGROUND

The underlying intent of this observation is addressed in Part 2.1, ISS Continuous Improvement Actions 1, 2, 3, 4, and 7. While the ISS Program does not use this specific hardware, it does closely manage the design and operational safety margins of its systems and components.

ISS PROGRAM IMPLEMENTATION

The ISS Program implemented an extensive design review and test and verification process on its hardware to ensure that requirements are documented, tracked, and verified through the hardware's design, development, and delivery to NASA. Requirements and their verifications on contractor-furnished hardware are tracked through extensive Verification Logic Networks and Verification Closure Notices, which are negotiated and reviewed by the system technical experts through tightly controlled processes. Through standard practices, all designs are reviewed and approved by both NASA engineering and safety and mission assurance personnel to ensure that the appropriate design and safety factors are used by the contractor with documented results. The accepted processes for documenting deviations from the requirements, acceptance of a requirement's noncompliance, or identification of a design safety issue are through the Program's waivers, deviations, and exceptions, Nonconformance Reports (NCRs), Failure Modes and Effects Analyses/Critical Items Lists (FMEA/CILs), and Hazard Reports.

STATUS

The ISS Program continually strives to improve its processes for identifying, assessing, and mitigating the risks of its hardware. It uses operational scenarios as well as newly acquired knowledge of the on-orbit ISS environment and the existing condition of the on-orbit vehicle. After the *Columbia* accident, the Program initiated several activities to ensure that the design and risks are assessed periodically. The ISS Continuous Improvement activities related to these activities are as follows:

Continuous Improvement Action ISS-1

As part of ISS Continuous Improvement Action ISS-1, all Program waivers, deviations, and exceptions (over 700 in all) were assessed to determine whether the Program risk posture had changed due to insight from *Columbia*, as an aggregate risk, or by revised understanding of the existing on-orbit environment. During that review, no waivers, exceptions, or deviations were discovered in which the Program inadvertently accepted hardware whose design did not maintain the appropriate factor of safety. In addition to the technical assessment of the waivers, deviations, and exceptions, the JSC Safety and Mission Assurance organization independently reviewed the documentation and developed the same conclusion.

Continuous Improvement Action ISS-2

As part of ISS Continuous Improvement Action ISS-2, the ISS Safety Review Panel conducted a review of the NCRs that carried the greatest amount of Program risk and were affected by anomalous performance. For example, NCRs addressing the control of touch temperatures were not re-assessed because the associated risks are well managed with operational controls. On-orbit anomalies with safety implications were reviewed to see whether they had any impact on NCRs. The results of the review identified a few areas where the Program can improve their risk posture, most notably in the External Active Thermal Control System area. Appropriate remedial actions are under way.

Continuous Improvement Action ISS-3

Continuous Improvement Action ISS-3 addressed the need for possible improvement of the ISS Certification of Flight Readiness (CoFR) process. The process was changed to increase focus on the risks associated with new operations and hardware. This action provided another review of the hardware and the risks related to operating the hardware. In the past, when the hardware was accepted, the operational scenarios were not fully developed. To ensure that operational scenarios don't introduce new risk to the hardware or personnel, the CoFR process was improved to add specific identification and review of potential risk with new hardware. The Mission Integration and Operations Office is responsible for addressing and implementing the results of the CoFR process studies. In addition, the Vehicle Office, the Avionics and Software Office, and the Safety and Mission Assurance Office have adopted new processes for the review of all open nonconformances to ensure that there are no outstanding issues with the hardware prior to increment and flight readiness assessments.

Continuous Improvement Action ISS-4

The ISS Program Reliability and Maintainability Panel review is revalidating all ISS-critical items for accuracy and consistency with current use and environment, reassessing the retention rationale associated with each critical item, and capturing any new on-orbit or ground processing experience that may impact the retention rationale. The team is using the review to update the existing FMEA/CILs and is having any changes reviewed by the systems teams. Any changes to the CILs will be presented to the S&MA Panel and the Space Station Program Control Board.

Continuous Improvement Action ISS-7

A major objective of the Certification Baseline activity is to consolidate the specifications and as-tested data on all Orbital Replacement Units at the subsystems and systems level. This activity is currently under way under Change Request 7938. The intent of this change is to provide a resource tool to the system and operational teams so that the hardware capabilities and limitations are clearly defined and accessible. In addition, it provides a way to document any limit expansions that the Program grants on the system hardware. The Baseline is approximately 30 percent complete and is scheduled for completion in fiscal year 2005. Following *Columbia*, an extensive activity was conducted to identify preventive maintenance requirements for the hardware. Through this activity, the Program established on-ground preventive maintenance requirements for spare hardware and assessed the need for performing some type of testing or maintenance for the hardware integrated on the elements. The Program has initiated activities for items that have been identified as requiring action.

FORWARD WORK

The ISS Program continues to ensure that it is correctly assessing the risk posture of continued ISS operations, especially during the Shuttle stand-down. The ISS Program has taken steps to (1) understand the assumed risks, (2) assess the existing hardware risks, (3) improve the current understanding of the design baseline and its capabilities, and (4) understand how current operational flight scenarios and environmental conditions impact the hardware design and capabilities. The Program has improved the processes by which these data are reviewed and flight and increment readiness is assessed.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Ongoing	Continue to implement and improve risk assessment processes

Columbia Accident Investigation Board

Observation 10.11-1

Assess NASA and contractor equipment to determine if an upgrade will provide the reliability and accuracy needed to maintain the Shuttle through 2020. Plan an aggressive certification program for replaced items so that new equipment can be put into operation as soon as possible.

International Space Station (ISS) Corollary: Assess ISS ground test equipment at the Kennedy Space Center (ISC) to determine whether upgrades are needed to ensure the reliability and accuracy needed for long-term hardware testing processing purposes. Assess the ISS certification program for test equipment to ensure that new equipment can be operational as soon as possible.

Note: The ISS response to this Columbia Accident Investigation Board Observation was approved by the ISS Support Equipment Control Board (SECB) on February 3, 2005. The SECB will track implementation of ongoing continuous improvements. Individual owners of continuous improvements are responsible for ensuring their improvement implementation.

BACKGROUND

The ISS/Payloads Processing Directorate at KSC uses NASA and contractor equipment that is similar in function to that of the Space Shuttle Program. In general, the ISS ground systems and equipment are less than seven years old. In addition to certified ground support equipment (GSE), the ISS uses factory equipment (FE) developed throughout the Program for use in the factory environment and with appropriate approvals for limited use at KSC. Minimal new GSE is in development at KSC for future ISS missions.

KSC-designed ISS Program GSE is certified to satisfy SSP 50004, Program Ground Support Equipment Design Requirements, through a Design Certification Review process and includes periodic maintenance requirements. For additional information on equipment certification limits, see ISS Continuous Improvement Action ISS-7. KSC maintains historical records of these GSE certifications. ISS Program contractors, International Partners, International Participants, and Payload activities conducted at KSC are reviewed and approved by the Ground Safety Review Panel (GSRP). The GSRP is an ISS Program-level board at KSC that approves these activities prior to commencing ground processing to assure safety. This process includes assessing the safety of support equipment, including FE, design, and use. FE is limited for use with specific flight hardware. At KSC any deviation from the originally intended use is reviewed and approved by an ISS Program-level board, the SECB, and the GSRP. Historical records of GSRP and SECB decisions are maintained.

ISS electronic ground systems, equipment, and simulators at KSC are predominately digital technology. Electronic test equipment and computer hardware/ software used for ISS and payloads are updated and maintained in operational condition. Verification is performed prior to use to ensure that the test equipment is properly calibrated and meets the accuracy specifications of the hardware processing work documentation. Calibration is planned, tracked, and managed through the Repeatable Maintenance Recall System. The KSC calibration system includes historical equipment calibration records.

An extensive array of state-of-the-art nondestructive evaluation (NDE) and troubleshooting equipment is available to the KSC checkout, assembly, and payload processing services contractor, NASA engineering, and KSC institutional services. American Society of Nondestructive Testing certified inspectors are available for test and interpretation. The KSC NDE Working Group shares experience, knowledge, and equipment between the ISS and Space Shuttle Programs.

Johnson Space Center and Marshall Space Flight Center designed, developed, and sustained ISS support equipment (hardware and software) is governed by SSP 50004, Ground Support Equipment (GSE) Design Requirements. Implementation of this document consolidates the requirements under which the GSE will be designed and satisfies ISS Program requirements for support equipment. This top-level instruction covers analyses, design, and fabrication of the GSE for the full life cycle. This document is controlled by the Space

Station Control Board, and any changes or revisions are approved by the Program Manager.

ISS PROGRAM IMPLEMENTATION

GSE is certified for use and controls are in place to modify or develop new pieces of equipment. Noncertified FE requires ISS SECB approval prior to use at KSC. The SECB also approves requirements, implementation plans, and support equipment deviations and waivers.

Payload Processing Checkout Systems, classified as GSE, have planned obsolescence and replacement strategies in the existing budget baseline. KSC monitors flight hardware and software upgrades and modifies respective ground simulators to emulate on-orbit functional performance. Additionally, existing custom-built systems are being phased out and upgraded to commercial off-the-shelf distributed networks-based hardware and software systems.

ISS FE outside the factory environment is not sustained and maintained uniformly. To mitigate the risk of diverse sustaining methods that do not meet ISS Program requirements, the SECB evaluates and approves FE maintenance and sustaining processes proposed by the users prior to use at KSC. Any FE upgrades and changes that affect form, fit, and function are reviewed and approved by the SECB prior to use at KSC.

Prior to conducting formal operations involving ISS assets, KSC performs Test Readiness Reviews (TRRs) per ISS Program Directive ISSP-JPD-304, Standards and Guidelines for the Conduct of ISS Test Readiness Reviews. TRRs conducted by KSC assess the readiness of the GSE to support each operation. This includes verifying that: the GSE is certified; GSE (hardware and software) configuration and design details are defined and controlled, and changes made since last use are reviewed; fixtures that carry loads or support flight or qualification hardware have acceptable margins of safety for all planned loading conditions; proof-load certifications are current; and GSE used to accomplish a go/no-go check or dimensional verification has current calibration certification.

STATUS

The use of digital technology and the appropriate sustaining and maintenance tasks in ISS ground systems has reduced the need for upgrades and provided the reliability and accuracy needed for long-term testing processing purposes.

ISS maintenance and calibration of existing equipment is managed to ensure readiness for use on flight hardware. Obsolescence upgrades have been planned and included in budget projections. Other enhancements are referenced in ISS Continuous Improvement Action ISS-8.

GSE is approved for use at KSC through a Design Certification Process. FE is approved for use at KSC by the SECB and the GSRP. These certification and approval processes are appropriate to assure that new and ISS provided equipment are operable as soon as possible.

Prior to the conduct of formal operations involving ISS assets, KSC performs a TRR. TRRs include verifying GSE readiness (certification, maintenance, calibration, proof-load, proof-pressure, etc) to support the operation.

FORWARD WORK

The ISS Program will continue monitoring flight hardware and software modifications for ground system applicability. The ISS Program and KSC will execute and approve modifications, replace obsolete equipment, and continue development of new GSE for future ISS missions.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
KSC ISS/ Payload Processing Directorate	Apr 04 (Complete)	Assess ISS support equipment to determine whether it provides needed reliability and accuracy
KSC ISS/ Payload Processing Directorate	Aug 04 (Complete)	Assess ISS support equipment certification program to assure it puts reliable accurate replacement equipment into operation as soon as possible
ISS Program and support centers	Ongoing	Continual improvement assessment as part of normal management

Columbia Accident Investigation Board

Observation 10.12-1

NASA should implement an Agency-wide strategy for leadership and management training that provides a more consistent and integrated approach to career development. This strategy should identify the management and leadership skills, abilities, and experiences required for each level of advancement. NASA should continue to expand its leadership development partnerships with the Department of Defense and other external organizations.

International Space Station (ISS) Corollary: Review the ISS professional development and training strategy to ensure that leadership skills are identified and enhanced through an organized, planned program.

Note: The ISS response to Columbia Accident Investigation Board (CAIB) Observation O10.2-1 was presented to the ISS Program Manager on September 23, 2004. Forward actions will be tracked by the ISS External Relations Office and periodically briefed to ISS management staff.

BACKGROUND

The CAIB found that NASA has a wide range of training and education programs to prepare its personnel for roles of increased responsibility, but the timing and strategy for leadership and management development varied widely across NASA.

ISS PROGRAM IMPLEMENTATION

The ISS Program recognizes the need for an improved career development program for its personnel. While supporting training provided at the Agency, center, and Program level, it is recognized that future managers should also be versed in techniques developed elsewhere; i.e., other government agencies and non-governmental entities.

Agency Level

NASA, in recognizing that its most critical asset is the excellence of its personnel, has recently established a Human Capital Plan (http://nasapeople.nasa.gov/hcm) to ensure that it executes an integrated, systematic, Agency-wide approach to management of the “One NASA” workforce.

The Diaz Team Report (“A Renewed Commitment to Excellence”) defined seven leadership actions for implementation. NASA Headquarters is in the process of assigning the actions to respective activities within NASA centers and programs, including the ISS. Follow-up audits and surveys will ensure that the recommendations for improvement are being implemented.

The NASA Training and Development Division offers a wide curriculum of leadership development programs. The content of the internally sponsored programs is based on the NASA leadership model, which delineates six leadership competencies at four different levels. The four levels are executive leader, senior leader, manager/supervisor, and influence leader. Each level contains distinct core competencies along with suggested curricula. NASA also develops leadership skills in the workforce by taking advantage of training and development opportunities at the Office of Personnel Management, Federal Executive Institute, Brookings Institute, and the Center for Creative Leadership, among other resources. In addition, the Agency sponsors leadership development opportunities through academic fellowships in executive leadership and management as well as through the NASA-wide Leadership Development Program. More information on this program can be found at http://leadership.nasa.gov/nasa/lmd/home.htm.

The CAIB Observation is the inspiration to the One NASA Strategy for Leadership and Career Development; i.e., for the Agency to develop a more integrated strategy to identify the management and leadership skills, abilities, and experiences necessary for advancement through various leadership roles. The strategy was formed by data gathered from a process of meetings and benchmarking. It presents an overall competency-based framework and approach for leadership development at NASA, outlining leadership roles and core and elective experiences and training.

The underpinnings of the strategy are (1) the NASA Values – safety, the NASA family, excellence, and integrity; and (2) the NASA Leadership Model with its six performance dimensions that define the competencies, knowledge, skills, and abilities necessary for demonstrating excellence in various leadership roles.

The strategy includes a framework that is intended to provide a consistent and integrated approach to leadership and management career development. Each leadership role within the framework contains components that are designed to enable employees to achieve and demonstrate the NASA values along with the identified competencies for that role. Common elements in each role include:

- Core experiences and broadening opportunities including mobility – intellectual as well as geographical.
- Core and optional courses relevant to both achieving mastery in the role as well as preparing for the next step.
- Required role-specific courses on safety and diversity.
- Assessments – analysis of feedback from subordinates, supervisors, customers, peers, and stakeholders.
- Continuing education.
- Individual Development Plans.
- Coaching and mentoring.

As adopted in October 2004, this strategy provides the first step towards a more consistent and integrated approach towards leadership and career development, as it will give NASA employees a framework within which they can plan their NASA careers. The subsequent implementation plan will ensure that all Agency leadership development programs (Agency, center, and Program) are in alignment with the strategy.

Center Level

In addition to the Agency training programs, all NASA centers offer locally sponsored leadership development programs for their first-level and/or mid-level managers and supervisors; these programs are unique to the needs of each center. For example, the Johnson Space Center (JSC) created the JSC Leadership Development Program (JSCLDP) (http://leadership.jsc.nasa.gov/). JSCLDP uses the JSC Leadership Model, a model that incorporates the views of JSC leaders regarding the characteristics and behaviors that are important for effective leadership at JSC, where the primary responsibility is human space flight. The inaugural class for the JSCLDP was selected in spring 2002 and graduated in 2004. The program is designed as a one- to two-year program to develop JSC leaders. The inaugural class included five ISS Program Office leaders out of the 25 selected into the program.

Program Level

Partly in response to the CAIB observations and the subsequent Diaz Team Report, the ISS Program at JSC developed a Professional Development Program (PDP) to more consistently and effectively identify and develop future leaders. Another goal is to ensure that the ISS Program acquires knowledge and skills through sharing experiences and expertise gained from within the Program; i.e., that ISS is truly a Learning Program. The PDP consists of two elements: a training matrix and a shadowing approach.

The training matrix, shown in figure O10.12-1, is intended to supplement the specific technical training and skills enhancement classes specified by each ISS organization in their individual training plans. It includes a recommended core curriculum and an elective curriculum tailored to the individual employee's particular career path. The core curriculum takes advantage of existing training classes, although the ISS Program has recently identified the need for new courses covering the strategic context (political, economic, etc.) of the ISS Program within the Agency, the U.S. government, and the world, as well as the need for courses that will ensure that employees learn lessons from past tragedies such as the Apollo 1 fire and the *Challenger* and *Columbia* accidents. These new courses are at the concept stage. The matrix provides consistency and structure to the wealth of existing Agency and Center training resources. This matrix will ensure that all ISS employees understand training priorities to provide a common base for professional development.

Recognizing that training classes should be complemented by appropriate practical experience, the ISS Professional Development Program also encompasses a shadowing program. This allows individuals who have been identified by ISS management as emerging leaders to gain a wide variety of real work experiences by observing ISS managers in day-to-day management situations. Employees will learn how to adapt their management style to different situations and to achieve their full managerial potential.

	Technical/Project Mgmt	Safety/Quality	Communication/ Culture	Business Mgmt/Policy	Leadership
Level 0 SES and Aspiring Executives	**Level 1 courses not completed** **Program Management (HQ APPL)** *Potential program: JSC Mentoring Program*	**Level 1 courses not completed** **Interagency or Industry course (Special Request)**	**Level 1 courses not completed** **Media Training (JSC)** **Public Speaking as Two Way Dialogue (JSC)** **Interagency or Industry course (Special Request**	**Level 1 courses not completed** **National Space Policy and NASA Strategic Plan (TBD)** **OPM policies and emerging trends (OPM)** **Congressional Ops (Gov. Affairs Institute)** **Inside Congress or Inside Washington (Brookings Institute)**	**Level 1 courses not completed** **OPM Executive Seminars and/or University Executive Education Programs** **SES Leadership Program (HQ LMD)** **Development Program for Deputies (TBD HQ LMD)** **Executive Mentoring/Coaching: Protocol, interaction with dignitaries, political interactions** *Potential programs: Senior Executive Service Candidate Development Program (SESCDP)*
Level 1 Supervisory and/or GS-15	**Level 2 courses not completed** **Advanced Project Management (HQ APPL)** **Time Effective Meetings (JSC)** *Potential program: JSC Mentoring Program*	**DuPont Safety Seminar (JSC)** **Senior Managers Safety Seminar (JSC)** **Root Cause Analysis (JSC)** **Required Annual Training**	**Level 2 courses not completed** **The Human Element (HQ LMD)** **Communication Skills for the Technical Professional (JSC)** **Advanced Computer Skills (JSC)**	**Level 2 courses not completed** **Strategic Business Mgmt (HQ LMD)** **Business Education Program (HQ LMD)** **Appropriations Law Seminar (JSC)**	**Level 2 courses not completed** **Human Resource Management for the JSC Supervisor (JSC)** **Developing People (JSC)** **Conducting a Collaborative Performance Review (JSC)** **SIL for Leads and/or SIM for Supervisors (JSC by special call)** **MIP (Leads) or Management Education Program (MEP) (Supervisors) (HQ LMD)** *Potential programs: JSC LDP, NASA LDP, and NASA*
Level 2A AST GS-12/14	**Level 3 courses not completed** **Project Management (HQ APPL)** **International Project Management (HQ APPL)** **Requirements Writing (JSC Special Call)** **Space Launch and Transportation Systems (HQ NET)** **Human Space Flight and Mission Analysis and Design (JSC)** **Human Exploration and Development of Space (HQ NET)** **System Management (HQ APPL)** *Potential program: JSC Fellowship, JSC Mentoring*	**STEP - Safety Through Everyone's Participation (JSC)** **Required Annual Training**	**Level 3 courses not completed** **Dynamics of Daily Negotiations (JSC)** **Communication Skills for the Technical Professional (JSC)** **Cross Cultural Training (JSC)** **Powerful Presentations (JSC)**	**Level 3 courses not completed** **Procurement Process (JSC)** **C.O.T.R. (JSC) - if required** **Source Evaluation Board (JSC) - if required** **Export Control (JSC) - if required**	**Level 3 courses not completed** **Assessing Your Leadership Skills (JSC)** **Challenges Facing the Technical Leader (JSC)** **Crossroads (JSC)** **Conflict Management for Supervisors/Leads (JSC)** **SIL for Leads (JSC by special call)** **MIP (HQ LMD)** *Potential programs: NASA Leadership Development Program (NASA LDP), International Space University (ISU), NASA Administrator's Fellowship Program (NAFP)*

Figure O10.12-1. ISS Program Career Training Matrix

	Technical/Project Mgmt	Safety/Quality	Communication/ Culture	Business Mgmt/Policy	Leadership
Level 2B Non-AST GS-12/14	**Level 3 courses not completed** **Project Management (HQ APPL)** **International Project Management (HQ APPL)** **Human Space Flight and Mission Analysis and Design (JSC)** **Requirements Writing (JSC Special Call)** *Potential program: JSC Fellowship, JSC Mentoring Program*	**STEP - Safety Through Everyone's Participation (JSC) Required Annual Training**	**Level 3 courses not completed** **Dynamics of Daily Negotiations (JSC)** **Cross Cultural Training (JSC)** **Powerful Presentations (JSC)**	**Level 3 courses not completed** **Procurement Process (JSC)** **C.O.T.R. (JSC) - if required** **Source Evaluation Board (JSC) - if required** **Export Control (JSC) - if required**	**Level 3 courses not completed** **Assessing Your Leadership Skills (JSC)** **Crossroads (JSC)** **Conflict Management for Supervisors/Leads (JSC)** **Seminar in Leadership (SIL) for Leads (JSC by special call)** **Managing the Influence Process (MIP) (HQ LMD) for Leads** *Potential programs: NASA Leadership Development Program (NASA LDP), International Space University (ISU), NASA Administrator's Fellowship Program (NAFP)*
Level 3 Non-degreed and/or GS-9/12	**Phase I International Space Station (TBD)** **Art of Project Management (JSC)** **Understanding Space Seminar (JSC)** **Time Management (JSC)** University courses for credit *Potential programs: Project Increased Qualification (Project IQ), JSC Mentoring Program*	**STEP - Safety Through Everyone's Participation (JSC) Required Annual Training**	**Effective Presentation Skills (JSC)** **Writing that Works (JSC)** **Writing Effective Emails (JSC)** **Computer Skills (JSC)** **Seeing the Glass Half Full (JSC)** **StarCare (JSC)**	**Federal Budget Process (JSC)** **Funding Process (JSC)** **Purchase Request (PR) Process (JSC)**	**Influencing Others: The Leader's Toolkit (JSC)** **Crossing Department Lines (JSC)** **Situational Leadership (JSC)** **Assessing Your Leadership Skills (JSC)**
Level 4 Secretarial Support	**Phase I International Space Station (TBD)** **Building Blocks (TBD)** **Computer Skills (JSC)** *Potential programs: Project Increased Qualification (Project IQ), JSC Mentoring Program*	**STEP - Safety Through Everyone's Participation (JSC) Required Annual Training**	**Successful Communication for the Professional Secretary (JSC)** **Seeing the Glass Half Full (JSC)** **Ego Boosters vs. Ego Busters: Motivating Others Through Words and Actions (JSC)** **StarCare (JSC)**	**Federal Budget Process (JSC)** **ISS Travel orders process** **ISS Correspondence process**	**The Secretarial Leadership Development Workshop (JSC)**
Link to Courses:	https://training-registration.jsc.nasa.gov/TRS_Course_Catalog.cfm			Additional acronym explanation	HQ APPL: HQ Academy of Program and Project Leadership HQ LMD: HQ Leadership and Management Development

Figure O10.12-1. ISS Program Career Training Matrix (Continued)

The ISS Professional Development Program was communicated to the ISS workforce through a memorandum. Each department was directed to use the training matrix to develop each employee's individual training plan in the context of the annual performance planning and appraisal process.

In the interest of fully developing NASA's human capital, it is clear that employee morale is a critical component of a productive workforce. The ISS Program has taken steps to institute a more proactive and thoughtful system for awards and recognition by instituting an Awards and Recognition Board to ensure adequate advance thought, discussion, and review of potential candidates for awards and prestigious opportunities such as Agency and Center fellowships.

Finally, the ISS Program is fully supportive of the Agency's efforts to promote cross fertilization across the centers and has sent numerous employees on rotational assignments to other centers with the goal that they will broaden their perspective and bring this experience back to reinvigorate and improve the ISS Program. It is the intent of the ISS Program that every employee, at every center, has a documented training and career development plan, although implementation of this strategy is the responsibility of the host center.

STATUS

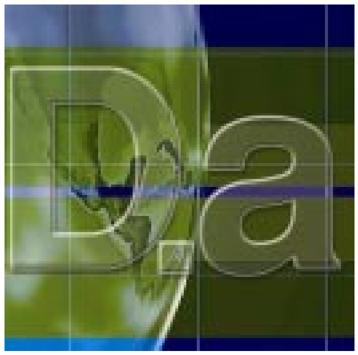
NASA, JSC, and ISS professional development programs are being refined on an ongoing basis. Lessons learned from pilot programs are being turned into improvements that will benefit the ISS Program technically and managerially. Other centers with ISS support personnel have separate training plans/processes and may emulate the JSC/ISS plan as they deem appropriate.

FORWARD WORK

The ISS Program will begin to actively implement the shadowing part of the ISS Professional Development Program and continue working with the NASA HQ Agency Training and Development Division and ISS center training personnel to develop the new courses that do not currently exist. As part of this effort, the ISS Program will also maintain awareness of the Agency's leadership strategy implementation that is being developed in fiscal 2005.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
ISS Program	Oct 03 (Complete)	Initiate Awards and Recognition Board
ISS Program	Jun 04 (Complete)	Complete JSC Leadership Development Program Inaugural Class
ISS Program	Jun 04 (Complete)	Develop/disseminate ISS Professional Development Plan
HQ Office of Human Capital Management	Oct 04 (Complete)	Identify requirements for new courses in compliance with new PDP
ISS Program and JSC Training Office	Ongoing	Identify requirements for new courses in compliance with new Professional Development Plan
ISS Program	Ongoing	Implement/improve ISS personnel training to new Leadership Model



Part 2.3
Appendix D.a

Volume II, Appendix D.a, also know as the "Deal Appendix," augments the Columbia *Accident Investigation Board (CAIB) Report and its condensed list of recommendations. This Appendix outlines concerns raised by Brigadier General Duane Deal and others that, if addressed, might prevent a future accident. The 14 recommendations and three observations contained in this Appendix expand and emphasize CAIB Report discussions of quality assurance processes, corrosion detection methods, factor-of-safety concerns, crew survivability, and ground facility security concerns relating to flight hardware management.*

The ISS Program is addressing each of the recommendations and observations offered in Appendix D.a. Many of these topics have been addressed in our response to the other formal recommendations and observations in Volume I of the CAIB Report and, therefore, our responses refer to the location in the plan where more complete information is found. Although the recommendations and observations are not numbered in Appendix D.a, we have assigned a number to each for tracking purposes.

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Recommendations D.a-1, D.a-2, D.a-6, and D.a-7

Recommendation D.a-1 Review Quality Planning Requirements Document Process

Perform an independently led, bottom-up review of the Kennedy Space Center Quality Planning Requirements Document to address the entire quality assurance program and its administration. This review should include development of a responsive system to add or delete government mandatory inspections. Suggested Government Mandatory Inspection Point (GMIP) additions should be treated by higher review levels as justifying why they should not be added, versus making the lower levels justify why they should be added. Any GMIPs suggested for removal need concurrence of those in the chain of approval, including responsible engineers.

Recommendation D.a-2 Responsive System to Update Government Mandatory Inspection Points

Kennedy Space Center must develop and institutionalize a responsive bottom-up system to add to or subtract from Government Inspections in the future, starting with an annual Quality Planning Requirements Document review to ensure the program reflects the evolving nature of the Shuttle system and mission flow changes. At a minimum, this process should document and consider equally inputs from engineering, technicians, inspectors, analysts, contractors, and Problem Reporting and Corrective Action to adapt the following year's program.

Recommendation D.a-6 Review Mandatory Inspection Document Process at Michoud Assembly Facility

Marshall Space Flight Center should perform an independently-led bottom-up review of the Michoud Quality Planning Requirements Document to address the quality program and its administration. This review should include development of a responsive system to add or delete government mandatory inspections. Suggested Government Mandatory Inspection Point (GMIP) additions should be treated by higher review levels as justifying why they should not be added, versus making the lower levels justify why they should be added. Any GMIPs suggested for removal should need concurrence of those in the chain of approval, including responsible engineers.

Recommendation D.a-7 Responsive System to Update Government Mandatory Inspection Points at the Michoud Assembly Facility

Michoud should develop and institutionalize a responsive bottom-up system to add to or subtract from Government Inspections in the future, starting with an annual Quality Planning Requirements Document review to ensure the program reflects the evolving nature of the Shuttle system and mission flow changes. Defense Contract Management Agency manpower at Michoud should be refined as an outcome of the QPRD review.

International Space Station (ISS) Corollary: Review the Quality Planning and Government Mandatory Inspection Point processes at Kennedy Space Center as applicable to ISS.

The ISS Program response to this subject is addressed in Part 2.2, Observation O10.4-1, of this Implementation Plan. The response does not address the implications related to the Michoud Assembly Facility because Michoud does not process ISS Program hardware.

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Recommendation D.a-3 Statistically Driven Sampling of Contractor Operations

NASA Safety and Mission Assurance should establish a process inspection program to provide a valid evaluation of contractor daily operations, while in process, using statistically-driven sampling. Inspections should include all aspects of production, including training records, worker certification, etc., as well as Foreign Object Damage prevention. NASA should also add all process inspection findings to its tracking programs.

International Space Station (ISS) Corollary: Same as Space Shuttle Program

The ISS Program response to the statistical sampling aspects of this recommendation is addressed in the combined response for Observations O10.5-1 through O10.5-3 in Part 2.2 of this Implementation Plan. The foreign object debris aspects of this recommendation are addressed by Recommendation R4.2-5 in Part 1 of this Implementation Plan. The status of evaluation of contractor training records and worker certification is addressed in Part 2.2, Observation O10.4-3, of this Implementation Plan.

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Recommendation D.a-4 and Observation D.a-15

Recommendation D.a-4 Forecasting and Filling Personnel Vacancies

The Kennedy quality program must emphasize forecasting and filling personnel vacancies with qualified candidates to help reduce overtime and allow inspectors to accomplish their position description requirements (i.e., more than the inspectors performing government inspections only, to include expanding into completing surveillance inspections.)

Observation D.a-15 Quality Assurance Manpower

As an outcome of the Quality Program Requirements Document review, manpower refinements may be warranted (for example, should a substantial change in Government Inspections justify additional personnel, adjust the manpower accordingly). While Board recommendations to evaluate quality requirement documents should drive decisions on additional staffing, in the interim, staffing with qualified people to current civil service position allocations should be expedited.

International Space Station (ISS) Corollary: Same as Space Shuttle Program.

Note: The ISS response to Deal Recommendations D.a-4 and D.a-15 was approved by the Kennedy Space Center (KSC) Center Director and the ISS Safety and Mission Assurance Panel (S&MAP) on January 13, 2005. All actions and responsibilities for ongoing management of these, as well as Observation O10.4-2, were assigned to the S&MAP.

BACKGROUND

The *Columbia* Accident Investigation Board (CAIB) expressed concern regarding staffing levels of Quality Assurance Specialists (QAS) at KSC. Specifically, they stated that staffing processes must be sufficient to select qualified candidates in a timely manner. KSC has processes, used in the past, for hiring and training QAS personnel including a cooperative (co-op) education program that brings in college students as part of their education process. The co-op program is extensive, including formal classroom and on-the-job training.

ISS PROGRAM IMPLEMENTATION

KSC completed a centralization of the Safety and Mission Assurance (S&MA) workforce to meet CAIB Observation O10.4-2 as reported in Part 2.2 of this Implementation Plan. As a part of that process, workforce staffing requirements, personnel qualifications, and position descriptions were assessed and updated. Since the creation of the S&MA organization supporting the ISS Program, personnel additions have brought the ISS/Payload Processing Division to a fully staffed level.

For future growth, the S&MA Directorate proposed to bring the ISS/Payload Processing S&MA Division to a total workforce complement of 57 full-time employees. This would include, as of January 2005, a backfill for the position of Lead, ISS/Payload Ground Safety Engineer, and additional positions for a Reliability Engineer, Quality Assurance Process Analyst, Quality Assurance Specialist, and Trending Analysis Engineer. Two S&MA engineering positions for the new Exploration Program were approved.

The KSC Annual Operating Agreement (AOA), which is an agreement between the S&MA Directorate and the Center Director, documents the levels and types of S&MA services to be provided to KSC Center Organizations in future years. The AOA development process is used to: (1) assure planning for S&MA functions to meet the institutional, Program, and project requirements; (2) establish a basis for the Center-level resource allocations necessary to meet institutional, Program, and project S&MA requirements; and (3) identify metrics used to manage the Center S&MA organizations. The AOA process encourages continuous improvement and closed-loop feedback of S&MA process performance.

In addition to the resources dedicated to the ISS/Payloads Processing Division within the S&MA Directorate, other S&MA resources are available to this division that resulted from the consolidation of the S&MA functions into a single S&MA Directorate. At the directorate level, two GS-15 subject matter expert positions were established to support Reliability Engineering and Quality Engineering across the directorate. A GS-14 Center Range Safety position and the Center Safety Officer/Ombudsman position at the GS-15 level have also been staffed. All of these preceding positions are staffed with full-time permanent employees. Also, a Chief Engineer at the GS-15 level has been created for the S&MA organization.

STATUS

Hiring practices were reviewed and improved. KSC began hiring temporary and term-limited appointments to provide flexibility for short-term staffing issues such as replacements for QAS military reservists who deploy to active duty and instances when permanent hiring authority may not be immediately available. KSC is using a Phased Hiring Plan to staff the S&MA organization.

The results of the Quality Program Requirements Document review are addressed in the ISS response to Observation 10.4-1, which can be found in Section 2.2 in this Implementation Plan. At this time, these results do not indicate any specific need to augment workforce refinements beyond the additions described above.

FORWARD WORK

The ISS support centers will address resource requirements through formal Program change requests, the annual Program Operating Plan (POP) process, and the AOA.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
NASA KSC	May 04 (Complete)	KSC S&MA organization centralized
NASA KSC	May 04 (Complete)	S&MA workforce requirements, qualifications, and position descriptions updated
NASA KSC	Aug 04 (Complete)	S&MA bottom-up review initiated
NASA KSC	Jul 05	Additional S&MA personnel hired per Phased Hiring Plan
ISS support centers	Ongoing	Annual POP process
ISS support centers	Ongoing	AOA process

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Recommendation D.a-5 Quality Assurance Specialty Job Qualifications

Job qualifications for new quality program hires must spell out criteria for applicants, and must be closely screened to ensure the selected applicants have backgrounds that ensure that NASA can conduct the most professional and thorough inspections possible.

International Space Station (ISS) Corollary: Same as Space Shuttle Program.

Note: The ISS response to Deal Recommendation D.a-5 was approved by the ISS Safety and Mission Assurance Panel (S&MAP) on January 13, 2005. All actions related to assuring implementation were closed and responsibility for Program-wide continuous improvement was assigned to the S&MAP.

BACKGROUND

The *Columbia* Accident Investigation Board (CAIB) expressed concern regarding staffing qualifications of Quality Assurance Specialists (QASs) at Kennedy Space Center (KSC).

ISS PROGRAM IMPLEMENTATION

NASA, by law, rule, and regulation, must use the qualifications standards published by the U.S. Office of Personnel Management (OPM) for the GS-1910 QAS in assessing the qualifications of applicants. In addition, selecting officials identify critical selection criteria to assess candidates and ensure they are selecting fully qualified individuals.

NASA currently uses two techniques for selecting and developing qualified QAS. First, NASA can hire a QAS at the GS-7, GS-9, or GS-11 level if the candidate meets a predetermined list of requirements and experience. QAS candidates at all levels require additional training. Candidates selected at lower grades require additional classroom and on-the-job training before being certified as a QAS as described in Observation O10.4-3 in Part 2.2 of this Implementation Plan. Additionally, NASA has a cooperative (co-op) education program that brings in college students as part of their education process. The co-op program is an extensive two-year program, including classroom and on-the-job training. KSC is also pursuing the use of the Federal Career Internship Program to hire Engineering Technology college graduates to staff future QAS positions.

Other related information can be found in the ISS Program responses to Deal items D.a-4, D.a-15, and D.a-17.

STATUS

KSC centralized the Safety and Mission Assurance (S&MA) workforce to meet CAIB recommendations as described in Observation O10.4-2. As a part of that process, workforce staffing requirements, personnel qualifications, and position descriptions were assessed and updated to reflect S&MA workforce improvements described in Observation 10.4-3 and Recommendation D.a-4.

NASA is continuing to hire qualified Quality resources that are capable and competent while satisfying OPM and NASA regulatory requirements. KSC, in support of the ISS Program, has hired three QASs within the past year and has converted a co-op to an entry-level QAS.

All KSC S&MA personnel selections (including new hires and promotions from within the directorate) must be concurred by S&MA senior management. This concurrence must be obtained prior to the KSC Human Resource Office being notified of the selection. All KSC S&MA high-grade (GS-14 and GS-15) supervisory and Group Lead position selections must use a Selection Panel. This panel has at least one individual from outside the Selecting Official's S&MA Division. The Panel membership is approved in advance by S&MA senior management. All KSC selections at the GS-15 level must also be approved by the KSC Center Director.

FORWARD WORK

Although there are no further specific actions regarding this recommendation, enhancing the skills and qualifications of current and new personnel, as addressed in the response to Observation O10.4-3, is a continual improvement process. Future actions will be identified and processed by the appropriate organizations.

SCHEDULE

	Due Date	Activity/Deliverable
NASA KSC	May 04 (Complete)	Centralize KSC S&MA activities
NASA KSC	May 04 (Complete)	S&MA Directorate Business Operating Agreement
NASA KSC	May 04 (Complete)	Revise staffing requirements and qualifications
NASA KSC	Nov 04 (Complete)	S&MA Annual Operating Agreement Fiscal Year 2005
NASA KSC	Ongoing	Continual improvement assessments

Columbia Accident Investigation Board

Recommendation D.a-8 Use of ISO 9000/9001

Kennedy Space Center should examine which areas of ISO 9000/9001 truly apply to a 20-year-old research and development system like the Space Shuttle.

International Space Station (ISS) Corollary: Assess the applicability of ISO 9000/9001 for ISS activities at the three primary ISS support centers.

The ISS Program response to this recommendation is addressed in Part 2.2, Observation O10.4-4, of this Implementation Plan.

Columbia Accident Investigation Board

Recommendation D.a-9 Orbiter Corrosion

Develop non-destructive evaluation inspections to detect and, as necessary, correct hidden corrosion.

International Space Station (ISS) Corollary: Same as Space Shuttle Program.

The ISS Program response to this recommendation is addressed in Part 2.2 of this Implementation Plan, in the combined response to Observations O10.7-1 through O10.7-4.

Columbia Accident Investigation Board

Recommendation D.a-10 Hold-Down Post Cable Anomaly,

NASA should evaluate a redesign of the Hold-Down Post Cable, such as adding a cross-strapping cable or utilizing a laser initiator, and consider advanced testing to prevent intermittent failure.

International Space Station (ISS) Corollary: Assess the safety of ISS-related pyrotechnic systems.

The ISS Program response to this recommendation is addressed in Section 2.2, Observation O10.9-1, of this Implementation Plan.

Columbia Accident Investigation Board

Recommendation D.a-11 Solid Rocket Booster External Tank Attach Ring

NASA must reinstate a safety factor of 1.4 for the Attach Rings – which invalidates the use of ring serial numbers 15 and 16 in their present state – and replace all deficient material in the Attach Rings.

International Space Station (ISS) Corollary: Assess the adequacy of ISS processes and products that ensure that factors of safety are maintained throughout the life cycle of the Station.

As reported in Part 2.2 of this Implementation Plan, Observation O10.10-1, the underlying intent of this recommendation is addressed in Part 2.1, ISS Continuous Improvement Actions ISS-1, ISS-2, ISS-3, ISS-4, and ISS-7.

Columbia Accident Investigation Board

Recommendation D.a-12 Crew Survivability

To enhance the likelihood of crew survivability, NASA must evaluate the feasibility of improvements to protect the crew cabin on existing Orbiters.

International Space Station (ISS) Corollary: Ensure that future vehicle developments use lessons learned from ISS development and operations to enhance crew survivability options.

The ISS Program response to this recommendation is addressed in Part 2.2, Observation O10.2-1, of this Implementation Plan.

Columbia Accident Investigation Board

Recommendations D.a-13 and D.a-14-Security Assessment

Recommendation D.a-13

NASA and ATK Thiokol perform a thorough security assessment of the RSRM segment security, from manufacturing to delivery to Kennedy Space Center, identifying vulnerabilities and identifying remedies for such vulnerabilities.

Recommendation D.a-14

NASA and Lockheed Martin complete an assessment of the Michoud Assembly Facility security, focusing on items to eliminate vulnerabilities in its current stance.

International Space Station (ISS) Corollary: Ensure that ISS processing facilities employ adequate processes and procedures to mitigate security threats.

Note: The ISS response to Deal Recommendations D.a-13 and D.a-14 was dispositioned by NASA Headquarters in November 2004. Implementation of the remaining improvement activities will be ensured by NASA security officials.

BACKGROUND

During security program assessments at the Reusable Solid Rock Motor facility and the Michoud Assembly Facility, the CAIB expressed concerns about several elements of the overall security of flight hardware involving adequacy of staff and surveillance of hardware in storage.

ISS PROGRAM IMPLEMENTATION

Subsequent to the attacks on September 11, 2001, NASA conducted a full security program vulnerability assessment across the Agency, including Kennedy Space Center (KSC), Johnson Space Center (JSC), and Marshall Space Flight Center (MSFC). The assessment addressed security at off-site as well as on-site facilities. As a result of Presidential Directive 63, which was recently superseded by Homeland Security Presidential Directive 7, a Minimal Essential Infrastructure (MEI) plan allocated substantial funding to reinforce the security at NASA centers.

STATUS

Kennedy Space Center

Security controls at KSC are strong and incorporate a series of increasing levels of protection. The first level of security is site perimeter control. Armed guards control all access routes onto KSC, and each individual coming on site must meet rigorous badging requirements and possess a valid badge to gain entry. Foreign national customers, suppliers, and Partners require additional reviews and screening.

Access to individual critical facilities within the center where ISS flight hardware is processed and/or stored is controlled via a physical access control system that only allows access to approved individuals. Fortified barriers and additional closed circuit television (CCTV) capability and other enhancements are in place in the most critical areas.

KSC security personnel inspect all payload hardware delivered to KSC from non-government customers, such as universities, and other hardware delivered for late stowage onto the Space Shuttle as the hardware enters the KSC gates.

Johnson Space Center

JSC also incorporates a comprehensive series of increasing levels of security controls to protect ISS flight hardware and other mission-critical assets at the center. The first level of security includes center site perimeter controls including a variety of methods. There is also an additional set of interior fortified perimeter controls supported by armed guards and CCTV capabilities for highly critical facilities complexes. Access to critical individual facilities, including entry into the mission control building, is via a physical access control system. Entry into the flight control rooms is via another security access control badge reader system. Only persons with approved entry can use their badges to gain entry to this area.

Flight hardware at JSC is protected by same site perimeter control and is stored in locked, caged, bonded storage. Only personnel with signature approval may remove items from bonded storage, and they are responsible for maintaining the items under locked conditions.

Marshall Space Flight Center

At MSFC, a similar set of security controls is in place. Military personnel from the Army Redstone Arsenal manage site perimeter control, and access to the site is limited. A physical access control system manages individual access to MSFC facilities. Mission-critical facilities within MSFC have an additional set of interior fortified perimeter controls including card reader access and CCTV capabilities. Payload control rooms within the complex have additional security access systems in place.

FORWARD WORK

Current security controls for access to KSC, including the ISS hardware located in the Space Station Processing Facility (SSPF) and the Operations and Checkout building, will continue to be strictly enforced. The facility modifications to the SSPF to support the MEI upgrades began in April 2004. Completion of the modifications is expected in October 2005.

SCHEDULE

Responsibility	Due Date	Activity/Deliverable
NASA	Since Sep 11, 2001 (Complete)	Agency vulnerability assessment
NASA Centers	2002–2005	Implement facility security improvements

Columbia Accident Investigation Board

Observation D.a-16 Quality Training Programs

NASA-wide quality assurance management must work with the rest of NASA (and perhaps with the Department of Defense) to develop training programs for its quality program personnel.

International Space Station (ISS) Corollary: Assess the training of quality assurance groups at the three primary ISS support centers.

The ISS Program response to this observation is addressed in Part 2.2, Observation O10.4-3, and in Part 2.1, ISS Continuous Improvement Action ISS-12, of this Implementation Plan.

Columbia Accident Investigation Board

Observation D.a-17 Quality Assurance Grade Structure

An evaluation of the disparity of Quality Assurance Specialist civilian grades at Kennedy Space Center compared to other NASA centers should be accomplished to determine whether the current grade levels are appropriate.

International Space Station (ISS) Corollary: Same as Space Shuttle Program.

Note: The ISS response to this Columbia Accident Investigation Board (CAIB) Observation was approved by the ISS Safety and Mission Assurance Panel (S&MAP) on January 13, 2005. All responsibility to monitor this activity Program wide was assigned to the S&MAP for ongoing management.

BACKGROUND

The CAIB expressed concern regarding civilian grade levels for Quality Assurance Specialists (QASs) at the Kennedy Space Center (KSC). Two areas of concern were noted. It was asserted that KSC Mission Assurance Chiefs are at a lower grade than the Chief Engineer or Launch Director. It was further stated that KSC is the only NASA center evaluated that has QAS grades set at GS-11 while other centers have QAS grades set at GS-12. CAIB pointed that this apparent disparity should be evaluated because it could cause pressure in resolving conflicting priorities between organizations.

ISS PROGRAM IMPLEMENTATION

In response to this CAIB Observation, KSC has reviewed its grade structure for QAS. Several reviews were conducted before and after the recent consolidation of KSC Safety and Mission Assurance (S&MA) organizations. Similarly, the ISS Program S&MA Office reviewed the QAS grade structure in other ISS organizations and centers.

STATUS

A comparative study of these journeyman-level QAS positions, functions, and pay grades across all NASA centers has been completed. This study concluded that KSC is consistent with all NASA centers in grading for positions performing the same type and level of work. GS-1910 is the Office of Personnel Management (OPM) classification code used for both Space Shuttle and ISS Program QAS positions.

After the KSC consolidation of S&MA into a single organization, a follow-on study assessed additional KSC QAS functional responsibilities. As a result, the journeyman-level position description was revised and submitted to the KSC Human Resources Office for review against OPM Position Classification Standards.

The KSC Human Resources Office also conducted a desk audit of the KSC Quality Assurance personnel supporting both the ISS and the Space Shuttle Programs. Based on their findings and with the support of the new KSC S&MA Directorate, a process was established to upgrade QAS grades from GS-11 to GS-12. This process includes the evaluation of the individual QAS's education, skills, and qualification and is based on meeting specified eligibility criteria to raise that individual's grade from GS-11 to GS-12.

At the other NASA centers supporting the ISS Program, grade disparity is not an issue.

Regarding the CAIB's second area of concern, the Mission Assurance Chiefs in the new KSC S&MA Directorate are at the same grade as their other center organizational counterparts.

FORWARD WORK

Implement the QAS upgrade process and monitor this activity for consistency within the ISS Program and across NASA programs.

SCHEDULE

	Due Date	Activity/Deliverable
NASA KSC	Dec 03 (Complete)	Review grade structure for QAS
NASA KSC	Jul 04 (Complete)	Perform follow-on study assessing additional KSC QAS functional responsibilities
NASA KSC	Oct 04 (Complete)	Perform second follow-on study assessing additional KSC QAS functional responsibilities
NASA KSC	Feb 05	Implement QAS upgrade process
ISS S&MA Program	Ongoing	Monitor this activity Program wide as part of ongoing management

Appendix A:
NASA's ISS Continuing Flight Process

NASA's ISS Continuing Flight Process

BACKGROUND

Reaping the lessons learned from the *Columbia* accident and the *Columbia* Accident Investigation Board's (CAIB's) findings started immediately after the accident. While the CAIB was conducting its investigation, the International Space Station (ISS) Program began an intensive effort to examine its own processes and operations to reduce risk under a continuous improvement initiative. As the CAIB released its preliminary findings, the ISS Program assessed them for applicability. Other continuous activities were derived from the experience the ISS Program has gained from three years of crewed ISS operations and five years of system operation.

Maj. General Michael C. Kostelnik, USAF, Retired, Deputy Associate Administrator for ISS and Space Shuttle Programs, charted the Continuing Flight Team (CFT) under the leadership of Mr. Albert D. Sofge. The CFT will review the output of the CAIB Report and determine the areas that are applicable to the ISS Program and ensure there are actions in place addressing those outputs.

CONTINUING FLIGHT TEAM DUTIES

The CFT will:

- Assess the CAIB Report for applicability to the ISS Program.
- Review ISS Program posture with respect to the applicability to the Report.
- Ensure ISS Program actions are in place to address applicable areas of the Report.
- Document ISS Program progress in addressing these actions.

CONTINUING FLIGHT TEAM PROCESS

The CFT will review the CAIB Report and will work in concert with the ISS Program to develop alternative options and proposals for the DAA, the ISS and Space Shuttle Programs, and the Space Flight Leadership Council (SFLC), as required, for addressing change requirements. The ISS Program Manager or Space Shuttle Program Manager will implement the approved change requirements, as appropriate.

The CFT will use existing ISS Program boards and panels as required to provide information and analysis. The ISS Program will provide administrative support, including action tracking, to the CFT. The CFT Lead and the ISS Program Manager will work closely to ensure full coordination of the CFT efforts across the Program elements.

SPACE FLIGHT LEADERSHIP COUNCIL

Cochaired by the Associate Administrator for Space Flight and the Associate Deputy Administrator for Technical Programs, the SFLC will provide guidance resulting from insights into ISS and Space Shuttle operations, and mission requirements. The SFLC may also direct independent analysis on technical issues related to CFT issues. The membership of the SFLC includes the Office of Space Flight Center Directors (Johnson Space Center, Kennedy Space Center, Marshall Space Flight Center, and Stennis Space Center) and the Associate Administrator for Safety and Mission Assurance. SFLC meetings are scheduled as needed.

CFT KEY MEMBERSHIP

Albert Sofge, NASA Headquarters, CFT Chairman
Richard Fullerton, NASA Headquarters, CFT Lead
Gordon Ducote, Johnson Space Center, ISS Program Lead
Kathy Laurini, Johnson Space Center
Josephine Burnett, Kennedy Space Center Lead
Cheryl McPhillips, Kennedy Space Center Co-Lead
Dave Dibler, Kennedy Space Center
Steve Tesney, Marshall Space Flight Center Lead
Kenny Mitchell, Marshall Space Flight Center
Eric Trail, Stennis Space Center Lead
Mike Dawson, Stennis Space Center
Ellen Baker, Astronaut Office
Gail Gabourel, NASA Headquarters
Larry Gagliano, NASA Headquarters
Tony Gallina, NASA Headquarters
Laura Giza, NASA Headquarters
Jacob Keaton, NASA Headquarters
Larry Manfredi, NASA Headquarters
Jim McGroary, NASA Headquarters
Theresa Maxwell, NASA Headquarters
Meredith McKay, NASA Headquarters
Don Schmalholz, NASA Headquarters
Gilbert White, NASA Headquarters

Appendix B:
ISS Continuing Flight Team
Charter Letter

National Aeronautics and
Space Administration
Headquarters
Washington, DC 20546-0001

Reply to Attn of: M-1

September 8, 2003

TO: Johnson Space Center
Attn: OA/International Space Station (ISS) Program Manager

FROM: M-1/Deputy Associate Administrator International Space Station and Space Shuttle Program

SUBJECT: ISS Continuing Flight Team (CFT)

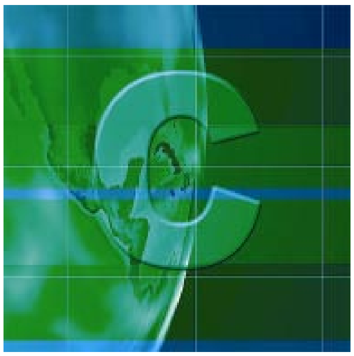
Administrator O'Keefe and the Agency have embraced the Columbia Accident Investigation Board (CAIB) report as a document that is applicable to all human space flight endeavors. Our response to the CAIB recommendations, "*NASA's Implementation Plan for Return to Flight and Beyond*", addresses the recommendations from primarily a Space Shuttle program perspective. During the timeframe prior to the publication of the CAIB report as the CAIB made public their preliminary recommendations, the ISS program also considered these and began factoring the intent into the ongoing execution of the Program as applicable. The ISS program has implemented several changes. With this letter I am chartering the CFT to formally assess and act upon the CAIB recommendations, observations, and findings as they apply to ISS and determine required additional changes.

The Space Flight Leadership Council will review the CFT proposed changes as required. Upon approval by the Space Flight Leadership Council, the ISS Program Manager will implement these changes. The CFT can also make recommendations for studies of long-term changes that will offer the possibility to bolster flight safety and operational resilience for the remaining life of the ISS.

Mr. Albert Sofge will lead the CFT. He will submit a plan outlining the team composition and concept of operations by September 19, 2003. To ensure coordination and efficient implementation of changes, the ISS program will have a significant role in the process.

The ISS Program Manager, Mr. William Gerstenmaier, retains full authority over and responsibility for management of the ISS. Mr. Gerstenmaier will work closely with Mr. Sofge to ensure coordination of CFT recommendations into the overall management of the ISS.

Michael C. Kostelnik



Appendix C: Continuing Flight Team Priorities

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
2101 NASA Road 1
Houston, Texas 77058-3696

December 18, 2003

Reply to Attn of: OX-03-009

TO: Distribution

FROM: OA/Manager, International Space Station Program

SUBJECT: Continuing Flight Team (CFT)

Our entire NASA family was affected by the tragic loss of the Space Shuttle Columbia and its crew. For the International Space Station (ISS) Program, our strategy during this difficult period is to address the Columbia Accident Investigation Board's (CAIB) report on three fronts: an unwavering commitment to learn from this tragedy; to reshape the ISS Program based on those lessons; and to carry out the NASA Administrator's directive to continue our mission of building and operating the ISS as effectively and safely as possible.

The CAIB report identifies many areas for improvement within NASA including systemic issues that directly or indirectly affect the way we plan, develop and operate. The Deputy Associate Administrator (DAA) for ISS and Space Shuttle Programs,
Major General Michael Kostelnik, chartered CFT to insure that actions are in place to address CAIB outputs that are applicable to ISS. In late October, the CFT published its initial response to the CAIB report. Entitled "NASA's Implementation Plan for ISS Continuing Flight," it embraced the CAIB report and explained what the ISS Program is doing to address each applicable CAIB recommendation. It also included a comprehensive set of self-initiated corrective actions and process improvements as ISS Continuous Improvement actions. The Implementation Plan will be periodically updated as our analyses and reassessments mature and to include the additional CAIB outputs. The target date for Revision 1 release is mid-December to early January.

The ISS strategy for continuing flight will examine and improve the following three key areas: technical (designs, analyses, and processes); management (roles, responsibilities, and decision-making); organizational structure and other matters (culture, attitudes, and mindset). Each applicable output or NASA-identified process improvement must have a specific plan for corrective action and implementation. Critical safety-of-flight issue identification and resolution is our highest priority. Within the framework of this commitment, we are reminded that our mission is, above all else, to keep the ISS crew safe and the Station operating in a safe manner. We must ensure that nothing dilutes our efforts in that regard.

With this in mind, I have created a core team of ISS personnel to work with the CFT to update the ISS CFT Plan in an efficiently managed process consistent with our ongoing responsibilities. This core team will be led by Mr. Gordon Ducote in the External Relations Office and supported by specific individuals in the ISS organization whose specialties are key to responding to and implementing these efforts, including vehicle engineering, safety, program and mission integration. We will have an on-going effort to work on all of the applicable CAIB outputs and Continuous Improvement areas but establishing priorities on select tasks is warranted. Our priorities and the key leads are:

1. Process improvements in key major reviews, (e.g. Certification of Flight Readiness) to ensure that all issues are identified and addressed by management (key lead: W. Rod Jones)

2. Assessing the validity of our software models to accurately characterize the risk environment and the threats to mission safety and success (key lead: Carol Rush)

3. Improve our ability to identify, track, analyze, and mitigate in-flight anomalies (key lead: Kevin Meehan)

4. Identify improved methods of tracking anomaly data for performance trending (key lead: Phillip Dempsey)

5. Develop improved methods for documenting operational constraints including the associated waiver/deviation process with emphasis on the Medical Operations Requirement Document and the Generic Groundrules Requirements and Constraints Document (key lead: Kathy Leary)

In addition, other process and technical improvements will continue to require our attention and key individuals will be named to support these tasks.

The ISS Program's part in the Space Shuttle return to flight and the ISS continuing to fly effort requires us to identify, understand, mitigate, and control risk while accomplishing the mission entrusted to us. The crew of STS-107 was dedicated to the vision of science and exploration and devoted their lives to further it. It is our job to continue their vision.

William H. Gerstenmaier

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