United States Government Accountability Office
Washington, DC 20548

April 11, 2011

The Honorable John D. Rockefeller IV
Chairman
The Honorable Kay Bailey Hutchinson
Ranking Member
Committee on Commerce, Science,
and Transportation
United States Senate

The Honorable Ralph Hall
Chairman
The Honorable Eddie Bernice Johnson
Ranking Member
Committee on Science, Space and Technology
House of Representatives

Subject: *International Space Station (ISS) – Ongoing Assessments for Life Extension Appear to be Supported*

This letter formally transmits the attached briefing (see encl. I) in response to the mandate contained in the National Aeronautics and Space Administration (NASA) Authorization Act of 2010, Pub. L. No. 111-267, Section 503(c)(2), for GAO to provide an evaluation of the accuracy and level of confidence in the findings contained in NASA's assessment of the essential modules, operational systems and components, structural elements, and permanent scientific equipment required to ensure complete, effective, and safe functioning and full scientific utilization of the International Space Station through 2020. We provided your staff a draft copy of this briefing in meetings with them on April 6 and 7, 2011. We also provided a draft to NASA for comment. NASA agreed with our findings and provided technical comments that we incorporated as appropriate.

Our objectives were to determine (1) how NASA will ensure that the ISS is structurally sound and that essential spares and replacement components are available to support safe functioning and full scientific utilization through 2020, and (2) the extent to which NASA's assessment of the essential spares necessary to assure continued operations of the ISS through 2020 is supported by sufficient, accurate, and relevant underlying data and appropriate and reasonable methodologies. NASA is using analytical techniques, physical tests, and inspections to assess primary structures and functional systems and determine sparing needed to support safe functioning and full scientific utilization of the ISS through 2020. These assessments are ongoing, so all results are not yet available. Our work indicates that NASA's assessments appear to be supported by sufficient, accurate and relevant underlying data. We found, however, that NASA's estimates of ISS sparing needs are sensitive to assumptions about hardware reliability.

To evaluate NASA's approach, we reviewed relevant technical documents and data NASA used to support its analysis and interviewed responsible officials. In a limited number of cases, we replicated NASA's calculation used to update predicted failure rates for essential spares. Our work was conducted in accordance with generally accepted government auditing standards.

As agreed with your staff, given the limited time available to conduct our analysis, we plan to continue our work to provide a more in-depth evaluation of the level of confidence and accuracy of NASA's assessment and provide an additional report to you at a later date.

We are sending copies of this report to the appropriate congressional committees. We are also sending copies to NASA. This report will also be available at no charge on the GAO Web site at http://www.gao.gov.

Should you or your staff have any questions concerning this report, please contact me at (202) 512-4841 or chaplainc@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of the attached report.

Key contributors to this report include Shelby S. Oakley, Assistant Director; John Warren, Analyst-in-Charge; Andrea Bivens; Tana Davis; Jay Tallon; Sonya Vartivarian; and Laura Greifner.

Cristina Chaplain
Director
Acquisition and Sourcing Management

Enclosures

Report to Congressional Committees
April 2011

International Space Station: Ongoing Assessments for Life Extension Appear to be Supported

For more information, contact chaplainc@gao.gov

Contents

Objectives

1. How will NASA ensure that the International Space Station (ISS) is structurally sound and that essential spares and replacement components are available to support safe functioning and full scientific utilization through 2020?

2. To what extent is NASA's assessment of the essential spares necessary to assure continued operations of the ISS through 2020 supported by sufficient, accurate, and relevant underlying data and appropriate and reasonable methodologies?

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Background

- The ISS is a research and development test bed that is, in itself, an experiment in design, development, and assembly of an orbital space facility.
- The ISS is composed of about 1,000,000 pounds of hardware brought to orbit over the course of more than a decade.
- The ISS includes (1) **primary structures**, i.e., the external trusses which serve as the backbone of the station and the pressurized modules that are occupied by the ISS crew, and (2) **functional systems** composed of **orbital replacement units (ORUs)**, i.e., system components modularized to support simple on-orbit replacement.

ISS Current Assembly

Source: NASA.

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Background

- Supporting remote operations is difficult and costly.
- NASA's logistics approach is in some ways similar to those used by other government agencies with remote-location programs:
  - National Science Foundation (NSF) Antarctic research station at the South Pole
  - National Oceanic and Atmospheric Administration (NOAA) Aquarius underwater research station in the Florida Keys
- All the agencies prioritize spares based on safety, mission, and comfort, in that order.
- The Space Shuttle's retirement eliminated NASA's ability to bring large external ORUs back to Earth and significantly reduced other ORU return capability for repair and eventual return to the ISS.
- As a result, NASA has adopted a logistics approach that differs from other agencies' approaches. NASA's current logistics approach uses a statistical methodology and modeling to forecast ISS sparing needs.

	NASA	NOAA	NSF
Sparing priority #1	Safety	Safety	Safety
Sparing priority #2	Mission critical	Mission critical	Mission critical
Sparing priority #3	Items not impacting safety or mission	Items not impacting safety or mission	Items not impacting safety or mission
Methodology for deciding sparing needs	Statistical forecasting and modeling	Log book and experience	Procure all manufacturer-recommended spares
Prepositioning spares	Key	Not as important	Key
Transportation	Complex	Straight-forward	Complex
Maintenance	ISS on-station crew	Dedicated staff onboard	Antarctic on-station crew

Source: Agency interviews and documents

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Background

- Until 2010, NASA was not authorized to continue participation in the ISS program beyond 2015.

- *The National Aeronautics and Space Administration Authorization Act of 2010*, Pub. L. No. 111-267, Sec. 503 required:
  - NASA to take "all actions necessary to ensure the safe and effective operation, maintenance, and maximum utilization of the United States segment of the ISS through at least September 30, 2020," to conduct an assessment of the sustainability and continued operations of the ISS through September 30, 2020, and to submit a report on the assessment.
  - GAO to report on NASA's assessment of the sustainability and continued operations and report back to the Senate Committee on Commerce, Science, and Transportation and House Committee on Science.

- In response to past GAO recommendations aimed at increasing scientific utilization of the ISS, NASA is in the process of creating an independent, nonprofit organization to manage and oversee ISS National Laboratory research by U.S. organizations other than NASA. (*International Space Station: Significant Challenges May Limit Onboard Research* (Washington, D.C.: GAO-10-9, Nov. 25, 2009))

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Scope and Methodology

- We interviewed and obtained briefings and relevant documents from knowledgeable NASA officials regarding the content and decision-making approach used to prepare the agency's ISS assessment. We reviewed the scope, methodology, and ground rules and assumptions NASA used in the ISS assessment.
- We analyzed launch schedules and manifests to determine the viability of NASA's findings regarding transportability for and supportability of the ISS.
- We compared NASA's approach to ISS logistics to the approaches used by other organizations to support remote operations.
- We conducted our work at NASA and the National Science Foundation Office of Polar Programs headquarters in Washington, D.C. and NASA's Johnson Space Flight Center, in Houston, Texas. We also interviewed University of North Carolina-Wilmington personnel responsible for managing the National Oceanic and Atmospheric Administration's Aquarius Undersea Laboratory via telephone.

Scope and Methodology

- For purposes of determining whether NASA's findings and conclusions are supported by sufficient, accurate and relevant underlying data as well as appropriate and reasonable methodologies, we focused our efforts on the statistical techniques NASA used to calculate operational mean-time between failure rates and the modeling techniques NASA uses to assess functional availability. For a limited number of orbital replacement units, we recalculated the values NASA obtained for the operational mean-time between failure based on its statistical methodology. We also conducted limited tests of the data NASA used to support the functional availability model.
- We limited the scope of our assessment to the scope of NASA's report, i.e., the sparing necessary to support critical functions as modeled in the ISS functional availability assessment. We did not examine the sparing needs of the international partners or the sparing needs of functions not included in the ISS functional availability assessment.
- We conducted this performance audit from February 2011 to April 2011 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings based on our audit objectives.

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Bottom Line

Finding 1

- NASA is using analytical techniques, physical tests, and inspections to assess primary structures and functional systems, to the extent possible, and determine sparing needed to support safe functioning and full scientific utilization of the ISS through 2020. NASA is confident that it can execute necessary functioning and utilization; however, the supporting assessments for primary structures and functional systems are ongoing and all results are not yet available.

Finding 2

- NASA's assessment of the essential spares necessary to assure continued operations through 2020 appears to be supported by sufficient, accurate, and relevant underlying data. We found, however, that estimates of essential spares are sensitive to NASA's assumptions about ORU reliability.

Finding 1
Ongoing ISS Life Extension Assessments

NASA is using a combination of on-orbit data, analytical techniques, hardware tests, and limited visual inspections to assess the feasibility of extending ISS life through 2020. These life extension assessments are under way, but results will not be available until assessments are completed in 2015. Assessments include examinations of the following:

- Primary structures
- Functional systems
- Safety & Mission Assurance (S&MA) documentation
- Transportation plans
- Essential spares

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ISS Life Extension Assessments: Primary Structures

- NASA continues to assess the structural health of the ISS primary structures, i.e., the external trusses which serve as the backbone of the station and the pressurized modules that are occupied by the ISS crew.
- NASA has extended its assessments to examine the ISS structural health through 2028 as a conservative approach to assessing continued operations through 2020. This approach is being used to minimize analysis resources and to identify indicators of structural limitations that could impact operations beyond 2020.
  - Structural health assessments involve
    - analytical assessments of the U.S. primary structure;
    - hardware tests on the ground test article for the US-funded, Russian-built Functional Cargo Block (FGB)—the first segment of the ISS placed in orbit; and
    - limited visual inspection of the assembled ISS in orbit.
- Planned assessments of primary structures are ongoing and will continue through 2015. Additional assessments beyond 2015 could be required for specific critical areas depending on the results of the assessments.

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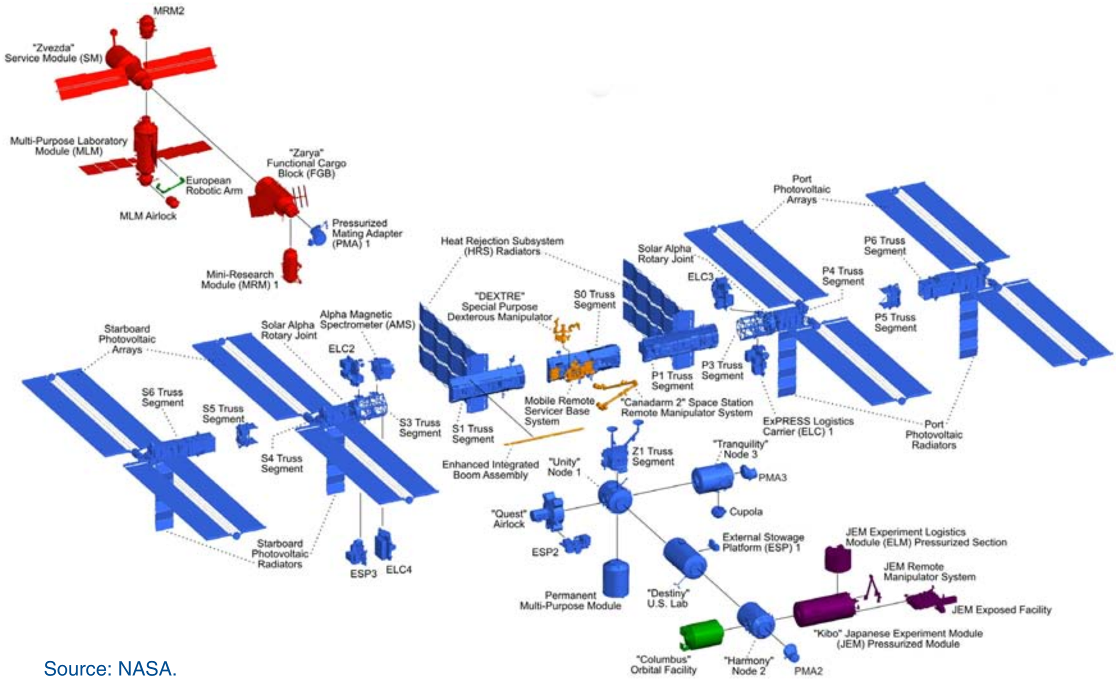
ISS Life Extension Assessments: Primary Structures



- NASA elements
- Russian elements
- Canadian elements
- Japanese elements
- European elements

Source: NASA.

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ISS Life Extension Assessments: Primary Structures

U.S. Primary Structures

- NASA initially certified ISS structural elements for 15 years of life after being placed in orbit: 5 years to allow for ISS assembly and 10 additional years for operation. Certifications for the initial structural elements begin expiring in 2013.
- To achieve a 15-year certification, NASA required analytical demonstration of sufficient design margin to maintain structural integrity for at least 60 years (i.e., 4 times the 15-year planned service life) based on:
  - anticipated mechanical, pressure and thermal loads, and
  - information in the national material properties database.
- NASA is examining the U.S. primary structures in phases to determine if the original certifications are still valid.
  - Phase I (under way): Hardware exceeding original certification limits starting in 2013.
  - Phase II (starts in 2012): Hardware with original certifications expiring in 2017.
  - Phase III (starts in 2012): Hardware with original certifications extending beyond 2020.

ISS Life Extension Assessments: Primary Structures

U.S. Primary Structures

- NASA is using the Structural Health Assessment Program (SHAP) to annually assess the validity of the ISS primary structures' original service life certifications.
- SHAP uses reconstructed mechanical, thermal, and pressure loads created from actual data gathered from sensors onboard the ISS to update predicted service life.
- Officials indicated that the current SHAP addresses about 40 percent, by weight, of the ISS—assembled through November 2002.
    - On-orbit time is necessary to conduct a meaningful SHAP analysis
- NASA is not assessing the international partner (IP) owned structures (this is an IP responsibility); however, NASA will assess structures built by IP's but owned by NASA.

ISS Assembly as of November 2002

Source: NASA.

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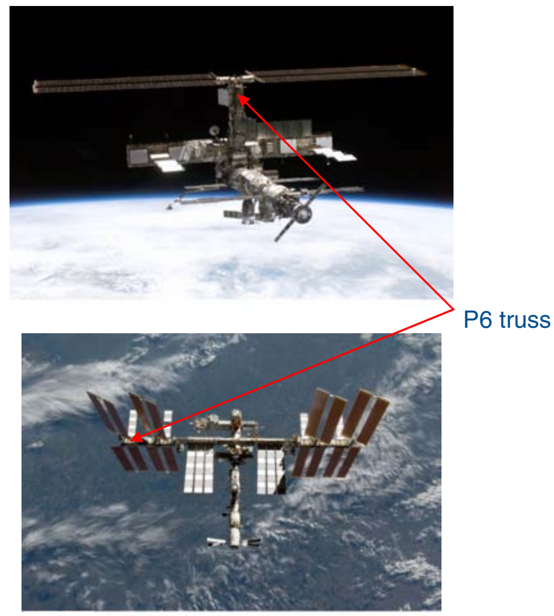
ISS Life Extension Assessments: Primary Structures

U.S. Primary Structures

- NASA considered over 10,000 design locations in preparing the current SHAP assessment.
- 829, about 7 percent, of these locations are examined in detail by the SHAP because they have less than 90 years of service life (i.e., 6 times the 15-year planned service life) or safety margins of less than 10 percent.
- 196 of the 829 locations are using life faster than originally predicted.
- 19 of the 196 locations are at less than 60 years of service life (i.e., 4 times the 15-year planned service life).
    - 15 of the 19 locations are on the P6 truss—left exposed to continuous thermal cycles for an extended period after the Columbia accident (see images).
    - Assessing mitigation options for these—considering thermal blankets.



Source: NASA.

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ISS Life Extension Assessments: Primary Structures

Functional Cargo Block (FGB)

- FGB was the first ISS component launched, in 1998.
    - Provided initial propulsion and power
    - FGB initial certification expires in 2013
- Initial Russian certification was achieved by conducting accelerated 15-year life-cycle testing to a full-scale FGB test article.
- In 2010, NASA conducted accelerated testing of the FGB test article hull structure and docking hardware to recertify to 2028.
- Final fracture analysis of testing to 2028, including analysis of weld seams, to be completed in Spring 2011.

FGB Docked to Unity Node 1998

Source: NASA.

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ISS Life Extension Assessments: Primary Structures

Assembled ISS

- NASA has limited capability to assess the overall structure of the entire station.
  - Extensive internal structures prevent x-ray or sonographic inspection of all weld seams from inside the ISS.
  - External television cameras support limited visual inspection of the ISS on orbit.

ISS Current Assembly

Source: NASA.

ISS Life Extension Assessments: Functional Systems

NASA is conducting four types of analytical assessments of ISS functional systems to identify technical issues that could impact continued operations through 2020.

- Critical operating hardware assessments, ongoing through 2011
- Nonreplaceable hardware assessments, ongoing through 2011
- Primary utilization facility hardware assessments, ongoing through 2015 (estimated)
- FGB nonreplaceable and critical hardware assessments, ongoing through 2014 (estimated)

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ISS Life Extension Assessments: Functional Systems

Critical Operating Hardware Assessments

- Assessment of all hardware and ORUs with catastrophic failure modes, to determine cycle or time limitations, as well as technical issues specific to continued operation beyond original certification.
- Catastrophic failure modes are those which could cause loss of crew or loss of station.
  - Example: pressure vessels can rupture and cause loss of crew or station.

Nonreplaceable Hardware Assessments

- Assessment of hardware not intended for on-orbit removal and replacement due to location, design, installation, or function.
  - Assessment to determine if sufficient work-around plans exist to ensure continued operation of a system if nonreplaceable segments fail or whether more plans are needed.
    - Example: assess capability to repair wire insulation jacket vs. spending resources to analyze wiring life.

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ISS Life Extension Assessments: Functional Systems

Primary Utilization Facility Hardware Assessments

- Analytical assessment of key laboratory science facilities/hardware that may have catastrophic failure effects or that may support critical functionality related to scientific utilization.
  - Example: the Material Science Research Rack and General Laboratory Active Cryogenic ISS Experiment Refrigerator.

FGB Nonreplaceable and Critical Hardware Assessments

- Analytical assessment of FGB propulsion, electrical, and ventilation systems.
- NASA in negotiations with Russian authorities to perform the assessments.

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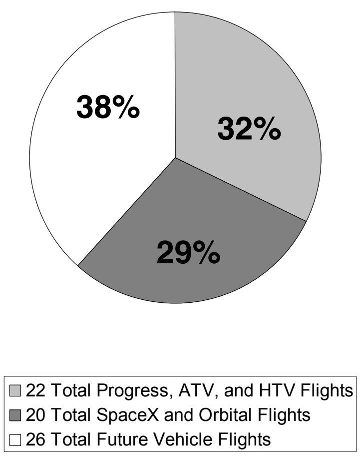
ISS Life Extension Assessments: Safety and Mission Assurance

The ISS Safety and Mission Assurance (S&MA) office will examine life extension from an ISS system-level perspective (in contrast to individual hardware assessments of critical operating hardware and ORUs).

- These dual methodologies (system-level and individual hardware perspectives) are intended to serve as a check and balance to insure critical areas and functionality are addressed.
  - S&MA will review existing documentation to determine if any waivers, closed risks, or corrective actions are impacted by extending service life or increasing cycles of use.
  - S&MA will update risk assessments on a case-by-case basis, e.g., increased risk from changes in the orbital debris environment.
- S&MA findings and conclusions will be coordinated with hardware teams and brought to the ISS program management for discussion.
- S&MA reviews are ongoing and will continue into 2015.

ISS Life Extension Assessments: Transportation Plans



Source: GAO analysis of NASA data.

- NASA's sparing plan for ISS life extension through 2020 relies on development of new launch and transport vehicles to support ISS operations.
    - NASA plans to use transportation systems developed commercially by Space Exploration Technologies (SpaceX) and Orbital Sciences Corporation (Orbital) to supply spares beginning in 2011.
        - Development of both systems are moving more slowly than planned.
    - 38 percent of the flights planned to support ISS operations through 2020 are dependent on vehicles not yet in development.
    - According to ISS program officials, the European Automated Transfer Vehicle (ATV) and Japanese H-II Transfer Vehicle (HTV) production facilities are not equipped to accelerate production rates and procuring additional Russian Progress resupply vehicles and Soyuz crew transport vehicles is problematic.
    - Reliant on new Commercial Crew System for crew transport in 2016.

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ISS Life Extension Assessments: Transportation Plans

- Shuttle retirement complicates ISS supportability.
    - Shuttle capability allowed NASA to return failed ORUs to the Earth for analysis, repair, and eventual return to the ISS.
    - Without the Shuttle, NASA lacks the ability to return large external ORU’s to conduct on-ground failure analysis to pinpoint causes of failures.
        - Example: Return capability helped NASA diagnose problems with ISS control moment gyroscopes.
    - One ORU, the heat rejection system radiator, is too large for transport on anything but the Shuttle.
        - One spare is prepositioned.
        - According to ISS officials, Micro-Meteoroids and Orbital Debris models indicate that portions of the heat rejection system radiator are likely to be damaged by strikes every 3 years. Although the heat rejection system radiator has been struck, it has never been disabled by a micrometeoroid and according to officials the radiators have unused capacity that provides redundancy.
    - According to the ISS program manager, NASA has prepositioned spares in anticipation of Shuttle retirement. If commercial vehicles are not available as expected, however, NASA will need STS-135 (the additional authorized Space Shuttle flight) to preposition additional spares or its ability to conduct science efforts will be limited in 2012.

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ISS Life Extension Assessments: Essential Spares

NASA uses **two analytical techniques** to assess the quantities and types of essential spares, i.e., ORUs needed to support ISS functionality, such as the control moment gyro within the guidance and navigation control system.

- A statistical methodology, called the **Bayesian update process**, to calculate an operational Mean Time Between Failure (MTBF) for an ORU using a manufacturer's estimated MTBF in conjunction with actual on-orbit operation and failure data.
- **Monte Carlo[1] modeling** techniques to prepare the Functional Availability Analysis (FAA), which calculates the probability that targets for key functions will be met at ISS end of life.
  - NASA uses the operational MTBF from the Bayesian update process as inputs to its Monte Carlo modeling.
  - NASA updated the FAA in 2010 to identify ISS sparing needs through 2020.

[1] Monte Carlo modeling is used to approximate the probability outcomes of multiple trials by generating random numbers.

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Finding 2
Evaluation of NASA Analytical Techniques for Assessing Essential Spare Needs

NASA's assessment of the essential spares necessary to assure continued operations through 2020 appears to be supported by sufficient, accurate, and relevant underlying data. However, we found that estimates of essential spares are sensitive to NASA's assumptions about ORU reliability.

- We examined the following areas:
  - Data underlying NASA's assessment
  - Bayesian update process
  - Functional availability assessments

:

Evaluation of Analytical Techniques: Data Underlying NASA's Assessment

NASA's findings and conclusions on ISS maintenance and continued operations through 2020 appear to be supported by sufficient, accurate, and relevant underlying data.

- Bayesian update process is an accepted tool for forecasting failures with limited data and is used by NASA, the Nuclear Regulatory Commission, and others to modify original estimates of failure rates as new information becomes available.
  - NASA applies the Bayesian update process to all ORUs that have experienced random failures.
  - Before applying Bayesian updates to an ORU that has not failed, NASA allows the ORU to operate at least one-half of its original predicted MTBF.

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Evaluation of Analytical Techniques: Data Underlying NASA's Assessment

- For each ORU, reliability of Bayesian update process depends upon the accuracy of four key pieces of input data: original MTBF; assumed original MTBF variance; run-time; and actual failure rates—data maintained in NASA's Modeling and Assessment Data Set database.
  - Original MTBF—GAO's limited tracing of original MTBF in the Modeling and Assessment database to source documentation provided by the original equipment manufacturer did not reveal deficiencies in the accuracy of the data. Our test, however, was for a very small number of records. Original MTBF estimates generated by original equipment manufacturers are paper records; according to NASA representatives, retrieving these records is a cumbersome, labor-intensive, and costly process.
  - Assumptions regarding original MTBF variance—involves selecting an appropriate dispersion of failure for the distribution of the MTBF.
  - Actual run-time and failure rates—according to NASA, they maintain detailed logs on each ORU at each location on the ISS.

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Evaluation of Analytical Techniques: Bayesian Update Process

Bayesian update process may overstate Operational MTBF in instances of few or no failures.

- Bayesian update process is a statistical methodology that NASA uses to calculate an operational Mean Time Between Failure (MTBF) for an ORU using a manufacturer's estimated MTBF in conjunction with actual on-orbit operation and failure data.
- Bayesian update process is very sensitive to assumptions and initial failures. A single failure of an ORU can dramatically change the operational MTBF calculated by this process.
- For example, as shown below, successive annual updates of the MTBF (in hours) for the ISS Pump Module Assembly increased each year through 2009. A single failure of the Pump Module Assembly in 2010, if determined to be random, would result in a significant decrease in MTBF.

Pump Module Assembly	**Original MTBF** In Oct. 2006 Data	**Updated MTBF** Oct. 2007	**Updated MTBF** Oct. 2008	**Current MTBF** Oct. 2009	**Estimated run-time hours at failure per ISS Risk Team to August 3, 2010**	**New MTBF** *Bayesian updated w/one failure Aug. 2010*
Hours	**39,800**	**52,450**	**86,560**	**104,683**	**63,600**	**58,119**

Evaluation of Analytical Techniques: Bayesian Update Process

Simplification of Bayesian mathematics decreases accuracy.

- NASA uses a simplifying assumption to reduce the computational complexity of the Bayesian calculations.
- Complex numerical integration is reduced to simple algebra at the cost of some accuracy.

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Evaluation of Analytical Techniques: Functional Availability Assessment

NASA's determination that 72 percent of ISS functions meet or exceed functionality targets with minimal risk acceptance to 2020 may be overstated.

- 22 functions assessed by FAA process does not include 10 additional functions needed for full utilization of station; other sparing methodologies are used on those 10 functions because most are government-furnished equipment lacking reliability data necessary for FAA.
- Statement in NASA's report to Congress suggesting 23 percent of functions "are within 5 percent" of their goal lacks clarity. Meeting a functional target at a 94 percent confidence is, in fact, much different than achieving a functional target at a 99 percent confidence—failure to meet a functional target one time in 20 vs. one time in 100.
- According to NASA representatives, each function is modeled independently and assumes other functional targets are met.

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Evaluation of Analytical Techniques: Functional Availability Assessment

The functional targets and confidence goals in the FAA were developed by the ISS team and endorsed by the ISS program manager.

- NASA assumes “graceful degradation” of ISS, which means ISS operations decline while critical systems continue to work until the end of ISS life. The functional targets and confidence goals protect full operations with reduced system redundancy.
- NASA officials indicated the program delays spares procurements as long as possible to provide for more informed decisionmaking and to conserve resources.
- The Functional Availability Assessment March 2010 was performed prior to NASA’s authorization to extend ISS operations to 2020. It indicates that, based on current data, additional spares procurements may be needed to achieve target functionality beyond the planned 2015 ISS end date.

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Evaluation of Analytical Techniques: Functional Availability Assessment-March 2010

System	Function	Functional Target	Confidence Goal	Confidence Status		At-Risk ORUs
				2015	2020	
Electrical Power System, Structural/Mechanical, Thermal Control	Usable Power	7 of 8 Power Strings	90%	95%	65%	X
Environmental Control and Life Support System (ECLSS)	Intramodule Ventilation	4 Strings	95%	95%	93%	
	Atmosphere Control System	All Valves/Sensors	85%	84%	57%	
		At least 2 Pressure Control Panels	95%	98%	83%	
	Trace Contaminant Control System	1 of 2 Strings	99%	100%	100%	
	Fire Detection System	All Detectors	80%	100%	99%	
	Carbon Dioxide Removal	1 of 2 Strings	98%	99%	97%	
	Major Constituent Analyzer	1 of 2 Strings	90%	98%	71%	X
	Vacuum	Full Functionality	90%	97%	93%	
	Sample Distribution	All Functionality	90%	95%	92%	
Internal Thermal Control System	Internal Thermal Control	All Strings	85%	97%	85%	
	ITCS Coldplates	All Functionality	95%	98%	95%	
Communications and Tracking	S-Band	1 of 2 Strings	98%	99%	94%	
	Ku-Band	1 of 2 Strings	98.5%	94%	73%	X
	Internal Audio	12 of 14 Strings	99.5%	99.40%	97%	
Command & Data Handling	Command & Data Handling	All Functionality	95%	97%	84%	
Guidance Navigation & Control	Attitude Determination	At least 1 String	95%	97%	95%	
	Attitude Translation	3 of 4 Strings	99%	99%	92%	
Video	Internal/External Video	3 of 4 ETVCG Strings	95%	93%	70%	X
Regenerative ECLSS	Oxygen Generation Assy	1 String	90%	76%	22%	X
	Water Processing Assy	1 String	90%	73%	5%	X
	Urine Processing Assy	1 String	90%	90%	29%	X

Source: NASA.

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March 2010 Functional Availability Risk Assessment

- NASA plans to monitor and track At-Risk ORUs annually to reassess risk.
- All 2020 functions with no At-Risk ORUs identified indicate that risk acceptance rationale is in place for ORUs impacting those confidence targets.
- Examples of risk acceptance rationale include:
  - Good on-orbit performance to date indicates low risk of failures through 2020.
  - Electrical boxes have demonstrated performance that far exceeds original manufacturer MTBFs.
  - Changes in on-orbit operational usage/design.

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Agency Comments

Agency officials agreed with our overall findings.

- NASA is using analytical techniques, physical tests, and inspections to assess primary structures and functional systems, to the extent possible, and determine sparing needed to support safe functioning and full scientific utilization of the ISS through 2020. NASA is confident that it can execute necessary functioning and utilization; however, the supporting assessments for primary structures and functional systems are ongoing and all results are not yet available.
- NASA's assessment of the essential spares necessary to assure continued operations through 2020 appears to be supported by sufficient, accurate, and relevant underlying data. We found, however, that estimates of essential spares are sensitive to NASA's assumptions about ORU reliability.

ISS officials provided technical comments that we have incorporated as appropriate.

GAO on the Web

Web site: http://www.gao.gov/

Contacts

Chuck Young, Managing Director, Public Affairs, youngc1@gao.gov
(202) 512-4800, U.S. Government Accountability Office
441 G Street NW, Room 7149, Washington, D.C. 20548

Ralph Dawn, Managing Director, Congressional Relations, dawnr@gao.gov
(202)512-4400, U.S. Government Accountability Office,
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