THE LOGISTICS PATH FROM THE INTERNATIONAL SPACE STATION TO THE MOON AND BEYOND

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INTRODUCTION

The period from the loss of the Space Shuttle Columbia in February 2003 to resumption of Space Shuttle flights, planned for May 2005, has presented significant challenges to International Space Station (ISS) maintenance operations. Sharply curtailed upmass capability has forced NASA to revise its support strategy and to undertake maintenance activities that have significantly expanded the envelope of the ISS maintenance concept. This experience has enhanced confidence in the ability to continue to support ISS in the period following the permanent retirement of the Space Shuttle fleet in 2010. Even greater challenges face NASA with the implementation of the Vision for Space Exploration that will introduce extended missions to the Moon beginning in the period of 2015 – 2020 and ultimately see human missions to more distant destinations such as Mars. The experience and capabilities acquired through meeting the maintenance challenges of ISS will serve as the foundation for the maintenance strategy that will be employed in support of these future missions.

ISS CHALLENGES AND RESPONSES

The planned retirement of the Space Shuttle fleet in 2010, part of the Vision for Space Exploration announced by President Bush in February 2004, has driven reconsideration of supply support plans and fundamental approaches to on-orbit maintenance. The hiatus in Shuttle flights beginning in February 2003 and extending to May 2005 sharply limited the amount of spares and equipment that could be shipped to orbit during this period.

Prior to the announcement of the Space Shuttle retirement, the logistics and maintenance support strategy centered on removal and replacement of failed orbital replaceable units (ORUs), return of the failed ORUs to Earth for repair and refurbishment, and subsequent re-launch as required. After the Shuttle retires, the expendable launch vehicles available to launch upmass include the Japanese HII Transfer Vehicle (HTV), the European Automated Transfer Vehicle (ATV), and the Russian Progress vehicle. The expected yearly flight rate will be two flights per year for the HTV, one ATV flight per year; and several Progress flights per year. None of these carriers provide the capability to return hardware to Earth. Therefore, from 2011 until the conclusion of NASA's planned participation in the ISS program in 2016, hardware flow will be in one direction only and no hardware will be returned for refurbishment and later use. Additionally, the only carrier that can carry external, unpressurized hardware is the HTV – although because of volumetric constraints its capability to do so is less than that of the Shuttle.

Because of the limitations on launching external, unpressurized cargo (especially very large items) after 2010, an effort will be made to preposition as much external hardware as possible at ISS before Shuttle retirement. The first logistics and maintenance external launch allocation occurs in February 2009. This will be followed by two dedicated unpressurized maintenance flights in 2010. In addition to making available items that cannot be launched later, prepositioning decreases response time to failures, increases the functionality of the ISS, and decreases the total external launch demand on HTV following Shuttle retirement. Despite this plan for prepositioning it is expected that by 2014 the external spares inventory may be fully expended and, therefore, no external maintenance could be performed after that point. This situation may improve somewhat if early failures of equipment deployed during the remainder of the assembly process are less than expected.

Internal maintenance is faced with different, but equally significant, challenges. Since the ATV, HTV, and Progress vehicles cannot return failed hardware to Earth for refurbishment, the ISS program will have a finite number of spares available. Because of economic factors, spares production lines cannot be kept open indefinitely for very limited production volume. Once production of spares is terminated, the ISS will be dependant on the spares available at that time and, when those have been used, no more will be available.

For this reason, expansion of maintenance and repair capabilities that allow the preservation of spares is highly attractive. Experience acquired during the recent Shuttle stand-down has shown that it is possible to perform maintenance that was previously not considered. For example, a pump was changed in one of the Extravehicular Mobility Units (i.e. spacesuits) upper torso assembly. This task would have normally been addressed by exchange of the complete upper torso. In the case of a failed bearing in the gyro unit of the Treadmill Vibration Isolation System, individual roller bearings were replaced rather than removal and replacement of the entire gyro unit. In both cases, the amount of time required for the more in-depth repairs was significantly greater than that which would have been required for the originally planned repair approach. These experiences demonstrate that maintenance actions can be performed that were previously considered to be beyond the capabilities of ISS astronaut crews. However, they also illustrate that unless systems are designed for maintenance, the time required can be excessive.

In summary, the new strategy for ISS maintenance – driven by reduced upmass capacity following Shuttle retirement and unidirectional cargo flow – is to preposition as much as possible with the Shuttle while it is still available and to perform more repair on-orbit. Maintenance actions undertaken during the recent Shuttle stand down have enhanced confidence in our ability to perform more aggressive repairs on-orbit. This experience has stimulated consideration of ways to further expand the maintenance capability envelope and to make these types of repairs more standard.

Supportability Challenges of the Vision for Space Exploration

Missions contemplated as part of the Vision for Space Exploration are characterized by great distances from Earth, widely spaced launch opportunities, and extended duration. For example, some missions to Mars could last as long as three years. Opportunities to launch payloads to Mars from Earth occur at intervals of approximately twenty-six months because of planetary alignment and, in the extreme, round-trip communication time can be as much as forty minutes. Thus, all equipment and components that the astronaut crews will need to support a mission to Mars must be launched with them or be prepositioned for them on the planet's surface as much as two years in advance of their arrival. Because of the extended communications time, they cannot rely on constant real-time interaction with support personnel on Earth to help them with maintenance and repair tasks and must be able to work autonomously.

The necessity to minimize the mass of equipment launched towards Mars, while providing everything required to support a three-year mission, suggests that it will be important to perform maintenance at the lowest hardware levels where the replacement components are smallest. This further implies a need for extensive commonality of components across systems and vehicles to reduce the total number of distinct parts. The recent repairs performed onboard the ISS, described above, have helped to build confidence that performing repairs at this level is feasible. The ability to do so extensively will be enhanced if this approach is embraced from the beginning of design so that enabling features are incorporated.

Because of the need for autonomous operations, all information required to perform maintenance at the expected levels must be carried onboard the spacecraft. Enhanced methods must be available to allow the crew to effectively utilize this information. For example, it will probably be impractical to develop all possible maintenance procedures in advance of a mission so the availability of intelligent systems that can develop a maintenance procedure based on failure signatures and onboard system design information would be highly desirable.

Summary

Challenges we have recently faced and new strategies developed in response to the impending retirement of the Space Shuttle have provided an opportunity for growth and expansion of the in-space maintenance capability envelope. These new capabilities are very similar to those that will be required to enable future human exploration missions to Mars and beyond. Continuing operation of the International Space Station provides an opportunity to further enhance the maintenance and repair capabilities that will be necessary to allow humans to continue the exploration of space beyond the immediate vicinity of Earth.

References

Dempsey, C., W. Winn, M. Powell, and J. Riggs. "Post Shuttle Retirement Study: A New Logistics & Maintenance Support Strategy," unpublished white paper, June 2004.

Watson, J.K., M.S. Ivins, W.W. Robbins, E.A. Van Cise, P.C. Curell, R.S. Rust, R.A. Cunningham, and W.E. Roy "Supportability Concepts for Long-Duration Human Exploration Missions" presented at AIAA Space 2003 Conference, Long Beach, CA, September 2003.

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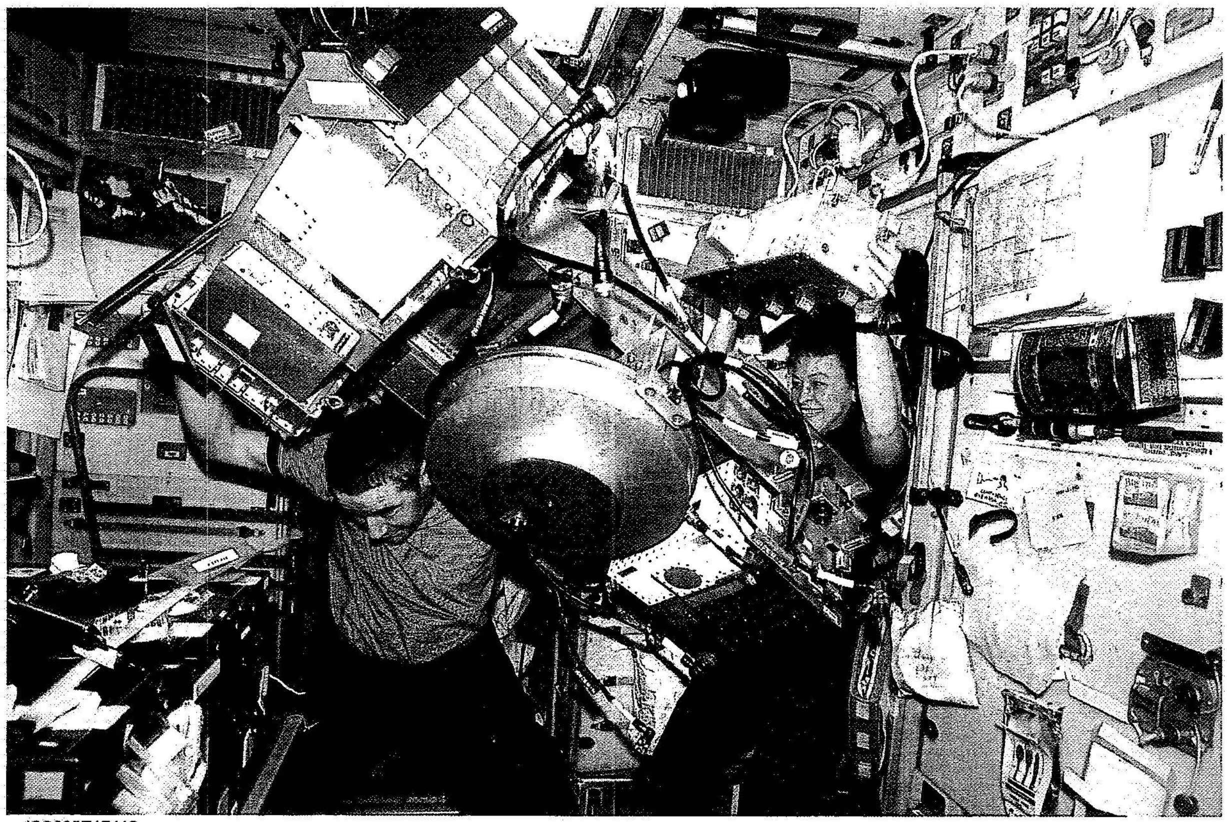
ISS Expedition 2 crewmember Jim Voss performs a soldering repair.



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ISS Expedition 5 crewmembers Valery Korzun and Peggy Whitson conduct a maintenance task on the Treadmill Vibration Isolation System.

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Expedition 6 crewmember Don Pettit uses a power drill to install fasteners on a rack closeout panel.