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Modification of the International Space Station USOS to Support Installation and Activation of the Node 3 Element

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ABSTRACT

The International Space Station (ISS) program is nearing an assembly complete configuration with the addition of the final resource node module in early 2010. The Node 3 module will provide critical functionality in support of permanent long duration crews aboard ISS. The new module will permanently house the regenerative Environment Control and Life Support Systems (ECLSS) and will also provide important habitability functions such as waste management and exercise facilities. The ISS program has selected the Port side of the Node 1 “Unity” module as the permanent location for Node 3 which will necessitate architecture changes to provide the required interfaces. The USOS ECLSS fluid and ventilation systems, Internal Thermal Control Systems, and Avionics Systems require significant modifications in order to support Node 3 interfaces at the Node 1 Port location since it was not initially designed for that configuration. This paper outlines the design, development, certification, and implementation of these changes in support of ISS assembly complete.

INTRODUCTION

The ISS program has reached an “assembly complete” configuration with the additional of the Starboard-6 truss section on STS-119. Although all of the capabilities required to support a six person crew and perform science aboard ISS are in place, additional hardware is still being prepared to increase the living area. The third resource node, or Node 3 element, is under final assembly and testing on the ground prior to a planned 2010 launch.

The purpose of Node 3 is to contain hardware necessary to support the six person crew on the USOS. Node 3 will house the Atmosphere Revitalization (CO2 and trace contaminant control, oxygen generation, and atmospheric monitoring) and the Water Recovery System racks (urine processing and water processing) as well as the Waste and Hygiene Rack and exercise facilities. This hardware is currently contained in the U.S. Laboratory element, which has allowed valuable operating experience in advance of six person crew operations. In order to maximize the science payload capability, however, this hardware is planned to be moved to the Node 3 element in 2010. The Node 3 element also includes an attached cupola which provides the crew with viewing for EVA robotic operations and general use.

The Node 3 element was added to the program after the deletion of the U.S. planned habitation module. The location selected for the Habitation module was the nadir, or earth facing, port on the Node 1 element. This port provided all of the interfaces required for the element and was flown configured for that purpose on STS-88, the first U.S. ISS mission. Node 3 has since been designed to the configuration of the Node 1 nadir port, while supporting all of the critical functions intended for that element.

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In 2007, an issue was identified with the approach corridor for vehicles docking with the ISS Russian segment. The resulting potential interference required either a reconfiguration of the Russian segment or the USOS. The program decided after evaluating both options to relocate the Node 3 module from the nadir port of the Node 1 module to the port. This would open the approach corridor and still provide a permanent location for the Node 3. In some respect, the move provided additional benefits:

- The module orientation is consistent with the other elements in the USOS, providing a better "floor down, ceiling up" perspective.
- The cupola element is oriented nadir, or earth facing, providing better viewing of the earth and the USOS surrounding components.

This paper discusses the integration of Node 3 into the ISS USOS at the port location on Node 1. It reviews all of the USOS modifications required to support the Node and ISS capability and a few of the key system analyses to verify system operations.

NODE 1 MODIFICATIONS

Node 1 requires several modifications to relocate critical utilities from the nadir facing port to the Port facing port. This section discusses these changes which are illustrated in Figures 1 and 2.

AVIONICS – The Node 1 avionics system does not provide much capability, but is complex in that it contains the network of cabling that interconnects the USOS and Russian segment. It is the heart of the ISS in that respect. The avionics modifications simply re-route all of the required signals from the nadir to the port. Because of signal loss issues, the audio/video cable required replacement.

ECLSS/ITCS – The ECLSS/ITCS distribution system is significantly modified in order to support the port side Node 3 installation as described below.

<u>ECLSS O2/N2</u> – Low pressure and recharge oxygen and nitrogen distribution lines are located at the nadir port for the original Node 3 location. The low pressure lines are disconnected at isolation quick disconnects located in the deck alcove and new lines are installed to the port bulkhead. Since there are no feed-throughs provided on the port bulkhead for oxygen and nitrogen, new parts are installed in place of unused electrical feed-throughs in order to avoid any new lines routed through hatch openings. The recharge lines are left unused, as there are no future plans to support oxygen and nitrogen re-supply from a vehicle docked to Node 3.

<u>ECLSS WRS</u> – Waste and potable water lines are also re-routed from the deck midbay to another set of new feed-throughs installed on the port bulkhead. These lines connect the water processor to the ISS USOS distribution, allowing for minimal water transfer operations.

<u>ECLSS ARS</u> – The ARS sample distribution system line is re-routed from the deck alcove to the port bulkhead. This provides a connection for the Node 3 Major Constituent Analyzer (MCA) to take samples from the other USOS elements.

<u>ECLSS THC</u> – The Node 1 THC system received the most significant design changes to allow installation of the Node 3 element on the port side of Node 1. The original IMV system was designed to support station growth from early configurations through assembly complete. The design air flow circuit is from the Russian segment, through Node 1, and into Node 3. From Node 3 the air returns to Node 1, and is sent to the U.S. Laboratory for conditioning. Since the existing ducting configuration would not support that flow routing, significant ducting modifications are required. The new configurations are illustrated in Figure 3 and 4.

The port side overhead supply duct is replaced with a new supply duct that routes the air from the Russian segment to Node 3. Because there is no isolation valve installed at the port side bulkhead, the nadir valve must be relocated to the port bulkhead. This required a closeout replacement to provide a provision for the actuator valve handle.

The Node 3 return was re-routed through the port and deck alcove sections to tie into the U.S. Lab return duct. In order to accommodate this routing, the port side IMV fan and silencers are removed. The existing damper valve and diffuser are also capped and are no longer required.

<u>ITCS</u> – The Node 3 element contains separate thermal loops for avionics cooling and ECLSS support. In order to provide more U.S. Laboratory cooling capacity, the U.S. Airlock servicing is planned to transfer the Node 3 thermal loops. In order to accomplish this, a new connection is made to the Node 1 bulkhead, and lines from the port side bulkhead are jumpered over to the Airlock cooling loop distribution. This in effect removes the flow from the U.S. Lab and establishes flow from Node 3.

NODE 1 TO NODE 3 VESTIBULE – Since the crew office desired a lights up and cupola nadir orientation of the Node 3 element, the resulting feed-through orientations are clocked ninety degrees apart. This results in many of the line routings to be more complex than other vestibule areas. Of particular concern is the IMV jumpers since the additional line length could result in pressure loss and acoustic noise concerns. Figures 5 and 6 illustrate the vestibule configuration.

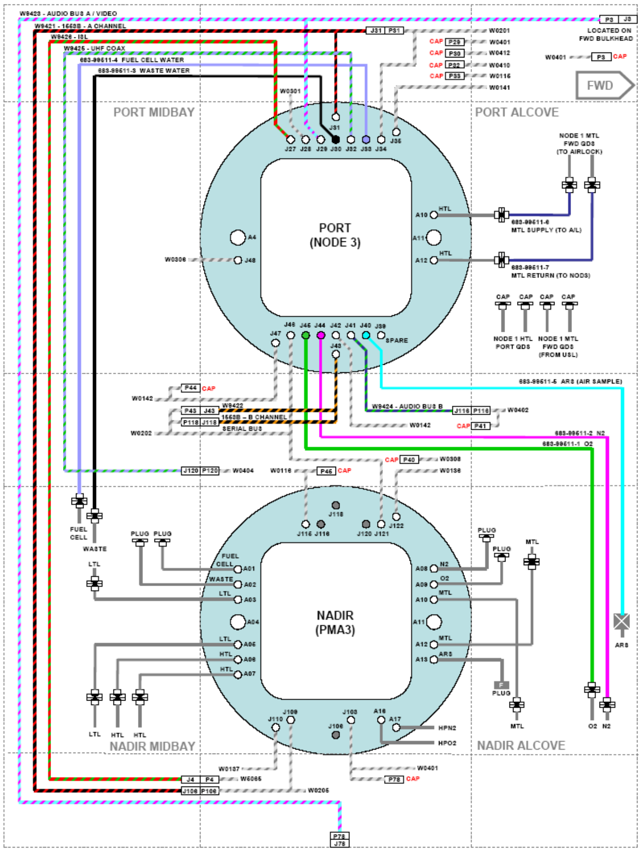

FIGURE 1 NODE 1 MODIFICATION ARCHITECTURE

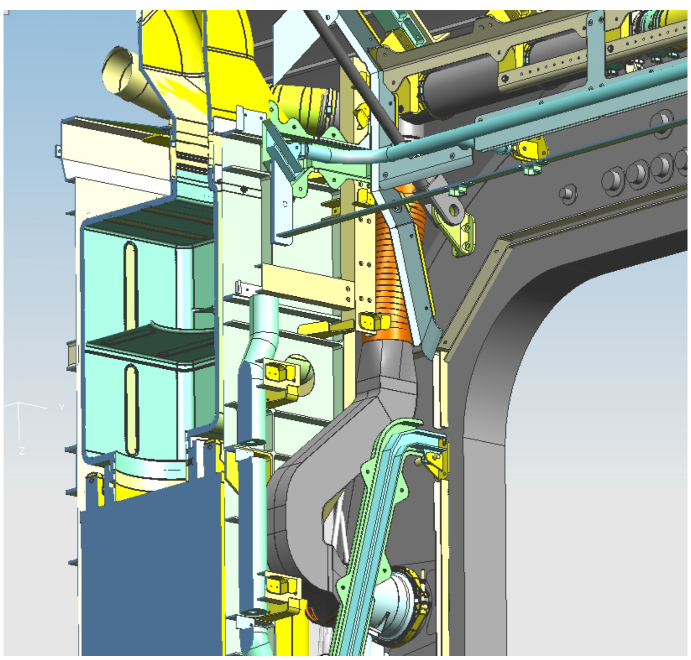

FIGURE 3 NODE 1 IMV SUPPLY MODIFICATION

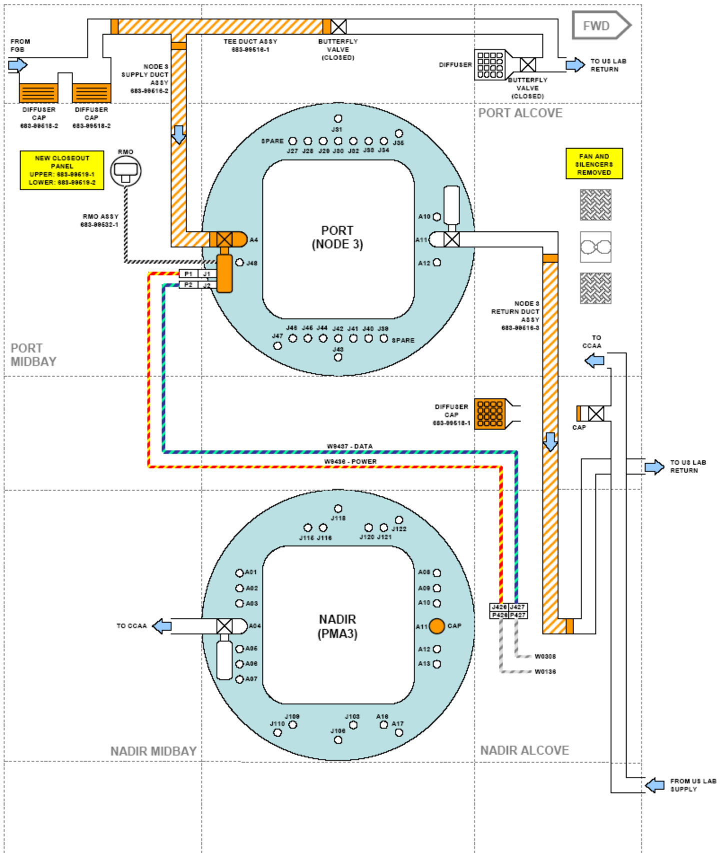

FIGURE 2 NODE 1 IMV MODIFICATION ARCHITECTURE

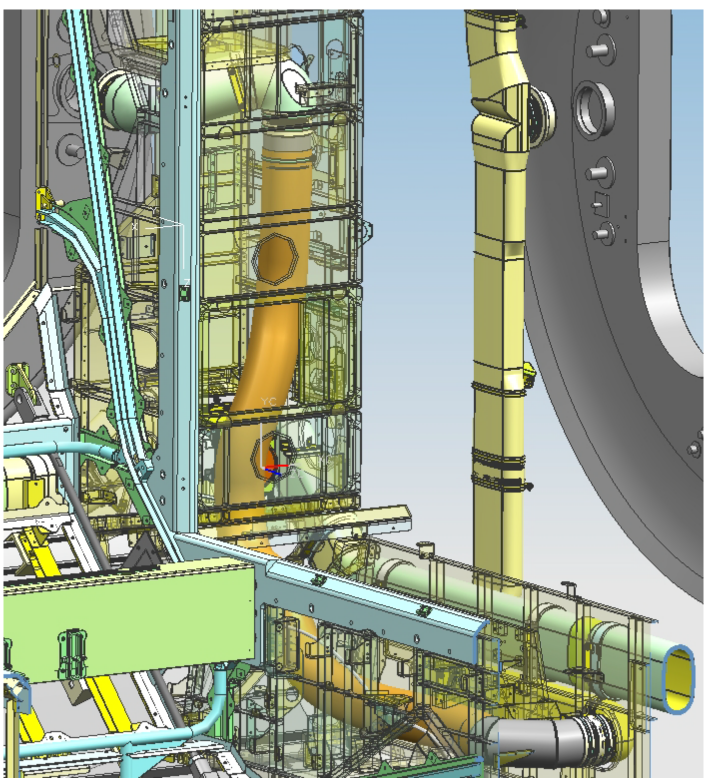

FIGURE 4 NODE 1 IMV RETURN MODIFICATION

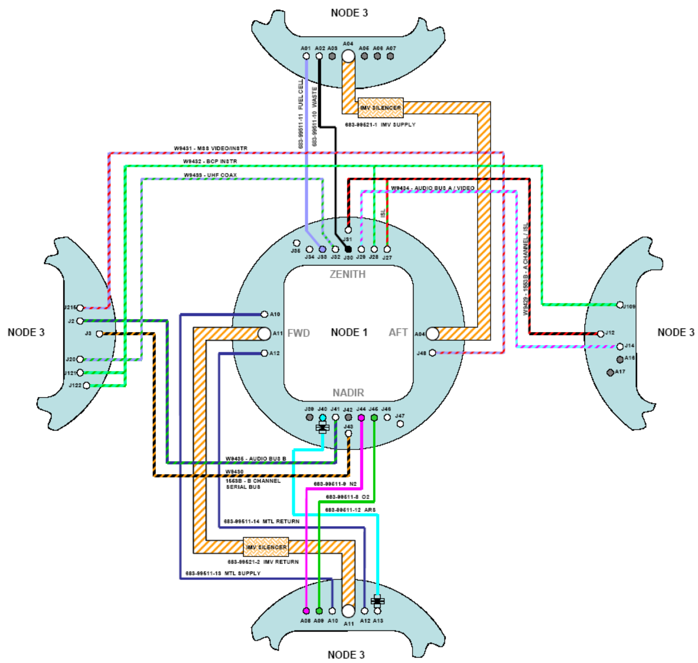

FIGURE 5 NODE 1 TO NODE 3 VESTIBULE ARCHITECTURE

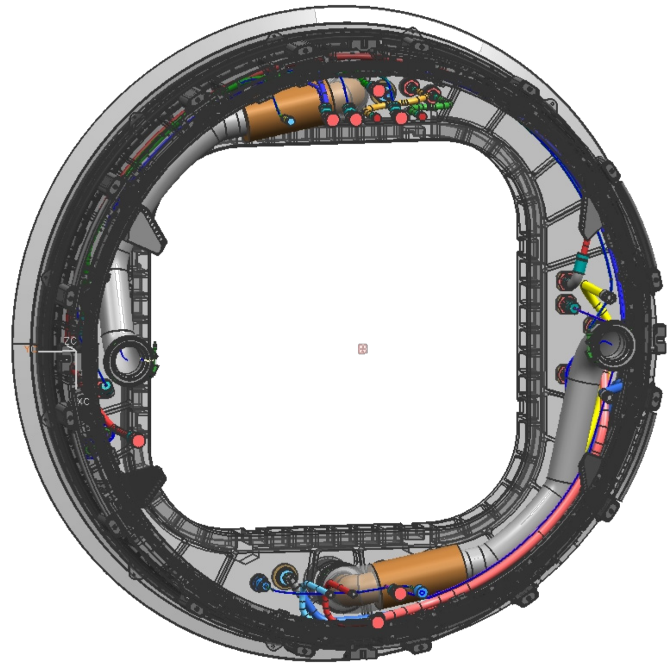

FIGURE 6 NODE 1 TO NODE 3 VESTIBULE LAYOUT

USOS EXTERNAL MODIFICATIONS

Node 1 and Node 3 require several modifications to relocate critical utilities from the S0 Truss segment and the U.S. Laboratory. In addition, the reorientation of Node 3 has affected the micro-meteoroid protection design. The external architecture changes are illustrated in Figure 7.

AVIONICS – The initial design for external utility connections from S0 to Node 3 included a complex utility tray which is deployed from the truss and attached to Node 3. Because of the new position of Node 3, the utility tray cannot be installed as originally planned. In order to provide the same connections, a new set of avionics cables will be installed from the S0 truss connector panel across the U.S. Laboratory and Node 1 to the Node 3 end cone. This will provide the required truss connections to operate Node 3. These new cables will be installed on an EVA prior to the arrival of Node 3.

EATCS – Since the Node 3 element has separate cooling loops, there are ammonia heat exchanger interfaces that must be installed in order to provide ammonia loop servicing. In the original nadir orientation of Node 3, the ammonia quick disconnects from the U.S. Laboratory were aligned directly adjacent and short jumpers could be used to make the connections. Since the Node 3 element is now located on the port side, longer jumpers will now be required in order to make the same connections. Because of the difficulty in handling long hoses on an EVA, there are concerns with this design. The longer hoses will also expose the jumpers to a harsher thermal environment and require additional protection.

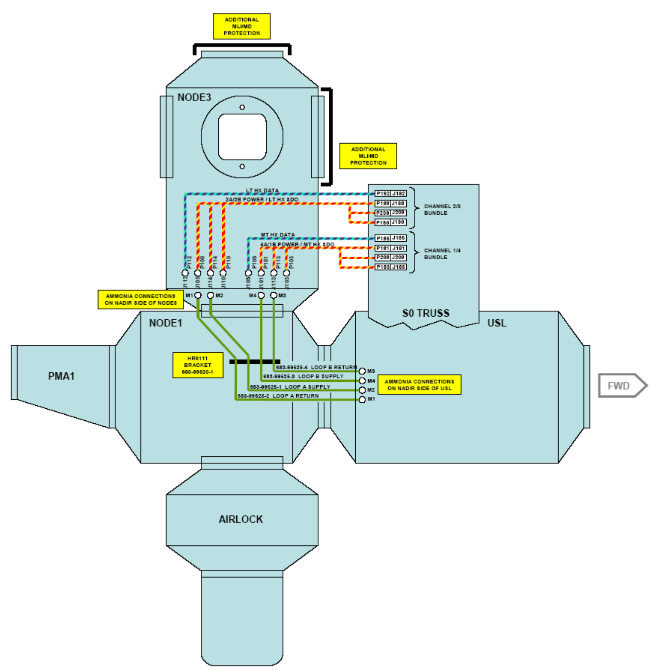

FIGURE 7 NODE 3 EXTERNAL ARCHITECTURE

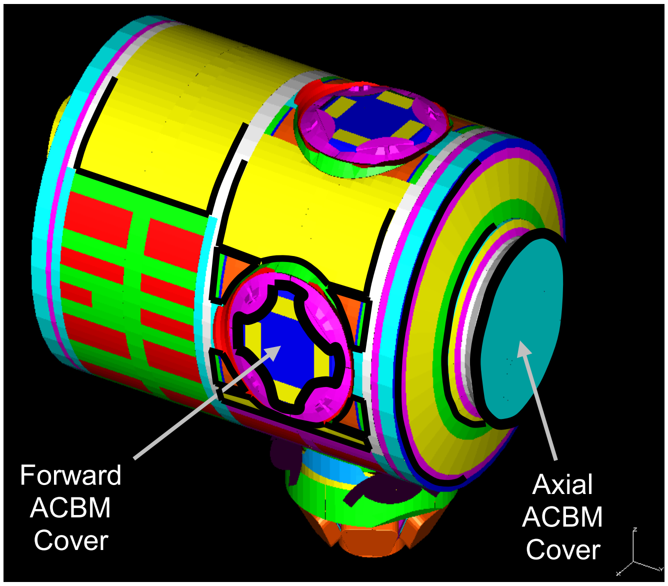

FIGURE 8 NODE 3 EXTERNAL MM/OD PROTECTION

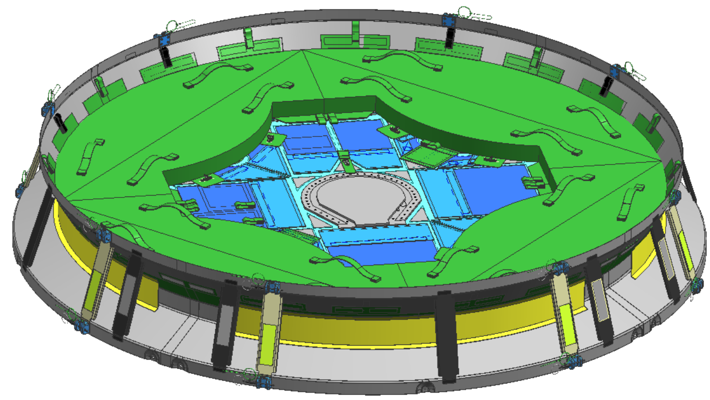

FIGURE 9 NODE 3 AXIAL ENDCONE LAYOUT

STRUCTURES – Each of the modules is protected from micro-meteoroid impact with a series of shields. The shield configuration is determined by the probability of impact based on the orientation relative to the ISS vehicle and the flight direction. Since the Node 3 element was repositioned relative to the flight direction, the exposed sections were not sufficiently protected. As a result several additional provisions were required to protect the element's primary structure from impact. These areas are illustrated in Figure 8.

First, the main surfaces of the element were enhanced by adding additional protection. In addition, the forward facing radial port required additional shielding that is provided by additional layers in the berthing mechanism center disc cover. Metallic shields were added as well as additional layers of Nextel fabric for surface protection.

The new Node orientation also results in a unique circumstance: an exposed axial port berthing mechanism. Because this had never been planned for, a new design was developed to provide protection in both the center disc cover and the exposed corners. Modifications similar to the forward facing radial port were made to the center cover. Since there are no corner shields on the axial port berthing mechanism, a new design was developed to provide a deployable shield to cover the exposed areas. The shields are launched in place on the stovepipe structure, and then deployed on an EVA to cover the exposed corners. The shields themselves are a unique design of layered foam, Nextel, and Kevlar layers designed to absorb an impact. This design is illustrated in Figure 9.

INTEGRATION ANALYSES

The changes made to the architecture of Node 1 require verification before implementation on orbit to assure that the Node 3 element will perform as designed after installation. The Node 1 inter-module ventilation configuration changes required extensive analysis and characterization testing to verify system performance could be maintained in the new configuration. The minimum airflow and supply pressure at the Node 3 interface must be met with the new ducting configurations or else the system will not perform as designed and critical functions such as carbon dioxide and oxygen partial pressure control may not be maintained properly, leaving the crew at risk.

System testing was performed in the IMV test bed at NASA Marshall Space Flight Center in Huntsville, Alabama. The ducting changes and the Node 3 element were simulated and airflows were measured to determine system performance. The resulting airflow at the Node 3 interface was measured as 135 CFM (requirement is 120 CFM). The minimum supply pressure was measured as 1.03 inches of water (requirement is 0.47 inches of water). Several other possible ducting configurations were tested and in all cases the minimum requirements were met. The predicted performance of the system is well in family with the rest of the USOS IMV system.

CONCLUSION

The addition of the Node 3 element to the ISS USOS will provide critical living space for the crew. The consolidation of ECLSS and crew system hardware into the Node 3 element in support of a six person crew will result in a more efficient and productive living and working environment. This will allow the U.S. Laboratory to be utilized in conjunction with laboratories operated by the European Space Agency and the Japanese Space Agency to fulfill the science mission of the International Space Station.

REFERENCES

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DEFINITIONS, ACRONYMS, ABBREVIATIONS

CFM: Cubic Feet per Minute

ECLS: Environmental Control and Life Support

ECLSS: Environment Control and Life Support System

FT/MIN: Feet per Minute

IMV: Inter-module Ventilation

ISS: International Space Station

NASA: National Aeronautics and Space Association

THC: Temperature and Humidity Control

UPA: Urine Processor Assembly

US: United States

USOS: United States Operating Segment

WRS: Water Recovery Subsystem