# International Space Station Environmental Control and Life Support System Status: 2009 - 2010

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**The International Space Station (ISS) Environmental Control and Life Support (ECLS) system includes regenerative and non-regenerative technologies that provide the basic life support functions to support the crew, while maintaining a safe and habitable shirtsleeve environment. This paper provides a summary of the U.S. ECLS system activities over the past year, covering the period of time between March 2009 and February 2010. The ISS continued permanent crew operations, with the start of Phase 3 of the ISS Assembly Sequence and an increase of the ISS crew size from three to six. Work continues on the last of the Phase 3 pressurized elements.**

## I. Introduction

THE ISS is a global partnership of 15 nations representing six space agencies, including the United States National Aeronautics and Space Administration (NASA), Russian Space Agency (Roscosmos), European Space Agency (ESA), Japan Aerospace Exploration Agency (JAXA), Canadian Space Agency (CSA), and Italian Space Agency (ASI). The participating countries are Belgium, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands, Norway, Russia, Spain, Sweden, Switzerland, the United States, and the United Kingdom. The ISS operates at an altitude of approximately 310 to 350 km (170 to 190 nautical miles) and an inclination of 51.6° to the equator.

The International Space Station Program is divided into three phases. Phase 1, completed in 1998, consisted of the joint Shuttle-Mir missions to prepare for the ISS build phases. Phase 2, the initial ISS construction phase, began assembly in November 1998, established permanent crew operations in November 2000, and culminated with the Joint Airlock delivery in July 2001. Phase 3 will increase the crew size from three-person to six-person and will complete the ISS assembly. A total of 95 flights have been completed to ISS, including 32 Shuttle flights. Figure 1 shows photos of key events in the past year.

The ISS ECLS system provides the basic life support functions to support the crew, while maintaining a safe and habitable shirtsleeve environment. The ECLS hardware providing this functionality is organized into seven subsystems: Atmosphere Revitalization (AR), Temperature and Humidity Control (THC), Fire Detection and Suppression (FDS), Atmosphere Control and Supply (ACS), Water Recovery and Management (WRM), Waste Management (WM), and Vacuum System (VS). The current principle ECLS hardware distribution across ISS elements is shown in Figure 2 and 3. The ECLS functions by subsystem are listed below:

Atmosphere Revitalization:
- Control and disposal of carbon dioxide ($CO_2$)
- Control of airborne trace contaminants
- Oxygen ($O_2$) supply via generation

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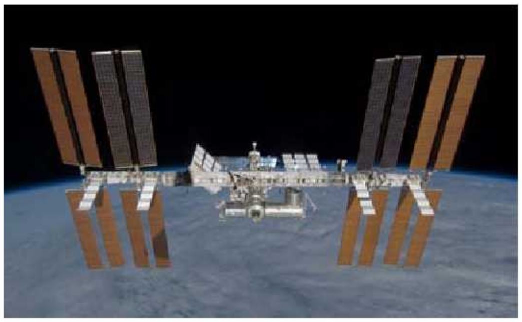
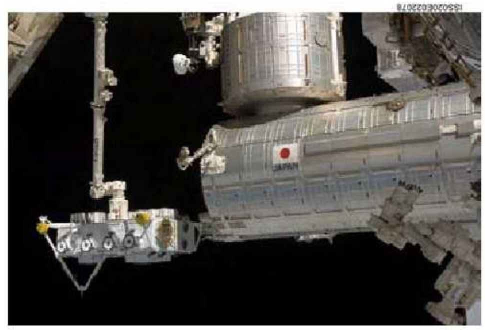


**ISS after Flight 15A**



**JEM – EF Being Deployed on Flight 2J/A**

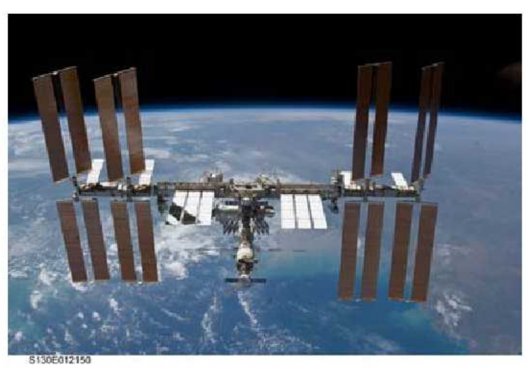
**OGA Filter Removed During Flight 17A**

**5th Joint Airlock O2 Tank Delivery on Flight ULF3**

**Node 3 and Cupola Delivery on Fight 20A**

**UPA DA R&R on Fight 20A**

**Relocating AR Rack into Node 3 on Fight 20A**



**ISS after Flight 20A**

**Figure 1 – Pictures of Key Events for the Year**

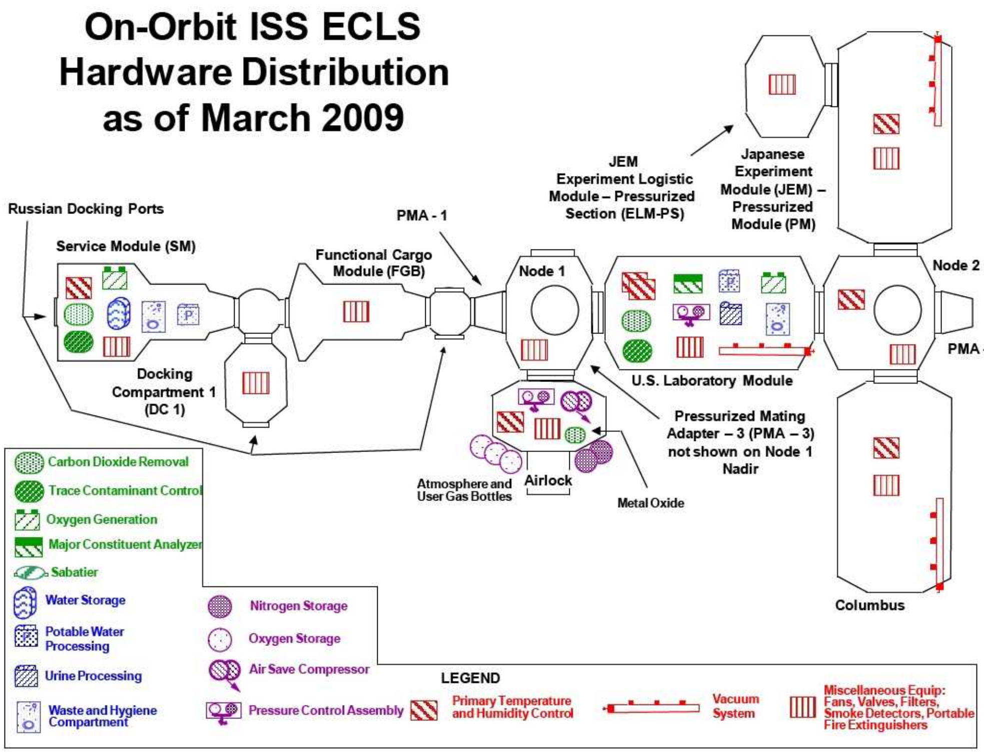



**Figure 2 – ISS ECLS Hardware Distribution at the Start of This Time Period Covered by This Paper**

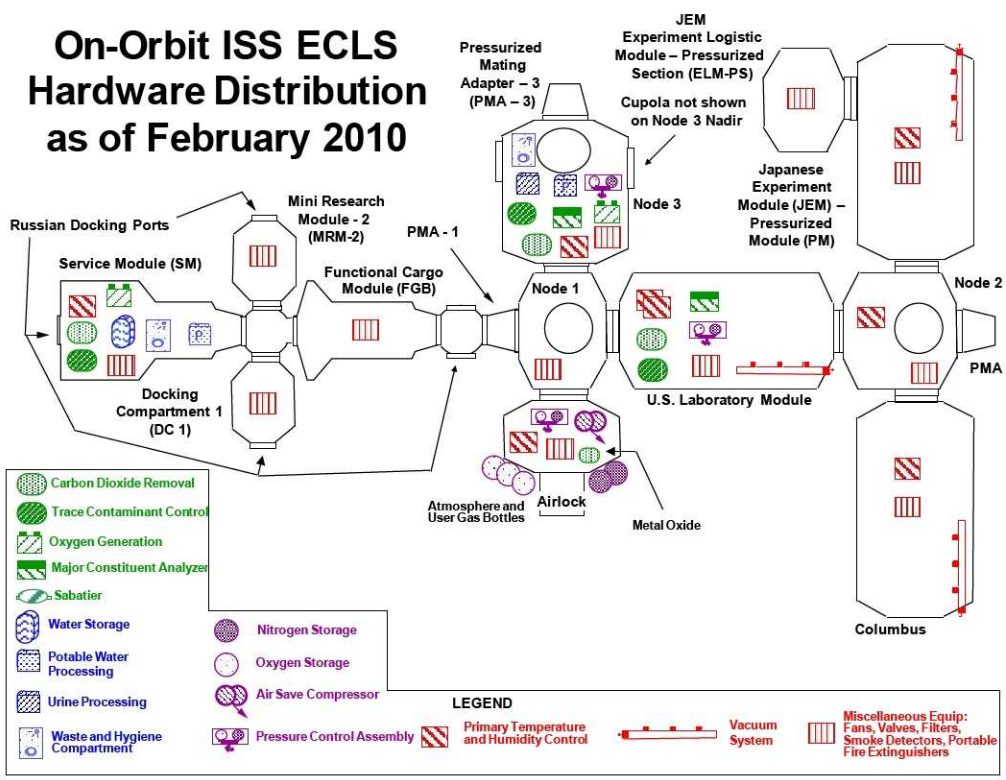



**Figure 3 – ISS ECLS Hardware Distribution at the End of This Time Period Covered by This Paper**

- Atmosphere monitoring of major constituents, including $CO_2$, $O_2$, nitrogen ($N_2$), hydrogen ($H_2$), methane ($CH_4$), and water vapor ($H_2O$)

Temperature and Humidity Control:
- Cabin air temperature and humidity control
- Equipment air-cooling
- Inter- and intra-module ventilation for crew comfort and station level control of $CO_2$, $O_2$, and trace contaminants
- Airborne particulate and microbial control

Fire Detection and Suppression:
- Smoke detection
- Fire extinguishment

Atmosphere Control and Supply:
- Total pressure and $O_2$ partial pressure control during normal one-atmosphere operations and Extra Vehicular Activity (EVA) preparation in the Joint Airlock at 70 kPa (10.2 psia)
- Total pressure monitoring and loss of pressure (dp/dt) monitoring
- Stored gaseous $N_2$ and $O_2$ supply and replenishment
- Over/under pressure relief to maintain structural integrity
- Pressure equalization between modules

Water Recovery and Management:
- Potable and hygiene water supply
- Wastewater and urine water collection, recovery, and disposal

Waste Management:
- Urine/fecal collection and processing

Vacuum System:
- Vacuum venting ($1.2 \times 10^{-3}$ torr-liters/sec at $10^{-3}$ torr) and maintenance ($1.0 \times 10^{-6}$ torr) for payload support.

The basic ISS ECLS design and architecture has been previously described and updated in papers previously written and presented at the International Conference on Environmental Systems [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, and 14]. This paper will focus on the ISS ECLS current status and updates between March 2009 until the end of February 2010, with activities that included the continuing permanent crew presence and the design/testing/ manufacturing of the hardware to be able to support six crewmembers on ISS.

## II. ISS ON-ORBIT OPERATIONS

Table 1 lists the ISS flight summary with special focus on key ECLS activities, Table 2 summarizes the Progress Resupply and Soyuz Taxis Flights to ISS, and Table 3 summaries the non-Russian Resupply Vehicles. There were fifteen flights to ISS from March 2009 until the end of February 2010. Of the fifteen flights nine were Russian flights. The nine Russian flights include four Soyuz flights, one new Russian pressurized module, and four Progress flights. One of the six non-Russian flights to ISS was the delivery of the second non-Russian resupply vehicle to ISS, the Japan Aerospace Exploration Agency (JAXA) H-II Transfer Vehicle (HTV). The five U.S. flights delivered one new pressurized module. A more detailed discussion of the key ECLS related occurrences on each flight for the year divided by Increments is provided below.

**<u>Increment 18:</u>**

Increment 18 crew members were ending their stay on ISS at the start of the time period that is described in this paper. They continued to do experiments and maintenance tasks. On March 5th the crew removed and replaced (R&R'ed) the Oxygen Generation System (OGS) Hydrogen (H2) Sensor Orbital Replacement Unit (ORU), since the old sensor's limited life was almost expired. Unfortunately, one of the three sensors in the ORU started to drift

**Table 1 - ISS Flight Summary**

| Launch Date | Flight | Key Elements | Key Events (ECLSS related) |
|---|---|---|---|
| *20-Nov-98* | *1A/R* | *FGB (Zarya)* | *Unmanned launch* |
| 4-Dec-98 | 2A | Node 1 (Unity), PMA 1 and 2 | First entry into ISS |
| 27-May-99 | 2A.1 | SpaceHab | Logistics/maintenance flight |
| 19-May-00 | 2A.2a | SpaceHab | Logistics/maintenance flight |
| *12-July-00* | *1R* | *Service Module (Zvezda)* | *Unmanned launch* |
| 8-Sept-00 | 2A.2b | SpaceHab | Logistic/maintenance flight; Entry into Service Module (SM); and A/C installation in the SM |
| 11-Oct-00 | 3A | Z1 truss, PMA 3 | Z1 truss, PMA3 installation; Z1 dome pressurization |
| *31-Oct-00* | *2R* | *Soyuz TM* | *Permanent crew ops - Expedition 1(ISS Commander – Williams (Bill) Sheperd; Soyuz Commander – Yuri Gidzenko; and Flight Engineer- Sergei Kritkalev); Vozdukh, Elektron, 2nd A/C installation & activation* |
| 30-Nov-00 | 4A | P6 truss - solar arrays, radiators | U.S. power activation |
| 7-Feb-01 | 5A | Laboratory Module (Destiny) | U.S. Lab activation - AR rack installation and activation |
| 8-Mar-01 | 5A.1 | MPLM (Leonardo) | Expedition 2 replacement crew (ISS Commander – Yury Usachev; Flight Engineer – James Voss; Flight Engineer – Susan Helms); first payload rack; logistic transfer |
| 19-Apr-01 | 6A | MPLM (Raffaello), Space Station Robotic Manipulator System (SSRMS) | Logistics transfer, additional payload racks |
| 12-July-01 | 7A | Joint Airlock (Quest), High Pressure Gas Assemblies (2 O2 and 2 N2) | The last EVA was performed out of the Joint Airlock; USOS ACS activation and checkout |
| 10-Aug-01 | 7A.1 | MPLM (Leonardo) | Expedition 3 replacement crew (ISS Commander – Frank Culbertson; Soyuz Commander – Vladimir Dezhurov; and Flight Engineer – Mikhail Tyurin), logistic transfer, additional payload racks |
| *14-Sept-01* | *4R* | *Docking Compartment 1 (Pirs)* | *EVA capability out of the Russian Segment; additional Soyuz/Progress Docking port* |
| 5-Dec-01 | UF1 | MPLM (Raffaello) | Expedition 4 replacement crew (ISS Commander – Yury Onufrienko; Flight Engineer – Daniel Bursch; and Flight Engineer – Carl Walz), Logistic transfer |
| 8-Apr-02 | 8A | S0 Truss, Mobile Transporter (MT) | |
| 5-June-02 | UF2 | MPLM (Leonardo); MBS | Expedition 5 replacement crew (ISS Commander – Valery Korzun; Flight Engineer – Peggy Whitson; and Flight Engineer Sergei Treschev) Logistics transfer, additional payload racks |
| 7-Oct-02 | 9A | S1 Truss | |
| 24-Nov-02 | 11A | P1 Truss | Expedition 6 replacement crew (ISS Commander – Kenneth Bowersox; Flight Engineer – Donald Pettit; and Flight Engineer – Nikolai Budarin) |
| *26-Apr-03* | *6S* | *Soyuz TMA* | *Expedition 7 replacement crew (ISS Commander- Yuri Malenchenko; and Flight Engineer – Ed Lu)* |
| *18-Oct-03* | *7S* | *Soyuz TMA* | *Expedition 8 replacement crew (ISS Commander- Michael Foale; Flight Engineer – Alexander Kaleri); and Visiting Flight Engineer – Pedro Duque [ESA]* |

Note: Italics represent Russian flights. Progress and Soyuz Taxi flights not included.

**Table 1 - ISS Flight Summary (cont'd)**

| Launch Date | Flight | Key Elements | Key Events (ECLSS related) |
|---|---|---|---|
| *19-Apr-04* | *8S* | *Soyuz TMA* | *Expedition 9 replacement crew (ISS Commander-Gennady Padalka; Flight Engineer – Mike Fincke); and Visiting Flight Engineer – Andre' Kuipers [ESA]* |
| *14-Oct-04* | *9S* | *Soyuz TMA* | *Expedition 10 replacement crew (ISS Commander-Leroy Chiao; Flight Engineer – Salizhan Sharipov); and Visiting Flight Engineer – Yuri Shargin* |
| *15-Apr-05* | *10S* | *Soyuz TMA* | *Expedition 11 replacement crew (ISS Commander-Sergei Krikalev; Flight Engineer – John Phillips); and Visiting Flight Engineer – Roberto Vittori [ESA]* |
| 26-July-05 | LF1 | MPLM (Raffaello); ESP- 2 | Logistics transfer, an additional payload rack, and a control momentum gyro (CMG) |
| *30-Sept-05* | *11S* | *Soyuz TMA* | *Expedition 12 replacement crew (ISS Commander-William McArthur; Flight Engineer –Valery Tokarev); and ISS Visitor – Gregory Olsen* |
| *29-Mar-06* | *12S* | *Soyuz TMA* | *Expedition 13 replacement crew (ISS Commander-Pavel Vinogradov; Flight Engineer –Jeffery Williams); and Brazilian Space Agency Astronaut - Marcos C. Pontes* |
| 4-July-06 | ULF1.1 | MPLM (Leonardo) | Expedition 13 third crewmember (Flight Engineer-Thomas Reiter (ESA))<br><br>Delivery of OGS Rack |
| 9-Sept-06 | 12A | P3/P4 Truss- solar arrays, radiator | |
| *18-Sept-06* | *13S* | *Soyuz TMA* | *Expedition 14 replacement crew (ISS Commander-Michael Lopez-Alegria; Flight Engineer –Mikhail Tyurin); and ISS Visitor – Anousheh Ansari* |
| 9-Dec-06 | 12A.1 | P5 Truss; SpaceHab; ICC | Expedition 14 replacement crew (Flight Engineer-Sunita Williams replacing Thomas Reiter (ESA)) |
| *7-Apr-07* | *14S* | *Soyuz TMA* | *Expedition 15 replacement crew (ISS Commander-Fyodor Yurchikhin; Flight Engineer - Oleg Kotov); and ISS Visitor – Charles Simonyi* |
| 9-June-07 | 13A | S3/S4 Truss- solar arrays, radiator | Expedition 15 replacement crew (Flight Engineer-Clay Anderson replacing Sunita Williams) |
| 8-Aug-07 | 13A.1 | S5 Truss; SpaceHab; ESP-3 | |
| *10-Oct-07* | *15S* | *Soyuz TMA* | *Expedition 16 replacement crew (ISS Commander-Peggy Whitson; Flight Engineer – Yuri Malenchenko); and ISS Visitor – Muszaphar Shukor Al Masri* |
| 23-Oct-07 | 10A | Node 2 (Harmony) | Expedition 16 replacement crew (Flight Engineer-Dan Tani replacing Clay Anderson) |
| 7-Feb-08 | 1E | Columbus Module; ICC-Lite | Expedition 16 replacement crew (Flight Engineer-Leo Eyharts (ESA) replacing Dan Tani) |
| 11-Mar-08 | 1J/A | Japanese Experiment Logistics Module-Pressurized Section (ELM-PS) and part of "Kibo"; Canadian Special Purpose Dexterous Manipulator (SPDM) "Dextre" | Expedition 16 replacement crew (Flight Engineer-Garrett Reisman replacing Leo Eyharts (ESA)) |
| *8-Apr-08* | *16S* | *Soyuz TMA* | *Expedition 17 replacement crew (ISS Commander-Sergei Volkov; Flight Engineer – Oleg Valeriavich Kononenko); and ISS Visitor – So-yeon Yi* |

<u>Note:</u> Italics represent Russian flights. Progress and Soyuz Taxi flights not included.

**Table 1 - ISS Flight Summary (cont'd)**

| Launch Date | Flight | Key Elements | Key Events (ECLSS related) |
|---|---|---|---|
| 31-May-08 | 1J | Japanese Experiment Module – Pressurized Module (JEM-PM) a part of "Kibo"; and the Japanese Remote Manipulator System (RMS) | Expedition 17 replacement crew (Flight Engineer-Greg Chamitoff replacing Garrett Reisman |
| *12-Oct-08* | *17S* | *Soyuz TMA* | *Expedition 18 replacement crew (ISS Commander-Michael Fincke; Flight Engineer – Yuri Lonchakov); and ISS Visitor – Richard Garriott* |
| 14-Nov-08 | ULF2 | MPLM (Leonardo) | Expedition 18 replacement crew (Flight Engineer-Sandra Magnus replacing Greg Chamitoff)<br><br>Delivery of WRS Rack 1&2, WHC, and other 6 crew hardware. |
| 15-Mar-09 | 15A | S6 Truss - solar arrays, radiator | Expedition 18 replacement crew (Flight Engineer-Koichi Wakata (JAXA) replacing Sandra Magnus) |
| *26-Mar-09* | *18S* | *Soyuz TMA* | *Expedition 19/20 replacement crew (ISS Commander - Gennady Ivanovich Padalka, Flight Engineer - Dr. Michael Barratt); and ISS Visitor Charles Simonyi (on his second ISS visit)* |
| *27-May-09* | *19S* | *Soyuz TMA* | *ISS starts 6 crew members operations on ISS with Expedition 20 (Future Expedition 21 Commander – Frank DeWinne (ESA), Flight Engineer – Roman Romanenko, and Flight Engineer – Bob Thirsk (CSA))* |
| 15-July-09 | 2J/A | Japanese Exposed Facility a part of "Kibo" | Expedition 20 replacement crew (Flight Engineer-Tim Kopra replacing Koichi Wakata (JAXA)) |
| 28-Aug-09 | 17A | MPLM (Leonardo) | Expedition 20 replacement crew (Flight Engineer-Nicole Stott replacing Tom Kopra)<br><br>Delivery of the Node 3 AR Rack. |
| *30-Sept-09* | *20S* | *Soyuz TMA* | *Expedition 21 replacement crew (Future Expedition 22 Commander - Jeffery Williams and Flight Engineer – Maxime Suraev); and ISS Visitor Guy Laliberté* |
| *10-Nov-09* | *5R* | *MRM 2 (Poisk)* | *Will replace DC 1 for EVA capability out of the Russian Segment; fourth Soyuz/Progress Docking port on SM Zenith; and it allows scientific research* |
| 16-Nov-09 | ULF3 | Two Express Logistic Carriers with unpressurized cargo | Delivery of the 5th Airlock Oxygen Tank |
| *20-Dec-09* | *21S* | *Soyuz TMA* | *Expedition 22 replacement crew (Future Expedition 23 Commander – Oleg Kotov, Flight Engineer – Soichi Noguchi (JAXA), and Flight Engineer – Timothy J. Creamer)* |
| 8-Feb-10 | 20A | Node 3 (Tranquility) and Cupola | Final home for the OGS Rack, WRS Rack 1 & 2, WHC, and Node 3 AR Rack. |

Note: Italics represent Russian flights. Progress and Soyuz Taxi flights not included.

Acronyms:

FGB - Functional Cargo Block
A/C - Air Conditioner
AR - Atmosphere Revitalization
EVA – Extra Vehicular Activity
MPLM – Multi-Purpose Logistic Module
USOS – United States On-Orbit Segment
Z - Zenith
S – Starboard
P – Port
MBS – Mobile Base System
U.S. – United States
ICC – Integrated Cargo Carrier
ESP - External Stowage Platform
ACS – Atmosphere Control and Storage
PMA – Pressurized Mating Adapter
WRS – Water Recovery System
WHC – Waste and Hygiene Compartment
OGS – Oxygen Generation System

immediately after it was installed. Since only one sensor of the three drifted, it was decided to inhibit it to prevent any problems with the operation of the OGS.

On March 10th the Increment 18 crew performed Stage Extra Vehicular Activity (EVA) 21A out of the Docking Compartment 1 (DC 1). The primary purpose of the EVA was to install payloads on the outside of the Russian Segment (RS), take photographs of the outside of the RS, and installed some new docking antennas on DC 1.

On the next day, the crew installed a protective cover over the Joint Airlock Prebreathe Hose Assembly (PHA) quick disconnect (QD) to protect it against inadvertent kick loads during the upcoming EVAs during the Shuttle docked operations. This was done, since the one of the three fasteners could not be re-engaged after the QD had been R&R'ed the month before. Also, to get ready for the upcoming Shuttle flight the Increment crew cleaned the Node 1 smoke detector #2 to prevent it from generating a false alarm during the docked operations.

15A:

On March 15th the Space Shuttle Flight 15A launched from Kennedy Space Center (KSC) and docked to ISS on March 17th. During the docked operations, the crew installed the S6 Truss Segment, deployed the S6 solar arrays and the electrical power system radiator, performed three EVAs, R&R'ed the Urine Processor Assembly (UPA) Distillation Assembly (DA) to return the old unit to determine the cause of the high current problem and the periodical single speed sensor problem, filled and transferred 12 contingency water containers (CWCs) of water, transferred 11.3 kg (25 lbm) of gaseous nitrogen (GN2) from the Space Shuttle tanks to the Joint Airlock tanks, and R&R'ed the UPA Recycle Filter Tank Assembly (RFTA) twice. The UPA RFTA had to be replaced twice, since the crew had trouble filling the first RFTA. After the crew filled the second RFTA they were able to operate the UPA and show that the new UPA DA would operate. The Space Shuttle undocked from ISS on March 25th and successfully landed at the KSC on March 28th.

As the crew was getting ready to return back to earth, the ground continued to monitor the slowly increasing Oxygen Generation Assembly (OGA) pump delta pressure. On April 7th visiting astronaut Charles Simonyi and Increment 18 crew members Michael Fincke and Yuri Lonchakov undocked Soyuz TMA-13/17S and landed in the steppes of Kazakhstan.

**Increment 19:**

The Soyuz with 2 of the 3 Increment 19 crew members launched on March 26th with Gennady Ivanovich Padalka [Commander (CDR)] on his second rotation to ISS and Dr. Michael Barratt [Flight Engineer (FE)] plus visiting astronaut Charles Simonyi on his second self-paid ISS visit. It docked to ISS on March 28th at the aft docking port of the Service Module (SM). The interesting fact about this Increment was that these two ISS crew members made up part of Increment 19 and Increment 20 crew too.

Two days after the new Increment crew docked to ISS, the crew had their first ECLS problem when the Node 2 Moderate Temperature Loop (MTL) Nitrogen Interface Assembly (NIA) vent valve inadvertently opened. This problem was a repeat of a Program accepted ground problem that could not be resolved prior to launching Node 2. When the valve opened, it vented the MTL Internal Thermal Control Subsystem (ITCS) pump package accumulator to cabin pressure. This problem did not affect ITCS pump operation for short term operations and the ground can reclose the valves quickly. Two weeks later the problem recurred again. The Program continues to investigate the problem to try and understand the cause but, it is only considered to be an operational nuisance.

On April 14th the Service Module (SM) Vozdukh was put in automatic mode in preparation for a SM avionic restart activity that was planned for later that day. Unfortunately, the Vozduhk experienced a carbon dioxide (CO2) sensor error. The Vozdukh needs the CO2 sensor to control the Vozdukh to a specific partial pressure of CO2 (ppCO2) set point in the automatic mode. Due to this problem, and, in order, to reestablish Vozdukh CO2 removal, the ground team directed the crew to put the Vozdukh in manual mode, which means that the Vozdukh half cycle is controlled on a specific fixed time and the Vozdukh blower is operated at a specific fixed speed. That same day one of the U.S. six crew checkout requirements was completed when the Waste and Hygiene Compartment (WHC) water tank automatically refilled.

Ten days later the crew had two problems in the United States (U.S.) Laboratory Module. The first problem was that a cabin smoke detector (SD) in the U.S. Laboratory module indicated a fire for 2 seconds but the crew and the ground investigated the problem and confirmed it was a false alarm. The other problem was that UPA experienced a check valve fault during four consecutive runs. This problem was a re-occurrence of the sticky check valve in a UPA line that delivers distillate water to the Water Processor Assembly (WPA). The check valve was originally designed to prevent back flow from the waste water tank in the WPA, but as described below is not required for this function. Since the UPA had lost the capability to process urine from the U.S. WHC, the crew was directed to use the SM toilet until the ground could resolve this problem. Three days later the ground tried multiple times to command the UPA to start processing again but the check valve would not open.

33P:

Progress 33P launched from Baikonur on May 7th and docked to ISS at DC 1 on May 12th. It brought 50 kg (110 lbm) of oxygen; 13.6 kg (29.9 lbm) of propellant nitrogen that was available for cabin usage; spare parts for the U.S. WHC; and spare Russian ECLS hardware. Unfortunately, the U.S. tool to remove the sticky UPA check valve did not make this flight and a new plan had to be developed to remove the check valve. The same day, as the Progress docked the ground team was able to successfully write to the UPA Electrically Erasable Programmable Read Only Memory (EEPROM). This capability was necessary to allow the ground team to modify the UPA software after UPA check valve removal. Also, during this time the ISS CDR Gennady Padalka and FE-1 Michael Barratt started preparing for the next two Russian Stage EVAs in early June.

Two days after the Progress had docked to ISS the crew started to troubleshoot a Columbus condensing heat exchanger water separator problem by attaching a water sample bag to the water separator via flight support equipment. This was a continuation of troubleshooting that was started back during Increment 17.

On May 18th the crew successfully removed the failed UPA check valve and some shims from the UPA Fluids Control and Pump Assembly (FCPA) in Water Recovery System Rack - 2 (WRS-2). After the task was completed the crew loaded pretreated urine into the UPA for a processing cycle and to perform a leak test to make sure the repaired ORU was not leaking. Due to the nature of the UPA design, the peristaltic pump provides sufficient backflow protection with the check valve removed. After the processing cycle was completed the ground team commanded the UPA to shutdown mode to provide additional backflow protection from the WPA waste tank. Two days after the UPA was repaired, the crew was given the 'go ahead' to consume the WRS processed potable water for the first time.

To get ready for the arrival of six permanent crew members on ISS, the OGS Rack was configured for activation on May 22nd and placed in standby mode. Three days later the OGA was commanded to 25% production to start increasing the O2 concentration inside ISS.

As the crew waited for the arrival of the next Soyuz, they removed the UPA RFTA QD key on May 28th from serial number (S/N) 003. This was the RFTA that was only partially filled during 15A due to a suspected blockage in the RFTA fill line. The ground believed that the filling problem was due to a combination of fluid dynamic pressures and air entrapment at the inline 100 micron filter. Removing the RFTA QD key allowed the crew to fill the RFTA employing a work-around using another QD that bypasses the inline 100 micron filter for future RFTA R&R's.

## Increment 20:

On May 27th Soyuz TMA-15/19S launched with crewmembers Frank DeWinne (future Increment 21 CDR), Roman Romanenko (FE), and Bob Thirsk (FE). They docked to the FGB nadir docking port on May 29th increasing the permanent crew size on ISS from three crew members to six crew members. This was the first time that the ISS Increment crew had at least one member from Russia, U.S, ESA, JAXA, and CSA.

On June 5th Stage EVA #22 was performed out of DC 1 by Gennady Padalka and Michael Barratt. The primary purpose of the EVA was to install KURS antennas on the SM zenith port in readiness for the future docking of the Mini Research Module 2 (MRM 2) and install and route some cables on the outside of the SM. Three days later the ground uplinked a software patch to obviate the need for the ground team to have to command the UPA to shutdown state between processing cycles to protect the UPA from WPA backflow. The new software automated the UPA reconfiguration procedure put in place after the UPA sticky check valve was removed. The software change reconfigured three UPA motor-controlled valves to perform the check valve function during Standby mode. That same day the ground was concerned about the OGA delta pressure increase since, the current trend indicated that the OGA would exceed its shutdown limit within 17 days.

On June 10th Gennady Padalka and Michael Barratt performed Stage EVA #23 out of SM transfer compartment. The purpose of this EVA was to replace the current SM zenith hatch with a hatch that contained a conical docking cone. This was the final EVA task in readiness for the delivery of MRM 2.

For the rest of June the only ECLS problem that occurred was a WPA potable bus leaks check fault that occurred on June 11th, 12th, and the 28th. These faults were due to multiple users using potable water over a short

**Table 2 - Progress Resupply and Soyuz Taxis Flight Summary**

| Launch Date | Flight | Key Elements | Key ECLS Hardware Delivery |
|---|---|---|---|
| 6-Aug-00 | 1P | Progress M1 (Progress 251) | Delivery of SM Elektron; Elektron support hardware; Solid Oxygen Cartridges and support hardware; DSD pressure alarm system; Vozdukh rotary equipment, control panels and support hardware; water supply system hardware for Elektron; Rodnik accessory hardware; SRV-K catalytic oxidizer; Air Conditioning system assembly kit; and some ventilation system hardware |
| 16-Nov-00 | 2P | Progress M1 (Progress 253) | Delivery of FGB dust filter; RS Depressurization Airflow Sensors; Solid Oxygen Cartridges; spare BMP fan; spare Elektron parts; spare SM Gas Analyzer parts; spare Vozdukh parts; spare SRV-K parts; spare water supply hardware for the Elektron; Rodnik accessory hardware; spare FGB fans; second SM Air Conditioning unit; and SM Air Conditioning support hardware |
| 26-Feb-01 | 3P | Progress M (Progress 244) | Delivery of spare FGB smoke detectors and dust filters; Vozdukh spare parts; SM Gas Analyzer spare parts; SM Gas Analyzer Calibration Gas Assembly; N2 Purge Assembly; spare Solid Oxygen system parts; spare SRV-K parts; Toxic Spill masks; spare ventilation system fans and hardware; and spare SM Air Conditioning system parts |
| 28-Apr-01 | 2S | Soyuz TM (Soyuz 206) | Soyuz Commander - Talgat Musabayev; Soyuz Flight Engineer – Yury Baturin; ISS Visitor – Dennis Tito |
| 20-May-01 | 4P | Progress M1 (Progress 255) | Delivery of spare FGB ventilation system fans and dust filters; 6 SM LiOH cartridges, spare SM LiOH fan; KKT payload vacuum access hardware; acoustic reduction hardware for the Vozdukh; spare Elektron water supply hardware; spare SRV-K hardware; SM ventilation system fans and dust filters; and SKV 1 compressor and condensate collection device |
| 21-Aug-01 | 5P | Progress M (Progress 245) | Delivery of spare FGB dust filters; spare SM smoke detectors; spare Gas Analyzers for the Elektron; spare BMP parts; spare Vozdukh parts; spare SRV-K parts; spare Rodnik parts; SKV-1 power supply; and spare ventilation system fans |
| 21-Oct-01 | 3S | Soyuz TM (Soyuz 207) | Soyuz Commander – Victor M. Afanasyez; Soyuz Flight Engineer – Konstantin M. Kozeev; and Soyuz Flight Engineer – Claudie Haignere' (CNES)<br><br>Plus delivery of DDI pressure sensor parts; repair kit for POTOK-150MK air decontamination equipment; spare ventilation system fans and parts |
| 26-Nov-01 | 6P | Progress M1 (Progress 256) | Delivery of spare FGB ventilation system fans; spare gas masks; spare FGB dust filters; spare SM smoke detector controller and power supply; spare BMP parts; new pressure manometer; spare water supply hardware to support the Elektron; spare SRV-K parts; soft Rodnik tanks; SKV parts; and SM dust filters |
| 21-Mar-02 | 7P | Progress M1 (Progress 257) | Delivery of spare FGB smoke detectors; spare FGB dust filter fans and filters; Vozdukh cable; SRV-K spare parts; spare water supply hardware for Elektron; spare SM dust filters; and spare ventilation system fans |

**Table 2 - Progress Resupply and Soyuz Taxis Flight Summary (cont'd)**

| Launch Date | Flight | Key Elements | Key ECLS Hardware Delivery |
|---|---|---|---|
| 25-Apr-02 | 4S | Soyuz TM (Soyuz 208) | Soyuz Commander – Yuri Gidzenko; Soyuz Flight Engineer – Roberto Vittori (ESA); and ISS Visitor – Mark Shuttleworth |
| 26-June-02 | 8P | Progress M (Progress 246) | Delivery of spare FGB ventilation system fans; spare DC1 smoke detectors; spare BMP filter; spare SM Gas Analyzer CO2 filters; Vozdukh CO2 sensor filter; spare water supply hardware for Elektron; Elektron pressure monitoring equipment; new design SM LiOH; spare SRV-K hardware; and Rodnik accessory hardware |
| 25-Sept-02 | 9P | Progress M1 (Progress 258) | Delivery of Vozdukh switch guard and spare part; spare Elektron Liquid unit, cables, and test panel; experimental Elektron air/water separator; spare SRV-K hardware; spare SM smoke detectors; and FGB dust filters |
| 30-Oct-02 | 5S | Soyuz TMA (Soyuz 211) | Soyuz Commander – Sergei Zalyotin; Soyuz Flight Engineer – Yuri Lonchakov; and Soyuz Flight Engineer – Frank De Winne (ESA) |
| 2-Feb-03 | 10P | Progress M (Progress 247) | Delivery of new BMP filter; spare SM Gas Analyzer parts; spare Vozdukh parts; spare water supply hardware for Elektron; spare SRV-K hardware; spare fire extinguishers; spare ventilation system fan; new frames for SM dust filters; spare SKV condensate pump; spare FGB smoke detectors; and spare FGB dust filter fans and filters |
| 8-June-03 | 11P | Progress M1 (Progress 259) | Delivery of SM Gas Analyzer spare parts; spare Elektron Liquid Unit; SRV-K spare parts; Rodnik accessory hardware; one Rodnik tank mounted in the cargo compartment; spare FGB fire extinguishers; spare FGB dust filters; and *two CDRA Air Selector Valves* |
| 30-Aug-03 | 12P | Progress M (Progress 248) | Delivery of two new SM LiOH canisters; new pressure manometer; spare BMP part; SM Gas Analyzer spare parts; spare Vozdukh parts; Elektron Nitrogen Purge Unit; SRV-K spare parts; Rodnik accessory hardware; spare gas masks; spare SM smoke detectors; spare DC1 smoke detectors; SKV-2 spare parts; air circulation equipment; FGB smoke detector cleaning unit; *US Hepa filters* |
| 29-Jan-04 | 13P | Progress M1 (Progress 260) | Delivery of GANK gas analyzer; spare Elektron Liquid Unit; Vozdukh spare parts; SRV-K spare parts; SM ventilation system parts; FGB dust filters; FGB smoke detectors; and *CDRA air selector valve sock filters* |
| 25-May-04 | 14P | Progress M (Progress 249) | Delivery of two new SM LiOH canisters, Elektron Nitrogen Purge Unit; and SRV-K spare parts |
| 11-Aug-04 | 15P | Progress M1 (Progress 350) | Delivery of one new SM LiOH canisters, SM Gas Analyzer spare parts; Elektron Cables; and SRV-K spare parts; SM Smoke Detectors; DC1 Smoke Detectors; Dust Filters; Replacement Condensate Lines; and *U.S. MCA Mass Spectrometer ORU and Flight Support Equipment* |
| 24-Dec-04 | 16P | Progress M1 (Progress 351) | Delivery of one H2 in O2 Gas Analyzer; Rodnik support HW; SRV-K spare parts; and FGB Dust Filters |

**Table 2 - Progress Resupply and Soyuz Taxis Flight Summary (cont'd)**

| Launch Date | Flight | Key Elements | Key ECLS Hardware Delivery |
|---|---|---|---|
| 28-Feb-05 | 17P | Progress M (Progress 352) | Delivery of newly designed Solid Oxygen Cartridges; newly designed Solid Oxygen Generator; spare Vozdukh parts; Elektron Nitrogen Purge Unit; container with electrolyte for Elektron; SRV-K spare parts; spare SM Dust Filters; a SM Crew Quarter Fan and Acoustic kit; and FGB smoke detectors |
| 16-June-05 | 18P | Progress M (Progress 353) | Delivery of newly designed Solid Oxygen Cartridges; spare Vozdukh parts; spare Elektron parts; Elektron Nitrogen Purge Unit; container with electrolyte for Elektron; SRV-K spare parts; spare SM dust filters; spare FGB dust filters; spare FGB gas masks; and *U.S. MPEV ISA replacement o-rings* |
| 8-Sept-05 | 19P | Progress M (Progress 354) | Delivery of newly designed Solid Oxygen Cartridges; spare Vozdukh parts; spare Elektron Liquid Unit; spare BMP part; SM Gas Analyzer spare parts; SRV-K spare parts; spare SM smoke detectors; spare ventilation fans and vibration isolation mounts; SKV spare parts; and SM dust filters |
| 21-Dec-05 | 20P | Progress M (Progress 355) | Delivery of newly designed Solid Oxygen Cartridges; spare Vozdukh parts; spare Elektron Liquid Unit; Elektron Nitrogen Purge Unit; spare Elektron parts; SRV-K spare parts; Rodnik accessory hardware; spare gas masks; FGB dust filters, *U.S. TCCS Sorbent Bed Assembly (SBA)* |
| 24-Apr-06 | 21P | Progress M (Progress 356) | Delivery of a spare Elektron data interface box; a new Elektron H2 vent kit; spare SRV-K parts; spare portable fire extinguishers; and spare smoke detectors |
| 24-June-06 | 22P | Progress M (Progress 357) | Delivery of 3 Russian LiOH cans; SM gas analyzer spare parts; spare Vozdukh parts; spare Russian water system and SRV-K parts; a spare ventilation fan; spare FGB smoke detectors; and replacement air duct |
| 26-Oct-06 | 23P | Progress M (Progress 358) | Delivery of 3 Russian LiOH cans; the new solid oxygen generator and control panel; Elektron spare parts; spare Russian water system and SRV-K parts; spare SM smoke detectors; and *U.S. replacement IMV Valve* |
| 18-Jan-07 | 24P | Progress M (Progress 359) | Delivery of 2 new -3 solid oxygen generators; new -3 solid oxygen cartridges; SM gas analyzer spare parts; spare Vozduhk parts; spare Liquid Unit; spare Elektron parts; spare SRV-K parts; and spare FGB dust filters |
| 12-May-07 | 25P | Progress M (Progress 360) | Delivery of 4 Russian LiOH cans; SM gas analyzer spare parts; spare Vozdukh parts; spare Russian water system and SRV-K parts; FGB smoke detectors and smoke detector cleaning kit; and *U.S. Clean Room Gloves* |
| 2-Aug-07 | 26P | Progress M (Progress 361) | Delivery of 3 Russian LiOH cans; Vozdukh spare parts; spare Russian water system and SRV-K parts; SM smoke detectors; FGB Dust Filters; *3 U.S. Hepa Filters; and U.S. Clean Room Gloves* |
| 23-Dec-07 | 27P | Progress M (Progress 362) | Delivery of Vozdukh spare parts; spare Elektron parts; spare Russian water system and SRV-K parts; DC1 smoke detectors; 2 spare ventilation fans; 1 SM Fire Extinguisher; *6 U.S. Hepa Filters* |

**Table 2 - Progress Resupply and Soyuz Taxis Flight Summary (cont'd)**

| Launch Date | Flight | Key Elements | Key ECLS Hardware Delivery |
|---|---|---|---|
| 5-Feb-08 | 28P | Progress M (Progress 363) | Delivery of 2 Russian LiOH cans; SM gas analyzer spare parts; spare Elektron parts; spare Russian water system and SRV-K parts; Russian 0.2 micron water filters; set of new condensate lines; FGB dust filters; and *U.S. Regen ECLS Modification Kit hose* |
| 14-May-08 | 29P | Progress M (Progress 364) | Delivery of spare pressure sensors; spare BMP fan; water microbial filter; spare water system parts; spare ventilation fan; Freon 218 resupply tanks; spare FGB gas masks; spare FGB smoke detectors; smoke detector cleaning unit; and *U.S. Regen ECLS Modification Kit hoses, wires, brackets, closeout cover, and purge adapter* |
| 10-Sept-08 | 30P | Progress M (Progress 365) | Delivery of Elektron power supply EMI filter; spare SRV-K and water system parts; and *U.S. Waste and Hygiene ASU parts* |
| 26-Nov-08 | 31P | Progress M (Progress 401) | Delivery of accessories kit to replace Vozdukh bed; spare SRV-K and water system parts; replacement SM Gas Masks; replacement SM Smoke Detectors; replacement FGB dust filters; FGB air decontamination unit; Soyuz replacement fan; and *U.S. Waste and Hygiene ASU parts* |
| 10-Feb-09 | 32P | Progress M (Progress 366) | Delivery of spare Gas Analyzer hardware; spare Vozdukh CO2 analyzer; spare Elecktron Gas Analyzer; spare water system parts; and *U.S. Waste and Hygiene ASU parts* |
| 7-May-09 | 33P | Progress M (Progress 402) | Delivery of portable air pressurization tank; spare SRV-K and water system parts; spare SM ASU parts; spare air/water separator parts; spare SM dust filters; spare SM fire extinguishers and gas masks; fire system data processing hardware; and *U.S. Waste and Hygiene ASU parts* |
| 24-July-09 | 34P | Progress M (Progress 367) | Delivery of 3 Russian LiOH cans; spare SRV-K and water system spare parts; spare SM ASU parts; spare SM dust filters; spare condensate lines; spare FGB dust filters; *spare OGA H2 Sensor ORU; and U.S. Waste and Hygiene ASU parts* |
| 14-Oct-09 | 35P | Progress M (Progress 403) | Delivery of 2 Elektron Liquid Unit Kits; SRV-K and water system spare parts; SM ASU spare parts; spare SM dust filters; 1 spare DC 1 fire extinguisher; *and U.S. Waste and Hygiene ASU parts* |
| 3-Feb-10 | 36P | Progress M (Progress 404) | Delivery of SRV-K and water system spare parts; SM ASU spare parts; spare SM dust filters; spare FGB dust filters; *and U.S. Waste and Hygiene ASU parts* |

period of time. It was decided to relax the leak detection algorithm on June 29th and the ground uplinked a leak algorithm software modification that to resolved this problem.

While the ISS crew and ground was waiting for the launch of the next Space Shuttle, they had to respond to three on-orbit problems and they fixed an old problem. The first problem occurred on July 6th when they got a WPA process fault due to a drop in the water storage inlet pressure. At the time the ground did not know what caused the problem, but the ground was able to restart the WPA. Three days later the crew fixed an old problem from the Flight ULF2 timeframe when they installed some protective insulation tape onto the potable water dispenser (PWD) standoff hose and the P4 Z-Panel feedthrough in the U.S. Laboratory Module. This task had resolved a concern that the hose could be chafed on the edges of the Z-Panel feedthrough. The next problem occurred on July 10th when the crew noticed steam coming out of the SM SRV-K's water dispensing and heating unit. This problem was similar to

**Table 3 – Non-Russian Resupply Vehicle Flight Summary**

| Launch Date | Flight | Key Elements | Key ECLS Hardware Delivery |
|---|---|---|---|
| 8-Mar-08 | ATV 1 | ATV (Jules Verne) | Demonstration flight for ESA's unmanned logistic resupply vehicle |
| 10-Sept-09 | HTV 1 | HTV 1 | Demonstration flight for JAXA's unmanned logistic resupply vehicle and scavenged the HTV 1 smoke detector prior to HTV 1 departure<br><br>*Delivery of spare U.S. WHC ASU components, Hepa filters, and IMV cap o-rings* |

a problem that had occurred the year before. To resolve the problem the crew R&R'ed SRV-K water dispensing and heating unit with an on-orbit spare the next day and the ground asked the crew to power down the unit for safety reasons prior to going to sleep every night. The final problem occurred on July 15th when the Node 2 MTL NIA valve inadvertently opened again. The crew reported that the failure occurred approximately around the time that they turned on the starboard crew quarter light. The ground continued to study the problem.

2J/A:

On July 15th the Flight 2J/A launched from KSC and docked to ISS on July 17th. During the docked operation, the joint crew performed five EVAs; installed the Japanese Experiment Module (JEM) – Exposed Facility (EF) onto the outside of the JEM – Pressurized Module (PM); transferred 5.5 kg (12 lbm) GN2 and 20.9 kg (46 lbm) gaseous oxygen (GO2) from the Space Shuttle to the ISS Joint Airlock tanks; filled 8 CWCs with silver biocide water; filled 10 CWC – Iodine (CWC-I) with iodine biocide water; and repressed the ISS with 12.4 kg (27.2 lbm) of nitrogen. The Space Shuttle also delivered a spare OGA pump ORU and filters to try and resolve the OGA delta pressure issue; new water conversion hardware to convert silver water into iodine water, a contingency water dispenser; a WPA potable water tee; and swapped out FE/Koichi Wakata with FE/Tim Kopra.

During 2J/A docked operations the crew and ground had to resolve three ECLS problems. The first problem occurred the day the Space Shuttle docked to ISS when the crew disconnected the condensate water tank tee to allow condensate to flow into the WPA instead, the disconnected condensate tank tee QD started to leak. The crew capped the leaky QD and cleaned up the 2 kg (4.4 lbm) of condensate that had leaked to the cabin. Two days later after one of the crew was using the WHC the toilet's pretreat chemical dose pump failed on, which ended up flooding the toilet's urine separator and the air outlet hardware with urine pretreatment solution. To resolve the problem the crew R&R'ed the dose pump, the contaminated hoses, and the toilet control panel during the next day. The final problem occurred on July 25th when the CDRA Bed 2 temperature sensors rose until a Remote Power Control Mechanism (RPCM) Remote Power Controller (RPC), which feeds the primary bed heaters tripped open. To work around the problem and start removing CO2 from the atmosphere, the ground manually commanded the CDRA half cycles using only the secondary bed heaters. To return CDRA to automatic operation, the ground uplinked to the Internal System (INTSYS) Multiplexer/Demultiplexer (MDM) a patch to the Dynamic Random Access Memory (DRAM) to mask the failed heater two days later. Later that day, the ground uplinked a software patch to the INTSYS MDM Electrically Erasable Programmable Read Only Memory (EEPROM) to avoid losing the software patch if the MDM lost power. The next day Space Shuttle undocked from ISS.

34P:

Progress 34P launched from Baikonur on July 24th during the middle of Flight 2J/A and docked to ISS at SM aft docking port on July 29th after the Space Shuttle had undocked. It brought 28 kg (61.6 lbm) of oxygen; 21 kg (46.2 lbm) of air; 420 kg (924 lbm) of water; spare OGA H2 Sensor ORU; spare parts for the U.S. toilet; and spare Russian ECLS hardware.

To get ready for the installation of the Node 1 modification kit to allow Node 3 to be docked at the Node 1 port interface instead of the Node 1 nadir interface, the crew removed the Node 1 nadir aft IMV valve on August 7th for installation later into the Node 1 port aft location. Later that day the crew moved Pressurized Mating Adapter – 3 (PMA – 3) with the Station robotic arm so that the crew could perform the Node 1 port bulkhead reconfiguration in a pressurized environment prior to the delivery of Node 3. Also, that same day the crew received a WHC bad pretreat quality light. Based on crew troubleshooting it was determined that the problem was most likely due to gas bubbles in the flush water. To fix the problem they had to purge the WHC flush hardware. Two days later the crew received a WHC check separator light. This problem was thought to be due to an intermittent sensor problem and was resolved by cycling the WHC urine separator mode from automatic to manual mode.

During this same time frame the OGA continued to be a concern. On August 10th the OGA water inlet pressure started dropping rapidly. Since the pressure reading dropped below cabin pressure it was thought that the pressure drop was due to the OGS Rack Avionics Air Assembly (AAA) over cooling the rack. The Rack over cooling caused the water solid hose pressure to collapse. To get ready for the next Shuttle flight it was decided to try and resolve the OGA increasing delta pressure problem and to clean the Node 1 SD. So on the next day the Increment crew cleaned the Node 1 SD #2 to prevent it from generating a false alarm during the docked operations. Seven days later the crew R&R'ed the OGA pump ORU filter. During the R&R the crew reported seeing some debris on the filter as they packaged it up for return on the next Shuttle mission. Unfortunately, this task did not reduce the OGA pump delta pressure problem. So on August 21st the crew R&R'ed the OGA water ORU. This task solved the pump pressure problem and the OGS was declared to be operational.

Finally just before the next Space Shuttle flight the UPA belt slipped during start-up on August 24th. This problem had been experienced twice before and the ground quickly recovered from this problem. Also, the next day the crew was able to scavenge the Crew Health Care System (CHeCS) Rack AAA and the Microgravity Science Glovebox (MSG) filter that had been installed in the CHeCS Rack to prevent debris from failing the CHeCS Rack AAA prior to disposal of the CHeCS Rack in HTV 1.

17A:

On August 28th the Flight 17 launched from KSC and docked to ISS on August 30th. During the docked operation, the joint crew performed three EVAs; filled one CWC with silver biocide water; filled 15 CWC-Is with iodine biocide water; and repressed the ISS with 4.1 kg (9 lbm) of oxygen. The Shuttle also delivered the Node 1 modification kit feedthroughs for the Node 3 relocation task, Node 3 Air Revitalization (AR) Rack, OGS Hydrogen ORU Calibration Kit (HOCK), WRS condensate transfer pump, Pre-Treat Urine (PTU) tee valve hose, the Treadmill 2 (T2) Rack, the third Crew Quarter (CQ) Rack, three payload racks, and swapped out FE/Koichi Tim Kopa with FE/Nicole Stott. With the HOCK the crew was able to check the calibration of the OGA H2 ORU pressure sensors and R&R the OGA water ORU filter during docked operations. This allowed the HOCK and the OGA water ORU filter to be returned on the Space Shuttle when it undocked from ISS on September 8th.

HTV 1:

On September 10th HTV 1 launched from Tanegashima, Japan and it berthed to ISS on September 17th. The next day the ISS crew installed the vestibule jumpers for HTV 1 and ingressed into the pressurized module.

At the end of the month the ISS crew completed many ECLS tasks. The ECLS tasks started on September 22nd when the crew swapped out the Node 3 AR Rack that was stowed in the JEM – PM with the U.S. Laboratory Module AR Rack. This allowed the ground to check out the Node 3 AR Rack on the next day except for the Major Constituent Analyzer (MCA) since the MCA was missing its Data and Control Assembly (DCA) ORU. That same day the crew removed the MCA DCA from the old U.S. Laboratory Module AR Rack. Two days later the MCA DCA ORU was installed into the Node 3 AR Rack to allow for the activation and checkout of the MCA too. During the middle of this AR Rack task the crew also took measurements of the United States On-Orbit Segment (USOS) IMVs and determined that the IMV flow between Node 1 and the Joint Airlock and the U.S. Laboratory and Node 2 had severely degraded.

Just prior to the arrival of the next Soyuz, the Node 2 MTL NIA valve inadvertently opened again on September 29th. They also performed a major six crew task by installing the T2 Rack into Node 2 on September 28th through October 1st. On October 10th visiting astronaut Guy Laliberté and Increment 19/20 crew members Gennady Padalka and Dr. Michael Barratt undocked Soyuz TMA-14/18S and landed in the steppes of Kazakhstan.

**<u>Increment 21:</u>**

On September 30th Soyuz TMA-16/20S launched with crewmembers Maxim Suraev (FE), Jeff Williams (FE), and plus visiting astronaut Guy Laliberté. They docked to the SM aft docking port on October 2nd.

Not long after the crew arrival the crew had their first ECLS problem when the UPA DA condenser experienced a high pressure reading was above the pressure shutdown level for almost an hour. Fortunately, the pressure level came down before the ground had to shutdown the UPA. Review of the data after the event showed that the increased pressure was due to the heaters running longer than normal prior to reaching the set point. At the time the cause of this problem was not known. Also on October 5th the WPA process pump speed increased above the software shutdown limit causing the WPA to shutdown. The review of the data for this fault indicated an increase in the particulate filter delta pressure, an increase in the WPA Mostly Liquid Separator (MLS) inlet pressure, and an increase in the MLS motor temperature. Based on review of the data it was decided to restart the WPA and monitor the situation. The next day the crew installed the newly delivered PTU tee valve hose. This hardware made the UPA filling operation from the WHC or the SM EDVs easier since the crew now had to only switch a valve position instead of having to reconfigure the UPA.

35P:

Progress 35P launched from Baikonur on October 14th and docked to ISS at DC 1 on October 18th. It brought 50 kg (110 lbm) of oxygen; 13.6 kg (29.9 lbm) of propellant nitrogen that could be available for cabin usage; 420 kg (924 lbm) of water; spare parts for the U.S. toilet; and spare Russian ECLS hardware. On the same day as the Progress launched the ground uplinked the INTSYS Release 5 (R5) and Laboratory System 3 Release 4 (LSYS 3 R4) MDM software revisions.

The end of October was busy for the ISS ECLS team. It started on October 23rd when the crew cleaned the Node 1 SD #2 again. To help minimize this problem in the future, the crew taped a cover over part of the inlet to the Node 1 Hepa filter box. This was done to reduce the flow rate past the smoke detectors to hopefully lengthen the time between cleaning of the Node 1 SD. That same day the crew also cleaned the Node 1 starboard IMV fan, which periodically gets clogged with debris/lint from the cabin.

The problems with the ISS ECLS hardware continued when on the next day the UPA indicated an internal leak following the transfer of pretreated urine from a SM EDV into the UPA. Based on the review of the data the problem was thought to be because the UPA DA overfilled due to particulate contamination from an unidentified source. On October 26th it was noticed that the OGA pump delta pressure was increasing again. Based on the rate it was predicted that the OGA water ORU would have to be replaced in early November. On October 29th the crew R&R'ed the UPA RFTA and then attempted a dry out of the UPA DA the next day to try and flush out the suspected particulate to the RFTA were it could be captured on the RFTA filters. Unfortunately, this procedure was not successful.

October ended with the crew removing the CDRA Desiccant/Absorption Bed (DAB) from the old U.S. Laboratory Module AR Rack that was being stored in the JEM – PM for return on the upcoming Space Shuttle Flight ULF-3 on October 28th. The next day the crew scavenged the smoke detector out of HTV 1 prior to its unberthing from Node 2 on October 30th for its planned destructive re-entry.

The early part of November continued to be busy for the ISS ECLS team. On November 2nd the crew R&R'ed the OGA water ORU to resolve the OGA pump delta pressure again. Two days later the crew drained the UPA DA into the UPA waste storage tank assembly (WSTA). Then on November 6th the crew and ground tried to process another tank of pretreated urine but the cycle had to be terminated early due to an increasing DA temperature reading. Based on the review of the data it was decided to try and limit the processing time with long cool down periods to avoid a DA thermal problem. Unfortunately, the UPA distillate conductivity reading would not come down so the system mainly kept reprocessing the same batch. By November 11th the ground team declared the UPA failed.

While the crew and ground worked to resolve the UPA and OGA problem they did have success installing the Node 1 modification kit to support the movement of Node 3 from Node 1 nadir to Node 1 port. It started on November 2nd when the crew repressurized PMA 3. The next day the crew removed the Node 1 port closeouts, ingressed PMA 3, installed the ECLS bulkhead fluid system feedthroughs, removed the Node 1 port aft negative pressure relief valve (NPRV), and installing an IMV valve at the same location that previously had contained a NPRV. On November 4th the crew depressurized PMA 3 with the Joint Airlock depressurization air save pump using a long vacuum access jumper. Then over the next twelve days the crew performed a leak check to make sure that the new feedthroughs, the IMV valves, and the hatch were not leaking.

MRM 2:

Mini Research Module 2 (MRM 2), also commonly called Poisk or Search/Quest, launched from Baikonur on November 10th and docked to ISS at SM zenith on November 12th. This was the first permanent Russian element added to ISS since DC 1 was added to ISS in 2001. It also provided the fourth docking port for the RS.

Just prior to the docking of the next Space Shuttle to ISS, the crew got a WPA fault due to a low WPA MLS inlet pressure. After the ground reviewed the data they concluded that the failure was mostly likely blockage between the Waste Water Tank ORU and the MLS. The next day the crew started the procedure for installing the last of the Node 1 modification kit to support the movement of Node 3 from Node 1 nadir to Node 1 port interface by removing the closeout panels, port IMV fan, and port IMV fan mufflers on November 17$^{th}$.

ULF3:

On November 16$^{th}$ the Space Shuttle Flight ULF3 launched from KSC and docked to ISS on November 18$^{th}$. During the docked operation, the joint crew performed three EVAs; filled 14 CWC with silver biocide water; transferred 5 kg (11 lbm) GN2 from the Space Shuttle to the ISS Joint Airlock tanks; repressed the joint stack with 30.9 kg (68 lbm) of oxygen; and repressed the ISS with 2.7 kg (6 lbm) of nitrogen. The Shuttle also delivered the third Joint Airlock oxygen tank, which brought an additional 437.8 kg (199 lbm) of high pressure gaseous oxygen to ISS. The same day the Space Shuttle crew docked to ISS and the ground was able to remotely operate the WPA again, but the flow rate through the WPA was severely reduced and the WPA kept returning to recycle mode. While the ground was evaluating the recent WPA flow problem, the crew finished installing the Node 1 modification kit on November 20$^{th}$. Finally, prior to undocking the crew removed the UPA DA on November 23$^{rd}$ and the OGA water ORU filter on November 24$^{th}$ for return on the Space Shuttle. On November 24$^{th}$ the Space Shuttle undocked from ISS returning the UPA DA, an EDV full of pretreated urine for ground analysis, the OGA water ORU filter, and FE/Nicole Stott.

On October 30$^{th}$ Increment 21 came to an end when CDR/Frank DeWinne, FE/Roman Romanenko, and FE/Bob Thirsk undocked Soyuz TMA-15/19S and landed in the steppes of Kazakhstan on December 1$^{st}$. On the day that the crew was leaving ISS, the crew installed the early OGS water delivery system (WDS) on the front of the OGS Rack in the event of a WPA failure. The early OGS WDS had provided water to the fuel cell water bus from a CWC-I. They also replaced the OGA water ORU filter in the ORU that was removed during the last Space Shuttle Flight.

**Increment 22:**

Increment 22 started with only two crew members being on ISS after the departure of the three Increment 21 crew members. On December 11$^{th}$ the crew inspected the flex hose and QD between the WPA waste water tank ORU and the WPA pump/separator ORU. The inspection revealed that the blockage was not in the flex hose.

On December 18$^{th}$ the crew investigated the low IMV flow between the RS and the USOS. They found very little debris in the U.S. Laboratory Module aft port and the Node 1 aft port IMV fans. The crew then checked the Node 1 port zenith manual isolation valve and found that it was partially closed. It was thought that it got bumped when the crew was installing the Node 1 modification kit during the last Space Shuttle flight. Repositioning the valve restored the expected IMV flow. Three days later the crew inspected and cleaned the FGB IMV fan. This restored the flow back to the normal flow rate.

That same day Soyuz TMA-17/21S launched from Baikonur with crewmembers future CDR/Oleg Kotov, FE/Soichi Noguchi, and FE/Timothy J. Creamer. They docked to the FGB nadir docking port on December 22$^{nd}$. December closed with the crew performing a checkout of the water delivery capability of the early OGS WDS by performing a partial fill of the WHC flush water tank on December 30$^{th}$.

The start of the New Year provided no relief for the ISS ECLS team. On January 11$^{th}$ the crew performed a reverse flush of the WPA. The next day the crew performed a leak check of the WPA with good results. Then on January 13$^{th}$ the WPA was restarted to see if the flow rate through the MLS had been improved by the reverse flush. At first the flow rate seemed to have returned to normal but near the end of the processing when the waste tank quantity was at approximately 17% the pressure at the MLS inlet started to drop off again until the inlet to the MLS was completely blocked. Based on these results the ground had decided to use the early OGS WDS to provide water to the fuel cell water bus, R&R the WPA pump/separator ORU, return the failed ORU to the ground for failure analysis, and to postpone the operation of the WPA until a new WPA filter could be installed in the system during the next Space Shuttle Flight.

On January 14$^{th}$ Stage EVA #24 was performed out of DC 1 by Maxim Suraev and Oleg Kotov. The primary purpose of the EVA was to install docking targets, antennas, and two EVA handrails on MRM 2, remove a Biorisk experiment container from the outside of DC 1 and install and route some cables between MRM 2 and the SM. The outfitting for MRM 2 finished the preparations for future rendezvous operations at the MRM 2 docking port. Seven days after the EVA had been completed Soyuz 20S was moved from SM aft to the new docking port on MRM 2.

To get ready for the next Space Shuttle Flight the crew moved PMA 3 from Node 1 port to Node 2 zenith on January 22nd. Then six days later the crew removed the rear CDRA DAB from the old U.S. Laboratory AR Rack that was being stowed in the JEM – PM for return on the next Space Shuttle mission.

February also was a busy month for the ISS ECLS team. It started with the crew R&R'ed the WPA pump/separator ORU on February 1st. Then on February 3rd and 4th the crew worked to remove the gas from the CWC-Is and the fuel cell water lines since the gas was causing problems with the crew being able to dispense water from the potable water dispenser (PWD) and the WHC kept having intermittent sensor faults due to the free gas in the water.

36P:

Progress 36P launched from Baikonur on February 3rd and docked to ISS at SM aft on February 5th. It brought 28 kg (61.6 lbm) of oxygen; 21 kg (46.2 lbm) of air, 13.6 kg (29.9 lbm) of propellant nitrogen that could be available for cabin usage; 420 kg (924 lbm) of water; spare parts for the U.S. toilet; and spare Russian ECLS hardware. To try and better understand the OGA pump delta pressure problem, the crew on February 5th took a sample of the OGA recirculation water. Unfortunately, during this procedure two strange signatures were seen. One was that the OGA rotary separator assembly (RSA) had a large transfer of water to it. The second problem was that the loop had a low head pressure, which caused the filling of the water sample bag to be longer than it was planned to take.

20A:

On February 8th the Space Shuttle Flight 20A launched from KSC and docked to ISS on February 10th. During the docked operation, the joint crew performed three EVAs; filled 8 CWC with silver biocide water; filled 8 CWC-Is with iodine biocide water, transferred 10.9 kg (24 lbm) GO2 from the Space Shuttle to the ISS Joint Airlock tanks; and repressed the joint stack with 30.9 kg (68 lbm) of oxygen. The same day the Space Shuttle crew docked to ISS the crew stowed the early OGS WDS as the crew got ready for the movement of the six crew equipment racks to Node 3 after Node 3 was berthed to Node 1 port interface. During the Shuttle docked operations the crew did a lot of different ECLS tasks. They started with the Regenerative ECLS water systems task when they installed the newly delivered UPA DA, UPA Fluid Control and Pump Assembly (FCPA), and the new WPA external filter assembly (EFA) to protect the WPA MLS inlet from blockage. The day after completing these tasks and installing a new UPA RFTA the crew and ground worked together to restart the UPA and the WPA. Unfortunately, near the end of the crew day the WPA MLS inlet indicated blockage again. The blockage did not stop flow through the WPA but, it did degrade the flow rate through the WPA again. After Node 3 was berthed to Node 1 the crew installed the Node 1 to Node 3 vestibule jumpers and moved the 7 m (23 ft) duct that had been used in Node 2 to route the Space Shuttle IMV air into the forward part of the U.S. Laboratory Module to Node 3 to provide ventilation in Node 3 until the Node 3 CCAA could be started up to support an early Node 3 ingress. This configuration allowed cool/dry RS IMV air to be routed into Node 3, unfortunately the air flow was lower than expected. On February 13th the crew was able to finally restart the OGA with the high OGA RSA quantity in the U.S. Laboratory Module and they also transferred the old U.S. Laboratory Module AR Rack from the JEM – PM to Node 3. Two days later the crew moved Cupola from its launch location of Node 3 port interface to its on-orbit location on the Node 3 nadir interface. With the Cupola moved the crew then moved the PMA-3 the next day from Node 2 zenith interface to Node 3 port interface. On February 18th the crew shutdown and moved the two WRS Racks, the WHC, and the OGS Rack from the U.S. Laboratory Module to Node 3. After the Racks were moved they were repowered at their new location as part of a checkout and leak check. During this task the ground noticed that the UPA waste tank quantity had dropped to zero. On February 19th the Space Shuttle undocked from ISS and landed back at KSC on February 21st. On the day of undocking the ISS crew checked that urine lines in the WHC, and in the WRS Racks, and in the standoff but, fortunately they did not find any free urine in the cabin.

On February 23rd the crew performed a leak check of the UPA WSTA to see if the WSTA bellows could be leaking by removing the PTU Tee valve hose and using the old hose. The test proved that the WSTA bellow was not leaking and based on this test it was determined that the leak had to be in the PTU Tee valve hose. Since the leak had been isolated the UPA was allowed to be restarted.

## III. Near Term Shuttle Flights

During the time period covered by this paper the Space Shuttle Program (SSP) was able to successfully launch the Space Shuttle with minor schedule problems. The launch windows are mainly driven by high beta angles because of thermal and power generation concerns, the traffic coming up to and leaving ISS, and the time required to process the next Space Shuttle. The current Space Shuttle Program direction is to fly the last Shuttle flights before the end of the calendar year. Next year's paper will discuss the last four Space Shuttle flights to ISS based on the current Space Shuttle Program plans.

## IV. ISS Element Integration Status

Most of the pressurized elements and all of the Truss Segments have been delivered to ISS. Even though the Space Shuttle is nearing the end of its life, ISS still has plans to add some additional pressurized modules to the Station, as can be seen in Figure 4. In fact, next year's paper will discuss the delivery of the last of the Russian pressurized elements [i.e., Mini Research Module -1 (MRM-1) and the Multi-Purpose Laboratory Module (MLM)], and the Permanent Multi-Purpose Module (PMM). The MRM-1 and the MLM will provide the Russian Segment with additional docking ports and additional areas to conduct research. As for the PMM it will provide additional stowage space on ISS. The Program is also working on a new docking adapter, called the Common Docking Adapter (CDA). The CDA will be used to dock the Constellation Program's Orion vehicle and/or Commercial Crew Transportation vehicles to ISS. These vehicles could be used as part of the strategy for rotating out the ISS crew members in conjunction with the Russian Soyuz.

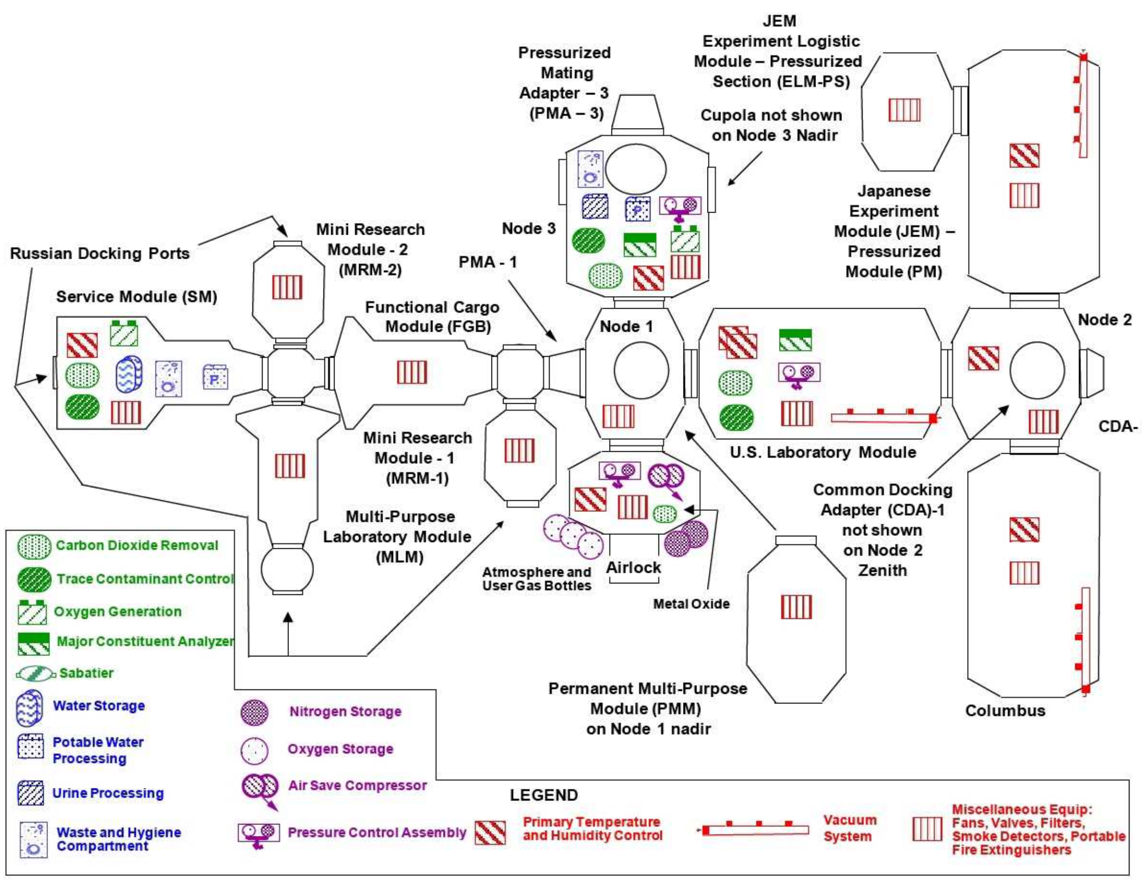



**Figure 4 – ISS ECLS Hardware Distribution at Assembly Complete**

## V. Shuttle Transition and Retirement Status

To prepare for Shuttle Transition and Retirement (STaR) the ISS ECLS team is currently working three major tasks. The first task being worked on is a system to be able to resupply oxygen and nitrogen to ISS after the Space Shuttle retires, which is called the Nitrogen/Oxygen Recharge System (NORS). The NORS has completed its System Requirements Review (SRR) and should be ready for the Project's Preliminary Design Review (PDR) soon. The second task is an Advance Recycle Filter Tank Assembly (ARFTA). This equipment is designed to minimize UPA resupply up mass while taking advantage of cheaper brine disposal methods. The final STaR is the delivery of additional spares to support the end of life of ISS. This will become a critical task due to post Shuttle retirement resulting in most of the ISS ECLS ORUs not being returned to the ground for failure analysis or refurbishment and due to the projected life extension of ISS from 2015 to post 2020.

## VI. Commercial Service Contracts

ISS is currently working with three different commercial service providers. Out of these three commercial providers ISS has a contract with one of the three vendors to provide a Sabatier that will be integrated into the Node 3 OGS Rack. The Sabatier will provide water to ISS by reacting the waste carbon dioxide from CDRA and the waste hydrogen from the OGA. ISS will pay the vendor based on their capability to make water. The other two commercial vendors that ISS are involved with have a contract with NASA's Commercial Crew and Cargo Program Office (C3PO) to resupply cargo to ISS. For these contracts the ISS ECLS team is involved with managing the on-orbit docked interface requirements for the commercial cargo vehicles and verifying that the two vendors meet these requirements. They are also working on coming up with the interface requirements for a commercial crew vehicle if one should dock to ISS.

## VII. Conclusion

This paper has outlined the ISS ECLS activities from March 2009 through the end of February 2009. The assembly of ISS has continued with the addition of the last Truss Segment, the last piece of the Japanese Kibo Segment, the last Node, and a new Russian Module. ISS has transitioned to a permanent crew size of six. It still has been a challenge to provide the resources necessary to support the six crew members on ISS with all of the problems that have occurred with the new regenerative ECLS racks, WHC, and CDRA. Next year's paper will discuss the delivery of the final pressurized elements and the final Space Shuttle flights. It will also talk about the status of the new commercial cargo delivery vehicles that will be used to deliver cargo to ISS after the Space Shuttle is retired. It will also discuss the final changes to ISS ECLS hardware due to the Shuttle Transition and Retirement.

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