

STS-122 SPACE SHUTTLE MISSION REPORT

October 2008



**National Aeronautics and
Space Administration**

**Lyndon B. Johnson Space Center
Houston, Texas**

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STS-122
SPACE SHUTTLE MISSION REPORT

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STS-122 SPACE SHUTTLE MISSION REPORT

INTRODUCTION

The Space Transportation System (STS) -122 Space Shuttle Mission Report presents a discussion of the Orbiter activities on the mission, as well as a summary of the External Tank (ET), the Solid Rocket Booster (SRB), the Reusable Solid Rocket Motor (RSRM) and the Space Shuttle Main Engine (SSME) performance during the 121st mission of the Space Shuttle Program. The purposes of this mission, designated as Assembly Flight 1E, were to deliver and install the *Columbus Laboratory* on Node 2 of the International Space Station (ISS), exchange the ISS Flight Engineer 2 crewmembers, and deliver critical supplies and cargo to the ISS.

STS-122 was the 8th mission since the return to flight following the STS-107 mission, and the 24th mission to the ISS. STS-122 was also the 27th flight of the *Atlantis* vehicle.

The flight vehicle consisted of the OV-104 Orbiter; the ET, a super lightweight tank (SLWT) designated ET-125; three Block II SSMEs that were designated as serial numbers (S/Ns) 2059, 2052, and 2057 in positions 1,2, and 3, respectively; and two SRBs that were designated BI-132. The two RSRMs were designated flight set RSRM-99. The individual RSRMs were S/N 360W099A (left) and S/N 360W099B (right). Launch pad 39A and Mobile Launch Platform (MLP) -1 were used as the platform for launch of the STS-122 mission.

The primary objectives of the STS-122 mission were as follows:

1. Install the European Space Agency (ESA) Columbus Laboratory on the starboard side of the *Harmony* Node 2 module.
2. Exchange the ISS Flight Engineer 2 crewmembers and transfer mandatory crew rotation cargo.
3. Perform three Extravehicular Activities (EVA's) to temporarily attach and activate the Columbus Laboratory.
4. Remove and replace the ISS Port 1 Nitrogen Tank Assembly.
5. Install and perform mandatory activation of the Columbus SOLAR external payload and the European Technology Exposure Facility (EuTEF) on the Columbus External Payload Facility (EPF).
6. Transfer mandatory quantities of water and nitrogen as well as other critical supplies to the ISS.
7. Return failed Control Moment Gyroscope (CMG) from the External Stowage Platform (ESP) -2.

The STS-122 mission was planned to be a 11-day plus 1 plus 2-contingency-day flight. Two additional docked days were approved during the flight by the Mission Management Team (MMT) to allow for the additional support to the ISS.

All times during the flight are given in Greenwich Mean Time (GMT) and Mission Elapsed Time (MET). Appendix A contains the sequence of events. Appendix B provides a table containing all Orbiter, SRB, ET, and Integration in-flight anomalies (IFAs) and their status at the time of the publication of this report. Appendix C provides a list of sources of data, both formal and informal, that were used in the preparation of this report. Appendix D provides a list of acronyms, abbreviations and definitions as used throughout this report.

The eight crewmembers (seven up, seven down) that were on the STS-122 flight were Stephen N. Frick, Captain, U. S. Navy, Commander; Alan Poindexter, Captain, U. S. Navy, Pilot; Leland Melvin, Civilian, Mission Specialist 1; Rex Walheim, Colonel, U.S. Air Force, Mission Specialist 2; Hans Schlegel, ESA, Mission Specialist 3; Stanley Love, Ph.D., Civilian, Mission Specialist 4; Leopold Eyharts, ESA, Mission Specialist 5 (ISS Flight Engineer-2 (FE-2), up to ISS); Daniel M. Tani, Civilian, Mission Specialist 5 (ISS FE-2, down from ISS).

STS-122 was the second Shuttle flight for the Commander, Mission Specialist 2, Mission Specialist 3, and Mission Specialist 5 (FE-2 down from ISS). STS-122 was the first Shuttle flight for the Pilot, Mission Specialist 1, Mission Specialist 4, and Mission Specialist 5 (FE-2 up to ISS).

MISSION SUMMARY

Pre-Launch

The first launch attempt of the STS-122 vehicle on December 6, 2007, was scrubbed for 48 hr to December 8th during the External Tank (ET) cryogenic loading. While in fast fill, the Liquid Hydrogen (LH₂) Engine Cut-Off (ECO) sensor circuits 3 and 4 failed wet while the simulated wet and dry commands were applied (IFA STS-122-I-010). During the detanking operations, the LH₂ 5-percent sensor was also observed to have failed wet, but the time of the failure was unknown. After drain operations were completed, the LH₂ ECO sensor circuit 1 failed to the wet state. All indications returned to the dry state within hours of drain complete.

The Mission Management Team (MMT) deferred the next launch an additional 24 hr to allow further review and discussion. A go was given to attempt the launch with the additional constraint that 4 of 4 functional ECO sensors were required to increase the likelihood that LH₂ low-level-cutoff protection would be available during ascent. In addition, the launch window was shortened to reduce the likelihood of an undetectable low mixture-ratio case resulting in a LH₂ low-level cutoff. Flight rules were also modified to allow use of the ECO voltage level measurements for system insight during ascent.

The second launch attempt on December 9th was also scrubbed during fast fill loading of the External Tank when the LH₂ ECO sensor circuit 3 failed wet while the simulated wet and dry commands were applied. Troubleshooting consisted of maintaining the liquid level in the LH₂ tank below the 5-percent sensor and above the ECO sensors for over 4 hr. This was an attempt to change the thermal properties at the feed-through connector. ECO sensor circuit 3 remained failed wet during this troubleshooting, but returned to nominal state during drain operations. The MMT deferred the next launch attempt until after the first of the year while a special team was convened to troubleshoot and isolate the cause of the ECO failures.

A dedicated tanking test was performed on December 18, 2007, in an attempt to repeat the ECO failure and thereby isolate the cause of the problem. The Orbiter aft compartment wiring was modified to allow the use of Time Domain Reflectometry (TDR) to pinpoint the source of an open circuit. Shortly after fast-fill commenced, the simulated dry commands were issued and both LH₂ ECO sensors 2 and 3 were observed to temporarily fail to the wet state for 3 sec and 5 sec, respectively. The LH₂ ECO sensor 1 remained failed in the wet state.

From within the Main Launch Platform (MLP), the troubleshooting team was able to use the TDR technique to successfully isolate the source of the open circuit to the ET feed-through connector. As a result of this finding, two additional teams were subsequently created, one to identify the root cause of the problem and develop a near-term resolution for STS-122, and the other to develop a long-term solution for the problem.

The feed-through connector was removed from the ET and subjected to laboratory testing at Marshall Space Flight Center (MSFC) to isolate the root cause. The open condition on LH₂ ECO sensor circuit 4 repeated. In parallel with the laboratory testing, a separate modified feed-through connector was installed in the ET at the pad, and the launch rescheduled for February.

During the pre-launch countdown, it was determined that the Shuttle Remote Manipulator System (SRMS) Elbow camera was improperly stowed for flight. A dynamic analysis was performed by the Flight Loads and Dynamics personnel to evaluate the camera position. The analysis determined that the pre-launch camera position relative to the payload bay door radiator with any angle between 0.0-deg and 10.6-deg tilt will maintain a positive clearance during ascent. An Operational Maintenance Requirements and Specification (OMRS) waiver for an out-of-print configuration was required.

Approximately 2 hr prior to launch, it was discovered that an oxygen hose that was manifested did not actually make it on board and was found in the Government Flight Equipment (GFE) area. The hose was delivered to the pad and stowed in the middeck. This hose was listed in the pre-launch transfer document and it has the same part number as a hose that is currently yellow-tagged on the International Space Station (ISS). The intent was to exchange hoses so that the ISS hose can be brought back to support troubleshooting of the problem that occurred on STS-120.

Ascent and Flight Day 1

The STS-122 mission was launched on the third attempt at 038/19:45:29.988 GMT on February 7, 2008, the twenty-fourth Space Shuttle Program (SSP) mission to the ISS. All Orbiter subsystems performed nominally during ascent and post-insertion.

The Solid Rocket Booster (SRB) and External Tank (ET) separations were clearly visible from the ET camera. A nominal Orbital Maneuvering System (OMS) assist maneuver was performed following SRB separation. Ignition occurred at 038/19:47:44.412 GMT [00/00:02:14.424 Mission Elapsed Time (MET)], and the maneuver was 113.3 sec in duration.

Main engine cutoff (MECO) occurred at 038/19:53:54 GMT (00/00:08:24 MET). The ET separated from the Orbiter at 038/19:54:14 GMT (00/00:08:44 MET).

A nominal OMS-2 maneuver was performed at 038/:20:23:10.012 GMT (00/00:37:40.024 MET). The maneuver was 103.8 sec in duration with a Differential Velocity (ΔV) of 158.3 ft/sec. The achieved orbit was 118.9 by 124.4 nmi. Both engines operated satisfactorily.

The payload bay doors were opened at 038/21:37:22 GMT (00/01:51:52 MET), and radiator flow was satisfactory.

The Ku-Band antenna was deployed at 038/21:42:02 GMT (00/01:56:32 MET). The system was powered-on at 038/21:45:11 GMT (00/01:59:41 MET). The RADAR self-test was completed at 038/21:54:11 GMT (00/02:08:41 MET). During the initial Ku-Band RADAR self test, the RADAR Active test failed due to a missing TRACK flag and an out-of-tolerance range. This failure is expected to occur periodically, due to timing and the missing TRACK flag, but in this case the range was also out of tolerance. A repeat of the self-test normally results in achieving the correct indications, and this occurred during the second self-test (the RADAR Active test flags and range were within tolerance). Performances of the Ku-Band RADAR and COMM functions for the mission were nominal.

An OMS-3 Nominal Correction (NC) -1 maneuver was performed nominally at 038/23:22:46.8 GMT (00/03:37:18 MET) with the cutoff at 038/23:23:01.2 GMT (00/03:37:32 MET) and both OMS engines operated nominally. The maneuver was 14.4 sec in duration with a ΔV of 22.2 ft/sec. The resulting orbit was 124.6 by 131.9 nmi.

The nominal procedure to download the 30 images from the ET Umbilical Digital Camera was unsuccessful due to an "error reading images from card" message. The crew made two attempts to download the images. This image-download problem was discovered pre-flight and was attributed to incompatible firewire drivers associated with the Payload General Support Computers (PGSC) upgrade from Windows 2000 to Windows XP. To protect for this potential problem, a spare hard-drive with Windows 2000 was manifested, and the images were successfully downlinked later in the flight.

Four occurrences of data dropouts occurred during launch. They were seen from both the Launch and Landing Tracking Data (LLTD) and the S-band. The data gaps were approximately 4 sec in duration. Mission Operations assessed the impact of these dropouts (IFA-STS-122-D-002). The anomaly was evaluated, corrections were implemented and the anomaly was closed.

Flight Day 2

Flight Day (FD) 2 activities included SRMS checkout, vehicle inspection and surveys, Extravehicular Mobility Unit (EMU) checkouts, rendezvous phasing burns, and preparations for the FD 3 docking with ISS.

An OMS-4 (NC2) and Nominal Phase Correction (NPC) combined maneuver was performed nominally at 039/12:42:44.2 GMT (00/16:56:14.2 MET) with the cutoff at 039/12:42:54.2 GMT (00/16:56:24.2 MET) and the right OMS engine operated nominally. The maneuver was 10 sec in duration with a ΔV of 7.7 ft/sec. The resulting orbit was 125.0 by 135.7 nmi. The maneuver was adjusted to provide an opportunity to perform a Maui Analysis of Upper Atmospheric Injections (MAUI) observation later in the mission.

The SRMS power-up and checkout was performed satisfactorily with no problems or issues noted.

The SRMS unberthed the Orbiter Boom Sensor System (OBSS) at 039/13:45 GMT (00/17:59 MET) for the FD 2 vehicle inspection surveys. The starboard-wing survey started at 039/14:28 GMT (00/18:42 MET) and was completed 94 min later. The nose-cap survey was started at 039/16:17 GMT (00/20:31 MET) and was completed approximately 43 min later. The port-wing survey was started at 039/18:00 GMT (00/22:14 MET) and was completed approximately 88 min later. The SRMS/OBSS performance was nominal throughout the surveys. The OBSS was berthed and the SRMS was parked with the brakes-on in the pre-cradle position.

During the starboard Manipulator Retention Latch (MRL) latching, the crew did not receive the Starboard Aft MRL System 2 latch indication. This is considered an expected/explained condition for the OV-104 vehicle. The Starboard MRL operations are performed using only a single motor because of a Flight Rule to protect against inadvertent Manipulator Positioning Mechanism (MPM) cycling. When the System-1 motor is driven in the latch direction, the system 1 latch microswitch is reached and the motor cuts off before the system-2 latch microswitch is reached.

At the FD 2 Mission Management Team (MMT) meeting, the ISS program requested to extend the mission two additional docked days. The current consumables status supported an 11+1+2 day duration, plus 21 hr margin with Oxygen (O₂) the limiting consumable. However, the Mission Priority list specified O₂ transfer as an objective. An early decision was requested so that a less aggressive power-down would be required. ISS was directed to come to the FD 3 MMT and state their priority.

Rendezvous Tools checkout was performed with no issues reported.

The NC3 maneuver was satisfactorily performed with a +X Reaction Control System (RCS) firing starting at 039/22:23:24 GMT (01/02:38:20 MET). The firing time was 9.3 sec with a ΔV of 2.1 ft/sec. The resulting orbit was 125.8 by 136.0 nmi. Thruster performance was nominal.

The Orbiter Docking System (ODS) was activated at 039/22:27:20 GMT (01/02:42:50 MET). Power-on time for the avionics was 8 min, 31 sec. Ring extension to the initial position was nominal, beginning at 039/22:30:51 GMT (01/02:46:21 MET) and ending 3 min, 38 sec (dual motor time) later. The ODS ring extension activity was nominal. The ODS was ready for docking operations.

The supply-water pressure alarm annunciated 1 hr into the crew sleep period when the supply water tanks A and B became full nominally and the supply water pressure began to increase. The pressure increased greater than the onboard upper limit (40 psi) which caused a fault summary message before the A/B and B/C check valves cracked. The limit was raised from 40 psi to 45 psi with a Table-Maintenance Block Update (TMBU) to prevent further nuisance alarms.

The Damage Assessment Team (DAT) reviewed images of blankets on the port and starboard OMS pods that were taken by the crew through the aft flight deck windows. A blanket on the port pod appeared to be slightly lifted and required DAT evaluation (IFA STS-122-V-01). A blanket on the starboard pod appeared to be peeled back to some extent.

Flight Day 3

The primary activities for Flight Day 3 were rendezvous and docking to the ISS, and unberth and handoff of the OBSS.

At approximately 040/08:24 GMT (01/12:38 MET), the Auxiliary Power Unit (APU) 3 fuel-seal-cavity drain-line heaters began to exhibit set-point shifts with the heater off (IFA STS-122-V-02). A total of four anomalous heater cycles were seen. The first two and the last anomalous cycles had set-points that were below nominal. The other anomalous cycle had a set-point that was above nominal. To avoid having a heater failure during a critical period or crew sleep, the A heaters were deactivated and the B heaters were activated.

In preparation for docking, General Purpose Computer (GPC) 3 was moded out of HALT. After 6 sec, GPC's 1, 2, and 4 voted GPC 3 out of the common set. The decision was made to proceed with rendezvous with a dual G2 configuration. A dump of GPC 1 and GPC 3 data was performed for analysis. All data was consistent with a nominal transition from RUN to STANDBY processing. A similar scenario occurred on STS-66, and a Hardware User Note exists which documents how this condition can occur. There was no constraint against using GPC 3 for the remainder of the flight.

The OMS-5 Nominal Height (NH) maneuver was a dual engine firing occurring at 040/12:16:15.5 GMT (01/16:30:45.5 MET). The firing time was 58.6 sec with a ΔV of 90.8 ft/sec. The resulting orbit was 128.8 by 182.70 nmi. Engine performance was nominal.

The OMS-6 (NC4) maneuver was a dual-engine firing occurring at 040/13:06:11 GMT (01/17:20:42 MET) with the maneuver complete at 040/13:07:00 GMT (01/17:21:31 MET). The firing time was 48.2 sec with a ΔV of 75.7 ft/sec. This placed the Orbiter into a 170.4 by 183.7 nmi orbit. Engine performance was nominal.

The Nominal Correction Combination (NCC) maneuver was a 1.0 sec RCS firing using seven thrusters that occurred at 040/13:39:45 GMT (01/17:54:16 MET). The maneuver provided a ΔV of 0.2 ft/sec. The resulting orbit was 170.4 by 183.7 nmi. Thruster performance was nominal.

The OMS-7 Target Intercept (TI) maneuver was a left-engine firing occurring at 040/14:37:27 GMT (01/18:51:58 MET) with the maneuver complete at 040/14:37:39 GMT (01/18:52:10 MET). The firing time was 9.7 sec with a ΔV of 8.4 ft/sec. This placed the Orbiter into a 174.7 by 184.6 nmi orbit. Engine performance was nominal.

Mid-course Correction-1 (MC1) was a 6.2 sec multi-axis RCS maneuver that occurred at 040/14:57:31 GMT (01/19:12:02 MET) with a firing duration 0.1 sec, and a ΔV of 0.5 ft/sec. The Out-of-Plane Null maneuver was combined with MC2. MC2 was a multi-axis RCS maneuver with an ignition time of 040/15:25:41 GMT (01/19:40:12 MET). The firing duration was 0.9 sec with a ΔV of 0.2 ft/sec. MC3 was a multi-axis RCS maneuver with an ignition time of 040/15:42:40 GMT (01/19:57:11 MET). The ΔV delivered was 1.5 ft/sec. MC4 was a 14.2-sec +X RCS maneuver. The ignition was at 040/15:52:40 GMT (01/20:07:11 MET). The ΔV delivered was 3.4 ft/sec and the Orbiter was in a 184.7 by 175.9 nmi orbit.

The R-Bar Pitch Maneuver (RPM) started at 040/16:24:02 GMT (01/20:38:33 MET) and ended 7 min, 55 sec later. The peak pitch rate during the maneuver was approximately 0.7 deg/sec. The maximum roll error reached approximately 1.43 deg and the maximum yaw error reached -0.62 deg. Performance was nominal.

The ODS was activated at 040/16:57:04 GMT (01/21:11:35 MET) and was deactivated after the avionics had operated for 43 min, 32 sec. Shuttle's capture of the ISS occurred at 040/17:17:15 GMT (01/21:31:46 MET). The system was allowed to dampen out for approximately 7 min, 31 sec. Ring retraction was started at 040/17:24:46 GMT (01/21:39:17 MET). Ring retraction, using dual motors, proceeded nominally for approximately 3 min, 21 sec with good ring alignment. The hooks were driven closed nominally and final ring extension was performed, releasing the capture latches with the ring final-position being acquired at approximately 040/17:33:07 GMT (01/21:47:38 MET), at which time docking operations were complete.

After about 4 hr of good communications, intermittent Ultra High Frequency (UHF) communications dropouts were observed between the Shuttle and ISS when the Space-To-Space Orbiter Radio (SSOR) and Station-to-Space Station Radio (SSSR) frame synchronization toggled for 15 min starting at 040/19:45 GMT (IFA-STS-122-V-09). The frame synchronization was then good for 2 min, after which the crew switched to SSOR no. 2.

The MMT decided to delay the first Extravehicular Activity (EVA) and the installation of the Columbus module by 24 hr due to a crew health issue. As a result, the Focused Inspection that was planned for FD 5 was moved forward to FD 4.

The Focused Inspection meeting was held to review DAT recommendations. The Reinforced Carbon-Carbon (RCC) team summarized the results of the FD 2 surveys, and cleared the RCC with no focused inspection required. The Tile and blanket team summarized results of their imagery assessment. A recommendation was made to conduct a focused inspection of a blanket on the starboard OMS that was slightly lifted.

During the processing of the FD 2 Laser Dynamic Range Imager (LDRI) video, intermittent flashes of color were noted in black and white video (IFA STS-122-V-05). This presence of occasional color was subsequently observed in video from other black and white cameras, but did not hinder the imagery analysis or other mission operations.

Flight Day 4

The replanned FD 4 consisted of Middeck transfers, the PGSC exchange to complete the ET Umbilical Camera photo downlink, the focused inspection of the OMS pod blanket, the fill and transfer of Contingency Water Containers (CWCs), initiation of Nitrogen (N₂) transfer from the Shuttle to the ISS, and campout in the ISS airlock at 10.2 psi in preparation for the first EVA on FD 5.

The Shuttle crew completed a Focused Inspection of the lifted thermal blanket on the starboard OMS pod using the SRMS and the OBSS without issue. Images were collected with the Laser Camera System (LCS), the Integrated Sensor Inspection System (ISIS) Digital Camera (IDC), and the Intensified Television Camera (ITVC) and the LDRI, and downlinked for ground analysis. Following the Focused Inspection, the SRMS returned to the Columbus Viewing position with the OBSS.

A spare hard-drive with Windows 2000 was installed in one of the PGSC's and the download of the images from the ET Umbilical Digital Camera was attempted again. The attempt was successful and all of the images from the digital camera were retrieved on the PGSC and downlinked.

The MMT formally approved adding a docked operations day to the mission and discussed potentially adding another docked day. In addition, the ISS requested the middeck return of the Bearing Motor Roll Ring Module (BMRRM). It required stowing on the middeck port floor.

The DAT cleared the vehicle RCC and tile on its underside for entry. Evaluation was still in progress to clear two minor tile damage sites near window 4, as well as the pending analysis of the FD 5 inspection imagery.

Flight Day 5

The crew's main tasks for FD 5 were the first EVA and the installation of the Columbus module.

Crewmembers Rex Walheim (EV1) and Stan Love (EV3) successfully completed the first EVA. The EVA officially began when the EMU's were placed on internal battery power at 042/14:13 GMT (03/18:31 MET) and ended when the cabin repressurization was initiated. The total time of the EVA was 7 hr and 58 min.

During the EVA, the Power Data Grapple Fixture (PDGF) was retrieved from the sidewall of the Orbiter payload bay and installed on the European Space Agency (ESA) Columbus Module. The Columbus Module was then unberthed from the payload bay and installed on the Harmony/Node 2 Starboard Common Berthing Mechanism (CBM) using the Space Station Remote Manipulator System (SSRMS).

The Ku-Band antenna system radiated for 1 min and 16 sec while operating in the high-power mode when the antenna was stowed prior to the Columbus Module installation. The ISS was subjected to momentary radiation between the S0 and S1 trusses. Analysis determined this occurrence was not an issue for the ISS.

Prior to EVA 1, at 042/11:18:00 GMT (03/15:32:31 MET), the ground attempted to route an ISS camera video signal to the Orbiter via the Channel 71 ISS Video channel. Once the route was in place, the Orbiter crew reported that the signal was not very good. The ground team performed some troubleshooting, but was not able to get a signal routed to the Orbiter. The ground team also determined that the accompanying video channel from the Orbiter to the ISS did not work. The second video channel from the Orbiter to the ISS was confirmed to be functional, so for the EVA, the crew used Orbiter Downlink to Channel 72 ISS to route the image to the Orbiter. Subsequent investigation determined that Node 1 was known to have a cross-wired condition and Node 2 was intended to accommodate the cross-wire. However, the corrective action on Node 2 was not implemented correctly. A pin swap at the pressurized mating adaptor (PMA) 2 restored the interface temporarily.

The revised attitude timeline was approved that included one extra docked day. Since the beta angle on the extra mission day was above -50 deg, the port OMS pod Entry Interface (EI) bondline limit was predicted to be within 2 °F of its limit. Therefore, a recommendation was made to change the -ZLV -XVV End-Of-Mission (EOM) thermal conditioning attitude to -ZLV +YVV for all of the possible EOM opportunities.

ET umbilical images were successfully downlinked for analysis. Four TPS items remained open, 2 window tiles, the port OMS stinger lost tile, and the starboard OMS Pod blanket damage. Assessment of the blanket damage continued.

Flight Day 6

The crew's main tasks for FD 6 were the activation and ingress of the Columbus module, and preparation for the second EVA.

The Orbiter assumed attitude control of the stack at 043/18:04 GMT (04/22:19 MET) and the water-dump attitude was reached approximately 8 min later. During the maneuver to the water-dump attitude, at about 043/18:16 GMT (04/22:21 MET), Oxygen tanks 1, 3, and 5 de-stratified. The crew was requested to activate the tank heaters to maintain tank pressures above the critical pressure.

The simultaneous (SIMO) dump of waste and potable water was completed with no issues. The maneuver back to Torque Equilibrium Attitude (TEA) began at 043/21:00 GMT (05/01:15 MET) and was completed a few minutes later. The Orbiter Digital Autopilot (DAP) was put in Free Drift mode at 043/21:20 GMT (05/01:35 MET) at which time the ISS resumed attitude control.

The third on-orbit fuel cell purge was commanded at 043/23:29:15 GMT (05/03:43:45 MET). The Power Reactant Storage and Distribution (PRSD) Oxygen/Hydrogen (O₂/H₂) manifold-2 isolation valves were cycled closed for the crew-sleep period at 044/00:49 GMT (05/04:31 MET) and reopened approximately 10 hr later.

The BMRRM transfer and stowage in the Orbiter was attempted by the crew. The foam that was used was the original foam that was used during the initial installation of the BMRRM in the ISS. This foam configuration was different than the configuration certified prior to flight. As a result, a team was formed to evaluate possible alternate methods of stowage.

The Thermal Protection System (TPS) DAT completed the analysis of the two damage sites around the cabin windows and the uplifted blanket on the starboard OMS pod for entry. The TPS DAT presented results of the tile and blanket damage assessment to the MMT. The MMT approved the TPS DAT recommendation and cleared all open TPS items with the exception of the missing tile on the Port OMS Pod RCS stinger.

Flight Day 7

The crew's main task for FD 7 was the second EVA. The EV1 and EV2 crewmembers successfully completed the EVA with a total EVA time of 6 hr 45 min. During the EVA, the crew successfully completed the removal and replacement of Nitrogen Tank Assemblies (NTA's) and secured the Laboratory Micrometeoroid/Orbital Debris (MMOD) shield.

Nitrogen transfer was completed with a total of 27 lb transferred to ISS.

At about 4:30 a.m. on February 13, 2008, the connection to the Johnson Space Center (JSC) Internet Network (JIN) went down in the Mission Control Center (MCC). The contractor repairman reported that the switch had lost a supervisor card. There was none in stock, but one was obtained and installed. The network was returned to nominal operation at 8:40 a.m. the same day.

The TPS DAT completed analysis of the missing tile on the Port OMS pod RCS stinger. The MMT approved the DAT recommendation, and declared the vehicle TPS cleared for entry.

The MMT also approved the mission duration extension to 13+0+2 in support of Columbus-module configuration activities. The additional day was added between the third EVA and undocking. Landing was moved to Wednesday, February 20, 2008.

Flight Day 8

FD 8 was an off-duty day for the crew. Their tasks included Public Affairs Office (PAO) events and a procedure review for the third EVA. The Columbus Commissioning

continued with the configuration of the Bio-Laboratory, European Drawer Rack (EDR), European Physiology Module (EPM), and Fluid Science Laboratory (FSL).

Video over-exposure was seen during the review of the middeck video downlink (IFA STS-122-V-03). The crew confirmed that the Advanced Video Interface Unit (AVIU) Hi-Z/75 switch was in the 75-ohm position. The crew also stated that there had been other issues with the same AVIU. The unit was replaced with an AVIU from the flight deck and the over-exposure cleared. The AVIU was marked as suspect.

Assessment of the BMRRM return stowage continued. The original stowage of the BMRRM was different from the analyzed configuration, as the old BMRRM stowage container foam was used instead of the Individual Equipment Linear Kit (IELK) foam. The team reviewed video of the stowage configuration and performed testing over in building 9. Two changes to the on-orbit configuration were identified to provide better loads distribution, and to remove the clamshell from the BMRRM, thus providing a better surface for the y-straps.

The troubleshooting in Node 2 for the problem of the video loss to/from Orbiter was successful. A crossover jumper was installed in one of the Node 2 racks. Good video was seen on Orbiter Channel 1 from Station-to-Orbiter and Orbiter-to-Station.

To support Flight Night (FN) 8 overnight troubleshooting, the crew switched back to SSOR 1 prior to crew sleep and then back to SSOR 2 in support of the third EVA. No anomalies were seen during the troubleshooting. The crew returned to SSOR 1 on FD 10 and remained there until FD 12 undocking. No repeats of the intermittent communications dropouts were seen.

Concerns with the Launch-to Activation (LTA) cable were resolved. The cable was located on the port side of the payload bay immediately behind the Integrated Cargo Carrier. During the first EVA, the cable was not wrapped and secured as expected as it was only secured in two places. The entry/landing loads were evaluated by the Space Shuttle Program (SSP) Office to ensure that the cable configuration would not come loose. A clearance analysis also verified that the cable would not become tangled in the Payload Bay Door (PLBD) bell-crank during door closure. Both issues were resolved and no on-orbit changes are required.

Flight Day 9

The EV1 and EV3 crewmembers successfully completed the third EVA with a total EVA time of 7 hr and 25 min. All EVA objectives were accomplished. The primary tasks completed during this EVA were installation of the External Payload Facility of Columbus (SOLAR) sun monitoring and European Technology Exposure Facility (EuTEF) exposure experiment packages on the Columbus external payload facility and the transfer of a failed Control Moment Gyro (CMG) from the ISS to the Orbiter for return. The extra time to inspect and photograph the Solar Alpha Rotary Joint (SARJ) was not available during this EVA.

The Columbus commissioning continued with the configuration of the Bio Laboratory, EDR, and FSL. After the EVA installation, both SOLAR and EuTEF payloads were activated and the Control Centers began receiving telemetry.

The fuel cell 3 oxygen flow-meter began displaying erratic behavior at 046/10:30:40 GMT (07/14:45:10 MET) (IFA STS-122-V-04). The reading went to off-scale-low for about two min, followed by erratic data. The Fault Detection Annunciation (FDA) upper limit was inhibited to prevent an alarm. The primary purpose of the flow-meter is to indicate purge flow, which can be verified by other parameters. Fuel cell flow-meter failures have occurred on previous missions, and no further action was required during the mission.

The Forward Reaction Control System (FRCS) oxidizer pressure line temperature was trending down below 60 deg, which is above the FDA limit of 46 deg. The trend had been observed over the prior two days. The crew switched to the alternate heater and the trend continued. The data was not consistent with previous OV-104 FRCS data from a previous flight (STS-104) with a similar thermal environment.

The crew reported that the galley cold-water hydration line was not pumping water. The hot water and the alternate cold line associated with the overnight configuration were dispensing nominally. The awake-configuration of the hydration line includes an iodine filter (ACTEX) which is bypassed in the sleep configuration. During subsequent troubleshooting, the line became functional again.

A modified BMRRM stowage procedure was up-linked to the crew. The revised stowage configuration for the BMRRM provided better loads distribution and removed the clamshell from the BMRRM, thus providing a better surface for the y-straps.

Flight Day 10

The primary Shuttle crew tasks for FD 10 were the Orbiter-assisted ISS re-boost and oxygen transfer. The Columbus commissioning continued with the outfitting activities for the Bio Laboratory, EDR, EPM and FSL. The crew also relocated the Active Rack Isolation System (ARIS) payload hardware to the Columbus Zero-G stowage rack.

The ISS crew set up and reconfigured the oxygen system to prepare for transferring oxygen from the Shuttle to the ISS Airlock oxygen tanks using the Oxygen Recharge Compressor Assembly (ORCA).

The FRCS oxidizer pressure line temperature downward trend was observed to level off. Even though the heater operation was shifted to the B system, the heater continued to operate at 100-percent, which is caused by the attitude environment.

The Orbiter-assisted RCS reboost session began at 047/12:17:00 GMT (08/16:3:30 MET) and was completed approximately 36 min later. The session was performed

while interconnected to the left OMS propellant system. The RCS performed satisfactorily with a ΔV of 5.4 ft/sec. The orbit was raised approximately 1.5 nmi with a resulting orbit of 187.7 by 176.3 nmi. This was the first Orbiter commanded reboost in five years; the last Orbiter commanded reboost occurred during STS-113 on December 1, 2002.

The fifth on-orbit fuel cell purge was commanded at 048/08:00 GMT (09/12:14 MET). During the purge, the fuel cell 3 oxygen flow meter indicated an increased flow-rate, but operation remained erratic. Hydrogen tank 4 and oxygen tank 5 were depleted to residual quantities at about 047/20:14 GMT (09/00:28 MET).

Flight Day 11

The crew's main tasks for FD 11 were transfer activities, rendezvous tools checkout, hatch closure, and centerline camera installation.

All planned transfers between Atlantis and the ISS were completed, including the transfer of the BMRRM, the heaviest item returned in the middeck.

The oxygen transfer from the Shuttle to the ISS Airlock oxygen tanks using the ORCA was terminated on FD 11 when the ISS tanks indicated full. Approximately 95 lb of Oxygen was transferred.

The nitrogen repressurization was completed with 27 lb transferred. Following the nitrogen repressurization, the nitrogen flow-meter transducer began to act erratically. Over a period of 5 min, five large data spikes were observed; however, no additional spikes were observed during the rest of the mission. The transducer was a brand new solid state transducer and will be monitored on future flights.

The 13th CWC was filled and transferred to the ISS. A 10 mmHg N₂ repressurization of the ISS stack was performed using Shuttle resources.

The APU 1 Gas Generator (GG) bed erratic temperature signature specific to OV-104 position 1 began at 048/20:52:30 GMT (10/01:07:00 MET) and returned to normal on FD 12 at 049/09:28:50 GMT (10/13:43:20 MET).

The radiator retraction hose imagery collection procedures were uplinked to the crew could record video of both port hoses and the aft starboard hose during payload bay door closure. The crew was also asked to give a verbal report on the hose configuration after door closure. These data will aid in the ongoing flexible-hose omega-bend troubleshooting during ground turnaround activities.

The Orbiter Communications Adapter (OCA) data indicated that the K-Band File Transfer (KFX) PGSC was exhibiting network dropouts (IFA STS-122-S-001). The crew reseated the network card, but the dropouts continued. The crew replaced the network card, and no dropouts were seen after the change. The crew tagged the suspect network-card for post-flight troubleshooting.

During the rendezvous tool checkout, the crew reported the Trajectory Control Sensor (TCS) data on the primary Rendezvous Proximity Operators Program (RPOP)/TCS laptop was good, but the TCS data could not get to the backup RPOP/TCS laptop (IFA STS-122-S-002). This problem had been seen previously during FD 3 rendezvous, and was reproduced during the tool checkout on FD 11. The crew changed out the RS-422 Quatech card twice and reported good TCS data on the backup RPOP/TCS laptop.

In preparation for undocking, the Flight Control Team requested an assessment of a 3 ft/sec Shuttle +X axis firing for the separation-2 maneuver. The request was made to minimize deorbit propellant costs by performing the maneuver using the aft RCS thrusters rather than the forward RCS thrusters. This change was requested to provide more landing opportunities. The current certified limit for a -X Sep-2 firing with the OBSS unstowed is 1.5 ft/sec.

The farewell ceremony was conducted between the ISS and Atlantis crews, followed by egress of the seven Shuttle crew members, hatch closing, ODS vestibule depressurization, and a leak check.

Flight Day 12

The Orbiter undocked from the ISS with no issues reported. The crew's main task for FD 12 was the RCC late inspection activities.

The ODS mechanism power-on was commanded at 049/08:25 GMT (10/12:39 MET) and the Orbiter was undocked from the ISS at 049/09:24 GMT (10/13:38 MET). All hooks and latches were driven with no anomalies observed and undocking was completed satisfactorily. The ODS was powered down after mechanism power had been applied for 1 hr 18 min 19 sec.

ISS Separation was initiated with a +Z pulse at 049/09:24:49 GMT (10/13:39:19 MET). The flyaround was initiated with +X pulse at 049/09:48:13 GMT (10/14:02:43 MET). The flyaround was completed and good photography of both ISS and Shuttle was obtained.

The Separation-1 maneuver, which was planned as a 1.5 ft/sec ΔV , was performed satisfactorily with a 6.0 sec pulse in the +X axis at 049/10:34:04 GMT (10/14:57:34 MET).

The Separation-2 maneuver, which was planned as a 3.0 ft/sec ΔV , was performed satisfactorily as a 12.2 sec pulse in the +X axis at 049/11:01:30 GMT (10/15:15:00 MET).

The RCC late inspection of the Starboard and Port Wing Leading Edge and Nose cap were performed using the OBSS. The survey began at 049/13:54 GMT (10/18:08 MET) and was completed 3 hr 02 min later, and the survey imagery was successfully down

linked for ground analysis. After performing the Late Inspection, the OBSS was berthed; the SRMS was cradled and latched.

At 049/15:47 GMT (10/20:02 MET), the crew turned on the six payload bay floodlights, and the current increase was lower than expected. The crew was asked to individually power-down each floodlight. When the crew turned off the mid-port floodlight, the current dropped less than the expected amount indicating this light was not working properly (IFA STS-122-V-08).

At 049/16:13:44 GMT (10/20:28:14 MET), the Hydraulic System 3 Right Outboard elevon actuator hydraulic return-line temperature exhibited a temperature excursion over a 10-hr period. A Table Maintenance Block Update (TMBU) was up-linked to inhibit the FDA and avoid any nuisance alarms.

At 049/18:41:49 GMT (10/22:56:19 MET), during the stowing of the port MPM, neither the System 1 nor System 2 stow indications were obtained on the Aft MPM (IFA STS-122-V-07). Both stow indications were obtained on Shoulder, Forward and Mid MPMs. Both Aft MPM close indications came-on approximately 11 hrs later.

Just prior to crew sleep, at 049/20:29:09.321 GMT (11/00:37:39.333 MET), an electrical current spike of greater than 12 amperes for approximately 20 msec was observed on Fuel Cell 3. This was followed by the RCS L5L thruster temperature indication decreasing. The other 3 aft vernier thruster heaters were off, due to injectors being warmer than the heater turn-off temperature. Subsequently, all 4 aft vernier injector temperatures continued to drop, each producing the appropriate "Fail-Leak" message when the injector temperature dropped below the Redundancy Management (RM) limit of 130 °F. The crew cycled the vernier thruster heater switch with no effect.

The MMT accepted the Orbiter Project Office (OPO) recommendation to continue with the nominal entry plan that does not require the isolation of Freon coolant loop 2.

Flight Day 13

The crew's main tasks for FD 13 were the Flight Control System (FCS) checkout and the RCS hot-fire.

The attitude was changed to the -ZLV YVV at 050/08:15 GMT (11/12:30 MET), and this change successfully initiated a warming of the Aft RCS manifold 5 thrusters.

The FCS checkout was performed satisfactorily. APU 3 operation was started at 050/10:11:10 GMT (11/14:25:50 MET). A total of 14 lb of fuel was used during the 4 min 23 sec run-time of the APU. All APU parameters were nominal during the FCS checkout.

The RCS hot-fire procedure was initiated at 050/10:54:50 GMT (11/15:09:20 MET), and the hot-fire was completed 17 min 19 sec later. All 38 thrusters were fired for at least 0.240 sec per pulse. All thrusters fired satisfactorily.

The MMT cleared the Orbiter for entry and landing at Kennedy Space Center (KSC).

Flight Day 14

Both Payload Bay Doors (PLBDs) were closed nominally by 051/10:26:31 GMT (12/14:41:01 MET) in preparation for landing.

The deorbit maneuver was performed on orbit 202 for the first landing opportunity at KSC. A dual-engine straight-feed firing was performed at 051/12:59:52.4 GMT (12/17:14:22.412 MET). The duration of the deorbit firing was 163.2 sec and the ΔV was 303.2 ft/sec. The orbit following the deorbit firing was 23.3 by 187.6 nmi. The engines performed satisfactorily.

Entry interface occurred at 051/13:35:30 GMT (12/17:50:00 MET), and entry was completed satisfactorily.

The main landing gear touchdown occurred on KSC concrete runway 15 at 051/14:07:09 GMT (12/18:21:39 MET) on February 20, 2008. The drag chute was deployed at 051/14:07:10 GMT. Nose-gear touchdown occurred at 051/14:07:16 GMT. Drag chute release occurred at 51/14:07:46.2 GMT. Wheels stop occurred at 051/14:08:07 GMT. The rollout was normal in all respects.

The flight duration was 12 days 18 hr 21 min 39 sec. The last APU was shutdown at 16 min 3 sec after landing.

PAYLOADS AND EXPERIMENTS

LAUNCH PACKAGE OVERVIEW

The International Space Station (ISS) 1E launch package consisted of the European Space Agency (ESA) Columbus Module, a sidewall-mounted Power and Data Grapple Fixture (PDGF), the Integrated Cargo Carrier Light (ICC-L) that launched with the Sun Monitoring on the External Payload Facility of Columbus (SOLAR), European Technology Exposure Facility (EuTEF) payloads and a replacement Nitrogen Tank Assembly (NTA). A failed Control Moment Gyroscope (CMG) was transferred from the ISS to the ICC-L for return to Earth.

The ISS Program Utilization payloads that were flown in the Middeck were 18 ambient Ice Packs, Particle Flux, Double Cold Bag with Ice Packs, ESA Waiving and Coiling response of Arabidopsis Roots (WAICO) samples with WAICO support hardware, and European Modular Cultivation System (EMCS) resupplies. Middeck payloads returned included LADA-Medical Information System (MIS) Optimization of Root Zone Substrates (ORZS); Stability of Pharmacotherapeutic and Nutritional Compounds (Stability), ESA EMCS Water Reservoirs, Knee Brace Assembly Replacement (KBAR) assembly; Coarsening in Solid-Liquid Mixture Sample Processing Unit (CSLM-SPU), Perceptual Motor Deficits in Space, ISS Integrated Immune Samples, and One Double Coldbag that was used to return Nutrition samples.

The Short Duration Bioastronautics Investigations (SDBIs) performed during the mission included SDBI-1503-S (Midodrine), SDBI 1490B/SDBI 1634 (Promethazine (PMZ)/SLEEP), ISS Integrated Immune and SDBI 1900 (Integrated Immune).

The Maui Analysis of Upper-Atmospheric Injections (MAUI), which was flown as a payload of opportunity, is an observational payload with no flight hardware.

Two Shuttle Development Test Objectives (DTOs) were flown and are discussed in the DTO section of this report. These DTOs were:

1. DTO 805 – Crosswind Landing Performance (DTO of opportunity).
2. DTO 853 – In-Flight Evaluation for Areas of Carbon Dioxide (CO₂) Concentration.

CREW ACTIVITY SUMMARY

Atlantis docked to the ISS on Flight Day (FD) 3, February 9, at 11:17 a.m. Central Daylight Time (CDT) (40/17:17:16 GMT, 01/21:31:46 MET). After the hatches were opened, Leopold Eyharts transferred to the ISS, officially becoming a member of the

Expedition 16 crew when he installed his Individual Equipment Liner Kit (IELK) into 15 Soyuz.

The FD 4 Columbus unberthing and Extravehicular Activity (EVA) activities were delayed 24 hours due to a crew health issue. FD 4 was replanned allowing several get-ahead tasks from the FD 5 plan to be completed on FD 4 as well as the starboard OMS Pod focused inspection.

On FD 5, the crew successfully completed the first EVA. During the EVA, the Power and Data Grapple Fixture (PDGF) was retrieved from the Orbiter payload bay and installed on the ESA Columbus Module. The Columbus was then unberthed from the payload bay and installed on the ISS Node 2 (Harmony) 2 Starboard Common Berthing Mechanism (CBM) using the SSRMS.

The FD 6 primary activities were the activation and ingress of the Columbus module, and preparation for the second EVA. Other activities included a simo waster and water dump as well as the Bearing Motor Roll Ring Module (BMRRM) transfer and stowage on the Orbiter middeck.

The FD 7 EVA included the removal and replacement of a NTA from the P1 truss as well as and securing the Laboratory Micrometeoroid/Orbital Debris (MMOD) shield.

FD 8 was an off-duty day for the crew. Their tasks included Public Affairs Office (PAO) events and a procedure review for the third EVA.

On FD 9, the crew successfully completed the third EVA which included the transfer and installation of two ESA payloads, the SOLAR and EuTEF (carrying eight experiments requiring exposure to the space environment), to the External Payload Facility (EPF) on the Columbus module. Also, a failed CMG was removed from its storage location on ISS and transferred to the ICC-L in the Shuttle payload bay for return to Earth.

On FD 10, a reboost of the ISS was performed and the firing consisted of 4.2 ft/sec Differential Velocity (ΔV), which resulted in a 1.9 mile gain in altitude. The last Orbiter reboost of the ISS was performed by STS-113 on December 1, 2002, making this reboost the first Orbiter reboost performed in 5 years.

FD 11 main tasks were transfer activities, rendezvous tools checkout, hatch closure, and centerline camera installation.

Atlantis undocked from the ISS on the morning of FD 12, February 18, 2008, at 3:24 a.m. (049/09:24 GMT, 10/13:38 MET), and a one lap fly-around was performed to obtain photographic imagery of the ISS with the new Columbus Module attached.

TRANSFER WEIGHT SUMMARY

The majority of the ISS-1E transfers were successfully accomplished during this mission. The following table and statistics provide a complete listing of the transfer operations.

Prior to launch, the ISS Program requested the return of the failed Bearing Motor Roll Ring Module (BMRRM) that was replaced during U. S. Stage EVA 14. At 242 lbm, the BMRRM was the heaviest item to ever be returned in the middeck. The final on-orbit stowage configuration of the BMRRM was different from the recommended analyzed configuration, as the old BMRRM stowage container was used instead of the Individual Equipment Liner Kit (IELK) foam. A video of the final stowage configuration was reviewed and testing was performed at Johnson Space Center (JSC) to address safety and loading concerns. Two changes to the on-orbit configuration were identified which provided better loads distribution and removal of the clamshell from the BMRRM which provided a better surface for the y-straps utilized to secure the item for entry.

TOTAL WEIGHT TRANSFERRED DURING THE MISSION

Parameter	To ISS, lb	From ISS, lb
Middeck	1423	1698
Columbus	26627	0
SOLAR	751	0
EuTEF	658	0
NTA	1069	1039
Dry Cargo	2079	0
Totals	32607	2737

Orbiter consumables transferred to the ISS during the mission included:

1. **Water** – The total quantity of supply water transferred was 1386.1lbm. A total 13 Contingency Water Containers (CWCs) were transferred along with 8 Portable Water Reservoirs containing 172.8 lbm
2. **Oxygen** – A total of 94 lbm of oxygen were transferred to the Airlock High Pressure Gas Tank (HPGT).
3. **Nitrogen** – A total of 25 lbm of Nitrogen was transferred to the Airlock tanks. In addition, a 10mm Hg N₂ was used to repressurized the ISS stack.
4. **Lithium Hydroxide** –.A total of seven new Lithium Hydroxide (LiOH) canisters were transferred to the ISS. A total of 11 LiOH canisters were transferred from the ISS to the Shuttle, of which 10 were used by the Shuttle and 1 was expired.
5. **Food** – No food was transferred to the ISS.

SIGNIFICANT FIRSTS

The first occurrences in the Space Shuttle Program are provided in the following list.

1. First Shuttle docking to the Node 2/Pressurized Mating Adapter (PMA) 2 configuration (configured following the 10A mission) on the Laboratory forward.
2. First Nitrogen Tank Assembly removal and replacement.
3. First flight of Integrated Cargo Carrier Lightweight (ICC-L).
4. First docked mission to use the Node 2 PDGF.
5. Launch of European Space Agency (ESA) element (Columbus Module).
6. First real-time operations with ESA and Columbus Control Center in Oberpfaffenhofen, Germany.
7. First flight of N₂/O₂ Control Panel Mass Flow sensor design.
8. First flight of Gas Generator Valve Module (GGVM) heater modification on all three Auxiliary Power Units.
9. Advanced Master Events Controller (AMEC)/Enhanced Master events Controller (EMEC) Station Multiplex Interface Adapter (SMIA) mounting nut modification.
10. Wing Leading Edge Impact Detection System (WLEIDS) Firmware update to Version 3 to enhance system reliability and performance.
11. First Space Shuttle Main Engine (SSME) flight with all oversized inserts with corrosion inhibitor on the Low Pressure Oxidizer Turbopumps.
12. First SSME flight with all three engines containing High Pressure Oxidizer Turbopumps with redesigned knife-edge seals.

SIGNIFICANT ISS ANOMALIES

During FD 6 final activation activities, the Columbus Moderate Temperature Loop (MTL) Interface Heat Exchangers (IFHX) were inadvertently forced on which raised the IFHX core temperature to approximately 65 °C (149 °F). The elevated temperature forced a transient hot water slug through the External Thermal Control System (ETCS) Loop A Pump and Control Valve Package (PCVP). The Flow Control Valve (FCV) responded to the transient by allowing more radiator flow. The FCV overcompensated which caused an under-temperature shutdown and subsequent caution alarm annunciation onboard the ISS. Loop A was recovered by ground controllers and the MTL was re-integrated with Columbus IFHX resulting in the Columbus ITCS being fully activated.

During final activation on FD 6 of the Columbus data management systems, the Columbus Command and Control System (CCS) output command queue could not command to the Columbus Mission Management Computer (MMC). The MMC is the inter-module interface computer required between the US Command and Data Handling (C&DH) system and the Columbus equipment monitoring computer, the Data Management Computer (DMC). A "Command from scratch" was uplinked, which was expected to clear the command buffer in the CCS. The command was sent multiple

times, but did not resolve the problem. It was later determined that the command queue contained stale data that would be cleared with a Multiplexer/Demultiplexer (MDM) transition. The transition was executed taking the primary to backup and the backup to primary. The transition was successful and the Columbus MMC received commanding. The final Columbus activations were then successfully completed.

On FD 6, the ISS Commander reported that a General Luminaire Assembly (GLA) was non-functional in Node 2. Subsequent investigation indicated that three of the four screws in the corners of the GLA appeared to have been over-torqued causing stress fractures in the cover of the GLA. The Baseplate Ballast Assembly (BBA) and Lamp Housing Assembly (LHA) will be replaced to restore the lighting on a future date.

Prior to the scheduled Orbiter water dump on FD 8 when Ground Controllers attempted to lock the port Solar Alpha Rotary Joint (SARJ), the Drive Lock Assembly (DLA) 1 experienced a tooth-crash. The Orbiter water dump activities were delayed until the ground performed a manual DLA recovery and locked the SARJ. The root cause is believed to be that the auto recovery timer expired before the "Lock Tooth Crash" algorithm had time to execute an unexpected response. After the water dump, the port SARJ was commanded to autotrack. A software exception was noted after the data were analyzed that was similar to several noted during Thermal Radiator Rotary Joint (TRRJ) tooth-crashes. Software to address both issues was being developed.

MAJOR ISS MISSION PRIORITIES

The following table provides a listing of all the ISS Mission priorities and their status as of the end of the mission.

MAJOR ISS MISSION PRIORITIES COMPLETED

Mission priority	Mission Task	Flight Day Completed
Category 1 Tasks		
1.	Rotate E15/16 ISS-10A FE with E16 ISS-1E FE, transfer mandatory crew rotation cargo per Flight 1E Transfer Priority List (TPL), and perform mandatory tasks consisting of Individual Equipment Liner Kit (IELK) installation and Sokol suit checkout.	FD 4
2.	Configure, mate, and safe Columbus Module to berthed survival mode at Node 2 Starboard Common Berthing Mechanism (CBM) location using Space Station Remote Manipulator System (SSRMS).	FD 5/EVA no. 1
	a. Remove Power and Data Grapple Fixture (PDGF) from sidewall carrier and install on Columbus.	FD 5
	b. Remove Columbus CBM protection cover segments and demate Launch-to-Activation (LTA) heater cable and install connector cap.	FD 5
	c. Perform Node 2 starboard Active CBM (ACBM) sealing surface inspection.	FD 5
	d. Perform Columbus Passive CBM sealing surfacing inspection.	FD 5

MAJOR ISS MISSION PRIORITIES COMPLETED (Continued)

Mission priority	Mission Task	Flight Day Completed
	e. Open Node 2 starboard CBM Berthing Camera System (CBCS) center disk cover flap.	FD 5
3.	Transfer mandatory quantities of water to the ISS per TPL.	FD11
	Category 2 Tasks	
4.	Perform minimum crew handover of 12 hr per rotating crewmen, which includes crew-safety handover	Completed FD10
5.	Remove and Replace the P1 Nitrogen Tank Assembly (NTA)	FD 7/EVA 2
6.	Complete purge of Node 2 O ₂ system	FD 3
7.	Install and perform mandatory activation of Columbus SOLAR external payload on the EPF	FD9/EVA 3
8.	Return failed CMG from ESP-2	FD 9/EVA 3
9.	Install and perform mandatory activation of Columbus EuTEF on the Columbus EPF	FD 9/EVA 3
10.	Transfer mandatory items per TPL.	FD 4-11
	Category 3 Tasks	
11.	Activate Columbus Module systems required for sustained crew presence, including.	Completed FD 11
	a. Remove Negative Pressure Relief Valves (NPRV's).	
	b. Install Inter-Module Ventilation (IMV) valves.	
	c. Remove four Node 2 starboard ACBM controller assemblies for return on STS-122.	
	d. Check out Columbus subsystems required for payload commissioning.	
12.	Perform requested Public Affairs Office (PAO) event with top level European Government leader as soon after initial ingress into Columbus Module and activation as practical.	FD 8
13.	Install trunnion and keel thermal covers.	FD 7 & FD 9 EVA 2 & 3
14.	Activate and initiate checkout/commissioning activities for SOLAR and EuTEF payloads and the EPF.	FD10
15.	Transfer remaining items per Flight 1E TPL.	FD11
16.	Mechanical setup, initial activation, and minimum interface checkout of the Columbus International Standard Payload Rack (ISPRs) in the following priority order: Note: Racks A, C, and D need to be transferred from launch to on-orbit location prior to activation. (Any activities not accomplished during the docked mission will be completed during the 1E Stage).	FD6-11
	a. BIOLAB	FD 11
	b. FSL	In-work
	c. EDR	Deferred
16.5	Install the Node 2 to Pressurized Mating Adapter vestibule barrier assembly.	FD 4

MAJOR ISS MISSION PRIORITIES COMPLETED (Continued)

Mission priority	Mission Task	Flight Day Completed
17.	Perform ISS daily payload status checks as required.	Daily
18.	Perform ISS science payload research operations tasks: Nutrition (NASA), Integrated Immune (NASA), MOP-M (ESA), MUS-M (ESA), MUS (ESA).	FD 4-11
	d. EPM	FD 10
	a. Schedule 5-min daily sleep log activity for FE-2 Dan Tani.	Daily
	b. Schedule WAICO seed insertion into Minus Eighty Laboratory Freezer for ISS (MELFI).	FD 5
19.	Perform functional testing of: ISPR interface.	
	a. BIOLAB	Partial
	b. FSL	Partial
	c. EDR	Partial
	d. EPM	Partial
19.5	Perform sharp edge inspection of Airlock Handrail HR-0506.	FD 9/EVA 3
20.	Install Columbus EVA aids.	FD 9/EVA 3
21.	Repair Laboratory C2-03 MMOD Dzus Fasteners and reinstall shield.	FD 7/EVA 2
22.	Perform remaining approved ISS and Shuttle crew Utilization activities:	Daily
	a. Russian activities	
	b. NASA PMZ/Sleep Short and ISS Sleep Long	
	c. NASA Integrated Immune	
	d. NASA Midodrine	
	e. ESA ISS Motion Perception	
	f. ESA Low Back Pain-Muscle	
	g. ESA ISS Low Back Pain-Muscle (Medium Duration)	
	h. MAUI	FD1
22.5	Perform Columbus Power Distribution Unit (PDU) Fuse Changeout for MISSE payload.	FD 8
23.	Reboost ISS with Orbiter if mission resources allow and are consistent with ISS trajectory analysis and planning.	FD 10
24.	Transfer O ₂ from the Orbiter to the ISS Airlock (A/L) High Pressure Gas Tanks (HPGT's) (as consumables allow).	FD 10-12
25.	Transfer required N ₂ from Orbiter to the ISS A/L HPGT's (as consumables allow).	FD 6,7
26.	Install hatch latch handle guide assemblies (x2) (Node 2 starboard, Columbus port).	FD 7
27.	Perform SDTO 13005-U, ISS Structural Life Validation and Extension, during Columbus installation ((ISS Wireless Instrumentation System (IWIS) only if crew time available).	FD 5
28.	Perform SDTO 13005-U, ISS Structural Life Validation and Extension, during Shuttle mated Reboost (IWIS only if crew time available).	FD 10

MAJOR ISS MISSION PRIORITIES COMPLETED (Concluded)

Mission priority	Mission Task	Flight Day Completed
29.	Perform DTO 853 - In-flight Evaluation for Areas of CO ₂ Concentration, if crew time permits.	Multiple
30.	Perform imagery survey of the ISS exterior during Orbiter flyaround after undock.	FD12
31.	Perform an additional 4 hours per rotating crewmember of ISS crew handover (16 hours per crewmember total).	Not completed
32.	Install Node 2 starboard hatch window cover	FD 7
33.	Complete Columbus checkout tasks (includes vacuum venting checkout).	In-work
34.	The following tasks (None) are deemed to fit within the existing EVA timelines; however, may be deferred if the EVA is behind schedule. The EVA will not be extended to complete these tasks.	N/A
35.	Perform program-approved EVA get-ahead tasks. The following EVA get-ahead tasks do not fit in the existing EVA timelines; however, the EVA team will be trained and ready to perform these tasks should the opportunity arise. EVA/Mission Operations Directorate (MOD) has the flexibility to select the tasks to be completed based on efficiencies gained in performing the already scheduled required tasks.	
	a. Stow ORU Temporary Stowage Device (OTSD).	FD5/EVA 1
	b. Relocate EVA aids (handrails and Worksite Interface Fixtures (WIFs) for subsequent flight.	Not completed
	c. Install Node 1 C2-02 MMOD shield.	Not completed
	d. Release Node 2 Port CBM petal restraints.	Not completed
	e. Return 3/8" Drive Ratchets S/Ns 1011 & 1012 to the ESTD after inspection of the EVA Palm Wheels.	Not completed
	f. Return GP cutter to A/L toolbox 2 (-303 version).	Not completed
	g. Connect S1-S3 NH3 contingency jumper.	Not completed
36.	Perform program-approved IVA get-ahead tasks.	
	a. Columbus commissioning tasks (At least 7 hours of Columbus commissioning is required to complete all activities).	FD 6
37.	Perform SDTO 15009-E, Recording of ICC-L Temperature via PC 104 System and ICC-L Instrumentation (This SDTO is only active when the ICC is powered and requires no crew activity).	Completed
38.	Perform SDTO 13005-U, ISS Structural Life Validation and Extension, during 1E Orbiter undocking (IWIS highly desired, but not required) (only if crew time available).	Daily

VEHICLE PERFORMANCE

LAUNCH DELAYS

The launch of STS-122 was scrubbed twice because of anomalies in the Liquid Hydrogen (LH₂) Engine Cut-off (ECO) system. The first launch attempt occurred on December 6th, 2007, and a subsequent launch attempt was made on December 9th, 2007. During the first launch attempt anomalies were observed on LH₂ ECO circuits no. 3 and no. 4 early in the LH₂ loading process. After the scrub was declared, additional anomalies were seen on the ET LH₂ 5-percent sensor circuit and the LH₂ ECO no. 1 circuit. During the second launch attempt, an anomaly was also observed on the LH₂ ECO circuit no. 3.

A tanking test was held on December 18th, 2007, to troubleshoot the LH₂ ECO Sensor System anomalies. During the tanking test, anomalies occurred on LH₂ ECO circuits no. 1 and no. 3. Data from the tanking test as well as other component testing led to the determination that the most likely cause was loss of continuity between the ET aft LH₂ external connector and the feed-through plug.

An interim redesign, which incorporated soldered connections between the ET aft LH₂ external connector and the feed-through plug, was approved and qualified for ET-125 (STS-122) and ET-126 (STS-123).

SOLID ROCKET BOOSTERS

All Solid Rocket Booster (SRB) systems performed as expected during the launch-countdown and ascent of the STS-122 mission, and one In-Flight Anomaly (IFA) was identified from the analysis of the hardware. The SRB pre-launch countdown was nominal. No SRB Launch Commit Criteria (LCC) or Operations and Maintenance Requirements and Specifications Document (OMRSD) violations occurred, and no waivers or exceptions were written.

Both SRBs were successfully separated from the ET and were towed back to Kennedy Space Center (KSC) for inspection and teardown. No in-flight anomalies were noted during the inspection.

During deployment of the left-hand main parachutes, one of the three main parachutes showed evidence of significant damage in the canopy (IFA STS-122-B-001). The parachute was never able to inflate. Consequently, the left SRB water impact velocity was significantly higher than normal (approximately 92 ft/sec versus 75 ft/sec nominal). There was no significant damage to the aft skirt structure and internal components.

REUSABLE SOLID ROCKET MOTORS

The STS-122 Reusable Solid Rocket Motor (RSRM) set performed within established and predicted limits (nominal). No RSRM LCC or OMRSD violations were identified. All Ground Environmental Instrumentation (GEI) and Operational Flight Instrumentation (OFI) performed within established requirements. Three in-flight anomalies were identified during the post-flight evaluation and these are discussed later in this section.

The motor performance parameters for this flight were within Contractor End Item (CEI) specification limits. Reconstructed performance parameters adjusted to a 60 °F Propellant Mean Bulk Temperature (PMBT) standard are listed in the table below.

RSRM PERFORMANCE PARAMETERS AT 60° F PMBT

Parameter	CEI specification limit, 60 °F	Left motor delivered	Right motor delivered
Web time, sec	105.4 – 116.7	111.0	111.0
Action time, sec	115.2 – 131.2	122.9	123.8
Head end pressure, psia	847.9 – 965.7	906.0	902.2
Maximum Sea Level Thrust, Mlbf	2.88 – 3.26	3.07	3.06
Web Time Average Pressure, psia	629.9 – 700.5	667.7	665.7
Web Time Average Thrust, Mlbf	2.46 – 2.74	2.61	2.61
Web time total impulse, Mlbf sec	285.8 – 291.6	289.8	289.4
Action time impulse, Mlbf sec	293.7 – 299.7	297.3	297.4
ISP average delivered, lbf sec/lbm	266.5 – 270.3	269.1	269.1
Loaded propellant weight, lbm	>1103750	1105525	1105723

Note: All times referenced to liftoff time (when chamber pressure reaches 563.5 psia),

The ambient temperatures recorded during the 110 hr prior to launch of STS-122 varied from 62 to 84 °F. The data recorded during this time frame was at the +0.5 σ to +2.0 σ range from historical February average hourly temperatures. At the time of launch, the ambient temperature was 84 °F. The average historical ambient temperature for the time of launch for the month of February is 68 °F.

Igniter joint heaters operated for 13 hr 24 min during the launch countdown. Power was applied to the heating elements 61-percent (average) of the time during the LCC time frame of the countdown to keep the igniter joints in their normal operating range. Field joint heaters operated for 13 hr 33 min during the launch countdown. Power was applied to the heating elements 37-percent (average) of the time during the LCC time frame of the countdown.

Propulsion performance is listed in the table below. The calculated PMBT was 68 °F at time of launch. The maximum trace shape variation of pressure vs. time during the 62-

80 sec time frame was calculated to be 2.7-percent at 73.5 sec (left motor) and 1.2-percent at 71.5 sec (right motor). These values were within the 3.2-percent allowable limits.

PROPULSION PERFORMANCE

Parameter	Left motor, 80 °F		Right motor, 80 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10 ⁶ lbf-sec	65.15	64.88	65.40	64.76
I-60, 10 ⁶ lbf-sec	174.54	174.47	175.10	173.96
I-AT, 10 ⁶ lbf-sec	296.84	297.57	296.89	297.62
Vacuum Isp, lbf-sec/lbm	268.5	269.2	268.5	269.2
Burn rate, in./sec @ 60 °F at 625 psia	0.3689	0.3682	0.3697	0.3677
Event times, sec ^a				
Ignition interval	0.232	N/A	0.232	N/A
Web time ^b	109.1	110.0	109.1	110.1
50-psia cue time	119.6	119.8	119.2	119.9
Action time ^b	121.8	121.8	121.4	122.8
Separation command	124.0		124.0	
PMBT, °F	68	68	68	68
Maximum ignition rise rate, psia/10 ms	90.8	N/A	90.8	N/A
Decay time, sec (59.4 psia to 85 K)	3.1	2.9	3.1	4.0
Tailoff impulse imbalance differential ^c	Predicted N/A		Actual 479.2	

^aAll times are referenced to ignition command time except where noted by footnote b.

^bReferenced to liftoff time (ignition interval).

^cImpulse imbalance = integral of the absolute value of the left motor thrust minus right motor thrust from web time to action time.

The aft skirt purge was activated four times during the countdown for a total of 9 hr and 33 min. It was necessary to thermally condition the aft skirt region prior to launch to achieve the nozzle/case joint seals minimum LCC temperature of 75 °F. It was not necessary to thermally condition the flex bearings to meet the 60 °F mean bulk temperature requirement. During the LCC time frame, the left- and right-hand motor nozzle/case joint temperatures ranged from 80 to 87 °F and 80 to 89 °F, respectively. The Flex Bearing Mean Bulk Temperature (FBMBT) was calculated to be 85 °F.

During the post-flight inspection of RSRM-99B, a missing section of cap-ply insulation was noted on the forward segment cylinder-to-cylinder factory-joint Weatherseal (IFA STS-122-M-001). The missing section measured approximately 2 in. circumferential by 3 in. axial, and the radial thickness of the missing section was approximately 0.06 in. Material resembling brown poly backing was visible on the surface of the remaining Weatherseal beneath the missing cap-ply insulation. Uncured insulation cap-plyies have poly backing on both surfaces that should be removed as part of the normal fabrication

sequence. It has since been concluded that the poly backing on the underneath side of the cap ply was inadvertently left in place during the build process. The most probable cause was poly backing that had not been removed from the un-cured Weatherseal cap ply during the Weatherseal build-up process.

Upon post-flight disassembly of RSRM-99A, a gas path/penetration was observed in joint 5 through an Room Temperature Vulcanizing (RTV) material non-contact area at 204 deg (IFA STS-122-M-002). Solid technical understanding of this condition has been established as the cause of voids in the RTV is known. The condition has been seen 22 times, including this instance, and is well bounded by PVM-1. Concerns for thermal effects to the primary and secondary O-rings are well characterized by ETM-2. This failure is self limiting as shown by PVM-1's intentional flaws (worst case) and ETM-2's thermal analyses. Strong data, testing, and analyses for the flight rationale exist. This condition is not consistent with design intent, however, the condition is well understood and each occurrence will be carefully evaluated for any challenge to flight rationale and level of risk assessment. The most probable cause is air entrapped in the RTV during assembly resulted in a gas path during motor operation.

Non-distinct gas penetrations were observed around the full circumference in Joint 2 through the RTV on both RSRM-99 A and B nozzles (IFA STS-122-M-003). Gas penetration through Joint 2 RTV is not consistent with original design intent, but is not unexpected at this point in the program with the accumulated flight experience. This phenomenon is well understood and each occurrence is carefully evaluated for any challenge to flight rationale and level of risk assessment. Deep voids in the RTV add to the cause of gas penetrations. This condition is inherent to the current joint 2 RTV design. This is the last time this configuration with RTV is scheduled to fly and closure of this item constitutes closure of the IFA.

EXTERNAL TANK

For the launch and ascent on Feb 7th, all STS-122 objectives and requirements associated with the Super Lightweight Tank (SLWT) External Tank (ET) -125 propellant-loading and flight operations were met. No significant oxygen or hydrogen concentrations were detected in the Intertank. All ET electrical equipment and instrumentation operated satisfactorily. Purge and heater operations were monitored and performed properly. No ET LCC or OMRSD violations occurred. Eight IFA's were identified during the post-flight data analysis and these are discussed in later paragraphs in this section.

No ET related documentation was taken during the count and launch. The Liquid-Level and Engine Cut-off sensors performed as designed.

ET separation was nominal. Since Main Engine Cutoff (MECO) occurred within expected tolerances, entry and breakup is expected to be within the predicted footprint.

Post-launch camera and film review identified four IFA's associated with Thermal Protection System (TPS) losses:

1. At two locations at the LH₂-to-Intertank flange closeout (IFA STS-122-T-001). Locations included: XT 1115 between the 5th or 6th stringer +Z of the -Y thrust panel (Stringer 5 Panel 2 or Stringer 6 Panel 2), and XT 1120 located in the 3rd stringer valley +Z of the +Y thrust panel (between Stringer 15 Panel 3 and Stringer 16 Panel 3 or Stringer 16 Panel 3 and Stringer 17 Panel 3).
2. In LH₂ Acreage foam forward of the Station 1129 LO₂ Feedline Bracket Base (IFA STS-122-T-002)
3. In LH₂ Acreage foam at Station 1145 during launch (IFA STS-122-T-003); and
4. In the LO₂ Umbilical Cable Tray (IFA STS-122-T-004)

Three foam insulation cracks were identified in the ET thermal protection system insulation during post the post-tanking inspection following the ET tanking test on December 18, 2007:

1. Approximately 7 in. in length in the +Y Longeron Closeout (C/O), was observed during the post-drain walk down after the tanking test (IFA STS-122-T-005).
2. At the +Y Vertical Strut (VS) fairing closeout-to-LH₂ Aft Dome interface was noted, which measured at 6 in. long with a 1/32 in. offset (IFA STS-122-T-006).
3. Approximately 4 in. in length was observed in the +Y SRB Protuberance AirLoad (PAL) Ramp (IFA STS-122-T-007). This crack had also been observed following the 2nd tanking performed on December 9, 2007.

One IFA was identified for the ECO sensor anomalies which occurred on the first launch attempt on December 6th (IFA STS-122-T-008).

SPACE SHUTTLE MAIN ENGINES

All Space Shuttle Main Engine (SSME) parameters were nominal throughout the pre-launch countdown and were typical of previous flights. The Block II engines were 2059, 2052, and 2057 and these were in positions 1, 2, and 3, respectively. No LCC or OMRSD violations were noted, nor were any IFA's identified during the data analysis. Engine "Ready" was achieved at the proper time, all LCC's were met, and thrust build-up was nominal.

This was the first flight of the change to the Low Pressure Oxidizer Turbopump (LPOTP) to incorporate oversized inserts with corrosion inhibitor on all 3 SSME's.

Flight data indicates nominal SSME performance during startup, mainstage, throttling, and shutdown. High Pressure Oxidizer Turbo Pump (HPOTP) and High Pressure Oxidizer Fuel Turbo Pump (HPFTP) temperatures appeared to be well within specifications throughout engine operation. Commanded Max Q throttle down was a one-step throttle to 74-percent instead of the predicted 72-percent, which indicates

Adaptive Guidance Throttling (AGT) was initiated. Propellant dump operations data appeared normal and the time of Main Engine Cutoff (MECO) time was Engine Start + 509.1 seconds.

The review of STS-122 Advanced Health Monitoring System (AHMS) vibration measurements indicates nominal performance. No Failure Identifiers (FIDs) were reported to the Vehicle Data Table (VDT) from start preparation through propellant dump on all engines. All accelerometer measurements appear healthy.

The average SSME specific impulse tag value was 452.34 sec at 104.5-percent power level.

SHUTTLE RANGE SAFETY SYSTEM

The Shuttle Range Safety System (SRSS) closed-loop testing was completed as scheduled during the launch countdown. There were no OMRSD or LCC violations. All SRSS Safe and Arm (S&A) devices were armed and system inhibits were turned off at the appropriate times. As planned, the SRB S&A devices were safed and SRB system power was turned off prior to SRB separation.

ORBITER SYSTEMS

Main Propulsion System

All Main Propulsion System (MPS) systems performed as expected during launch countdown and ascent. No MPS-related LCC and OMRSD violations occurred. The MPS pre-launch countdown was nominal, and no IFA's were identified during the post-flight data analysis.

The overall Gaseous Hydrogen (GH₂) system in-flight performance was nominal. All three Flow-Control Valves (FCVs) performed nominally with 1 cycle on FCV 1, 4 cycles of FCV 2 and 6 cycles on FCV 3.

The Gaseous Oxygen (GO₂) fixed-orifice pressurization system performed as predicted. Reconstructed data from the engines and MPS parameters closely matched the actual ET ullage pressure measurements.

Hazardous Gas Concentrations

The aft hazardous gas concentrations during the STS-122 loading for launch were nominal and are shown in the following table.

HAZARD GAS CONCENTRATIONS AT LAUNCH

Parameter	Peak, ppm	Steady State, ppm
Helium	10,300	6,200
Hydrogen	137	15
Oxygen	99	10
LD54/55	0	0

Gas Sample Analysis

The measured sample bottle pressures indicate the redesigned Orbiter aft fuselage gas sampler system successfully collected all six samples. It was the first flight for all six bottles. STS-122 was the eighth flight using the new gas chromatograph/mass spectrometer at the KSC Materials Science Laboratory.

One oxygen concentration was above the flammability limit. Bottle right hand no. 2 had a concentration of 4.98-percent, which is approximately 0.5-percent above the flammability limit. Only 0.55-percent of the total is attributed to Orbiter system leakage. The measured argon concentrations indicated air as a major source of the oxygen concentrations and not a MPS leak. The other five bottles had oxygen concentrations that were in family. The highest helium concentration was 5.02-percent in right hand no. 3 bottle. The helium concentrations were at normal levels consistent with previous

data samples taken. The following table provides a summary of the Right Hand (RH) and Left Hand (LH) gas sample data analysis.

SUMMARY OF BOTTLE PRESSURES AND GAS CONCENTRATION

Bottle No.	Position	Pressure, psia	Helium, %	Measured Oxygen, %	Hydrogen, %
1	RH 1	3.44	0.80	2.54	0.05
2	LH 1	1.41	0.39	3.03	0.04
3	RH 2	1.33	0.42	4.98	0.04
4	LH 2	0.82	0.60	3.75	0.07
5	LH 3	0.16	0.67	2.39	0.13
6	RH 3	0.06	5.02	0.93	0.52

Hydrogen concentrations were well below the flammability limit in each bottle, and the concentrations are shown in the following table.

HYDROGEN FIRING LEAK RATES

Bottle no.	Position	Hydrogen Firing Leak Rate, scim
1	RH 1	2450
2	LH 1	1000
3	RH 2	1000
4	LH 2	1210
5	LH 3	560
6	RH 3	855

The complete results of the gas chemical analysis, provided by Kennedy Space Center, are shown in the following table.

AFT FUSELAGE SAMPLE BOTTLE GAS ANALYSIS

S/N	Position	Actual pressure, torr	Ar, %	Air from Ar, %	He, %	CO, %	CH ₄ , %	CO ₂ , %	O ₂ from air, %	O ₂ found, %	H ₂ , %	H ₂ pyro corrected, %
1140 FLT-0	RH1	177.6	0.10	10.71	0.80	<0.01	<0.01	0.01	2.25	2.54	0.05	0.05
1135 FLT-0	LH1	72.8	0.11	11.99	0.39	<0.01	<0.01	0.01	2.52	3.03	0.04	0.04
1141 FLT-0	RH2	68.8	0.20	21.09	0.42	<0.01	<0.01	0.01	4.43	4.98	0.04	0.04

AFT FUSELAGE SAMPLE BOTTLE GAS ANALYSIS (Concluded)

S/N	Position	Actual pressure, torr	Ar, %	Air from Ar, %	He, %	CO, %	CH ₄ , %	CO ₂ , %	O ₂ from air, %	O ₂ found, %	H ₂ , %	H ₂ pyro corrected, %
1136 FLT-0	LH2	42.6	0.15	16.49	0.60	0.01	<0.01	0.01	3.46	3.75	0.07	0.07
1139 FLT-0	LH3	8.53	0.08	8.24	0.67	0.35	0.03	0.01	1.73	2.39	0.14	0.13
1143 FLT-0	RH3	3.05	0.06	5.89	5.02	0.08	0.09	0.02	1.24	0.93	0.53	0.52

The O₂ concentration in bottle Right-Hand (RH) bottle no. 2 was 4.98-percent, which is approximately 0.5-percent above the flammability limit. All but approximately 0.5-percent is attributed to air intrusion. The operation of the sample bottle hardware appears nominal. The pressures of the samples were within expected limits. Hydrogen leak rates based on sample bottle data were nominal.

Purge, Vent and Drain System

The Purge, Vent and Drain (PV&D) system performed well during launch. Purge readings and hazardous gas detection system readings were nominal except when the loading began (approximately 038/10:46 GMT), an approximate 110-ppm burp of Oxygen (O₂) occurred.

The PV&D system performed nominally during the entry and landing phases. The post-landing purge was not initiated within 45 min of touchdown (was 56 min). The purge was initiated within 30 min (was 29 min) of completion of the upper aft safety assessments.

Reaction Control System

The Reaction Control System (RCS) performed all functions required for successful completion of the mission. One In-Flight Anomaly (IFA) occurred during the latter portion of the mission and it is discussed in a later paragraph.

The propellant loading for the mission is shown in the following table.

RCS PROPELLANT LOADING

Parameter	Forward RCS		Left RCS		Right RCS	
	Oxidizer	Fuel	Oxidizer	Fuel	Oxidizer	Fuel
Target, %	67.70	67.41	100.48	100.76	100.48	100.76
Target, lb	1141	712	1523	962	1523	962
Calculated, %	70.99	69.41	100.76	100.92	100.72	100.85
Advertised, lb	1185.3	729	1526.7	963.3	1526.2	962.0
PASS WHI ^a	4.3492	4.3574	4.3563	4.2578	4.3779	4.2196
BFS WHI ^b	4.3531	4.3614	4.3673	4.2765	4.3961	4.2352

Notes:

^a PASS WHI – Primary Avionics Software System Initial Weight of Helium Load

^b BFS WHI – Backup Flight System Initial Weight of Helium Load

All Tyvek covers released nominally. Tyvek cover release speeds and vehicle alpha/beta angles at cover release are shown in the following table.

STS-122 TYVEK COVER RELEASE TIMES, VELOCITIES AND ALPHA/BETA ANGLES

Cover	MET (sec)	Velocity (mph)	Alpha (deg)	Beta (deg)
F2D	4.8	55	-3	-4
F1D	5.7	66	-2	-4
F4D	5.9	69	-2	-3
F3D	6.8	82	-1	-3
F4R	8.7	110	0	-3
F2R	8.9	113	-1	-3
F2F	8.9	113	+1	-3
F3F	9.1	117	+1	-3
F3L	9.5	122	+1	-4
F1F	9.9	128	+2	-4
F3U	10.4	136	+3	-5
F2U	10.5	137	+3	-5
F1U	10.6	139	+4	-5
F1L	11.4	151	+6	-5

The RCS window-protect firing of the F1U, F2U and F3U thrusters was initiated at 038/19:47:38 GMT (00/00:02:08 MET) for total duration of 2.08 sec. The Forward RCS performance was nominal. The Window protect firing is performed to deflect exhaust from the SRB separation motors away from windows during SRB separation.

The ET Separation maneuver was performed at 038/19:54:14 GMT (00/00:08:44 MET) and was a 6.0-sec, 10-thruster translation.

The RCS firings, times initiated, Differential Velocities (ΔV s), and firing times are listed in the following table.

RCS MANEUVERS AND FIRING DATA

Maneuver/Firing	Time of Ignition, GMT	ΔV , ft/sec	Duration, sec
RCS Window Protect	038/19:47:38	N/A	2.08
ET Separation	038/19:54:14	N/A	6.0
ET Photo +X	038/19:54:25	N/A	11.2
ET Photo Pitch	038/19:57:24	N/A	4.0
NC3	039/22:23:24	2.1	9.2
NCC	040/13:39:45	0.2	1.0
MC1	040/14:57:31	0.5	0.1
Out of Plane Null	Cancelled	N/A	N/A
MC2	040/15:25:41	0.2	0.9
MC3	040/15:42:40	1.5	6.2
MC4	040/15:52:40	3.4	14.2
Reboost	047/12:16:00	5.3	36 min
Separation 1	049/10:34:04	N/A	6.0
Separation 2	049/11:01:30	N/A	12.2
RCS Hotfire	050/10:54:50	N/A	N/A
Forward Reaction Control System Dump	051/13:17:31	N/A	10.0

Just prior to crew sleep on FD 12, at 049/20:29:09.321 GMT (11/00:43:39 MET), an electrical current spike of greater than 12 Amperes (A) and a duration of approximately 20 msec was observed on Fuel Cell 3 (IFA STS-122-V-06). This was followed approximately 2 min 15 sec later by the L5L vernier thruster heater shutting off. The other 3 aft vernier thruster heaters were already off because the injectors were warmer than the normal heater turn-off temperature. Subsequently, all 4 aft vernier thruster injector temperatures continued to decay, each producing the appropriate "Fail-Leak" message when the injector temperature dropped below the Redundancy Management limit of 130 °F. The crew cycled the vernier heater switch at 049/21:56:14 GMT (11/02:10:43 MET) with no effect. The loss of all 4 vernier heaters suggested that the current spike had blown the 5-ampere fuse in the associated hybrid driver within aft Load Control Assembly (LCA) 3. Sufficient propellant margins remained for the Orbiter to perform attitude control using Tail-Only Alternate Digital Autopilot (DAP) control (primary thrusters only) through the End-of-Mission (EOM). The vernier L5L thruster injector temperature reached a lower limit value of 37.6 °F at 050/08:33:00 GMT (11/12:47:30 MET) before passive thermal controls began to warm up the Aft vernier components with a new attitude. Post-flight troubleshooting confirmed the fuse had been blown in aft LCA 3, and isolated the source of the current spike to a short in the R5D thruster heater circuit.

The Aft RCS propellant usage during interconnect operations with the Orbital Maneuvering System (OMS) is shown in the following table.

AFT RCS INTERCONNECT USAGE

Parameter	Total, %	Total, lb
Left OMS	3.505	453.93
Right OMS	2.454	317.81

The RCS propellant consumption, based on the PASS model advertised load in the RCS residual propellant table is shown in the following table.

RCS PROPELLANT CONSUMPTION

Parameter	Oxidizer, lb	Fuel, lb	Mixture ratio, Oxidizer/Fuel
Forward RCS	889.4	587.4	1.51
Left RCS	666.3	422.6	1.58
Right RCS	653.6	427.9	1.53

The residual propellants at the end of the mission are shown in the following table.

RCS RESIDUAL PROPELLANTS

Parameter	Mission Operations Calculation		PASS Model Calculation ^s	
	%	lbs	%	lbs
Forward Oxidizer	6.2	84	5.1	68.9
Forward Fuel	0.0	.0	0.3	2.6
Left Oxidizer	51.6	697	51.4	693.9
Left Fuel	51.0	434	51.2	435.2
Right Oxidizer	53.0	716	52.3	706.1
Right Fuel	50.2	427	50.5	429.3

Note:

^a The official JSC Engineering RCS propellant residuals are those listed under the PASS model

The attitude control responsibilities between the ISS and the Orbiter are shown in the following table.

CONTROL RESPONSIBILITIES BETWEEN ISS AND SHUTTLE

Control Responsibility	Control Start, GMT	Orbiter DAP Mode	Comments
Orbiter	040/17:17:14	FREE	Docking / ISS Capture
Orbiter	040/17:40:35	LVLH	
Station	040/17:46:33	FREE DRIFT	
Orbiter	040/17:46:38	AUTO	Maneuver to TEA
Station	040/18:21:35	FREE DRIFT	
Orbiter	040/18:25:18	AUTO	
Station	040/18:30:12	FREE DRIFT	
Orbiter	043/18:04:31	AUTO	Simo Water Dump
Station	043/21:21:06	FREE DRIFT	
Orbiter	045/12:02:44	AUTO	Waste water dump
Station	045/15:23:07	FREE DRIFT	
Orbiter	047/11:45:32	AUTO	Maneuver to reboost attitude
Station	047/13:16:36	FREE DRIFT	
Orbiter	048/17:43:09	AUTO	Waste water dump
Station	048/19:36:15	FREE DRIFT	
Orbiter	049/08:04:42	AUTO	Maneuver to undocking attitude
Station	049/08:48:27	FREE DRIFT	
Orbiter	049/08:50:23	AUTO	
Station	049/09:21:46	FREE DRIFT	
Orbiter	049/09:22:47	B/ALT/No Low Z	
Orbiter	049/09:24:49		Undocking

As part of the undocking preparations, thrusters F1U, F2U and F3U were reselected. Undocking was initiated with a +Z pulse at 049/09:24:49 GMT (10/13:38:59 MET). The full flyaround maneuver was initiated with a +X pulse of L1A and R1A at 049/09:48:13 GMT (10/14:02:43 MET), and all thrusters operated properly during the undocking operations.

The primary thrusters were fired 3,871 times for a total firing time of 866.84 sec. The vernier thrusters were fired 6,048 times, with a firing time of 29457.48 sec.

Orbital Maneuvering System

The Orbital Maneuvering System (OMS) performed nominally throughout the mission, and no IFA's were identified in the review and analysis of the data.

Early in the mission while the crossfeed valves were closed, the crossfeed heater in zone 3 (Left-Hand inboard) temperature remained nearly constant during the pre launch operations, cycled once on-orbit and then remained constant on-orbit for approximately 10 hours after which nominal cycling was noted for the remainder of the mission.

The OMS configuration is shown in the following table.

OMS CONFIGURATION

Vehicle/ equipment	Flight	Orbital Maneuvering Engine (OME)	Ancillary data
Left Pod (LP) 04	29 th	L-OME S/N 108	3 rd rebuilt flight - 27 th flight
Right Pod (RP) 01	36 th	R-OME S/N 109	8 th rebuilt flight - 25 th flight

The propellant loading data showed that the totalizer readings all agree closely with expected values and with both the left and right oxidizer and fuel and the aft probe readings. The Official propellant residuals should be taken from the following table using the aft gage results. Burntime Integration and Shuttle Operational Data Book (SODB) Flow rate are presented for comparison purposes.

OMS PROPELLANT LOADING DATA

Parameters	Left OMS pod		Right OMS pod	
	Oxidizer	Fuel	Oxidizer	Fuel
Loaded, lbm	7051	4265	7050	4260
Residual, lbm (aft gage)	548	401	693	509
Residual, lbm (burn time integration)	647	402	754	392
Residual, lbm (SODB flow rate)	608	393	733	425

The following table shows the maneuvers that were performed during the STS-122 mission.

OMS MANEUVERS

Maneuver designation	Configuration	Time of ignition, GMT	Firing time, sec	ΔV , ft/sec/ interconnect usage, percent
Assist	Dual Engine	038/19:47:44	113.3	N/A
OMS-2	Dual Engine	038/20:23:10	103.8	158.3
OMS-3 (NC1)	Dual Engine	038/23:22:46	14.4	22.2
OMS-4 (NC2)	Right Engine	039/12:42:44	10.0	7.7
OMS-5 (NH)	Dual Engine	040/12:16:15	58.6	90.8
OMS-6 (NC4)	Dual Engine	040/13:06:11	48.2	75.7
OMS-7 (TI)	Left Engine	040/14:37:27	9.7	8.4
(Deorbit)	Dual Engine	051/12:59:52	163.2	303.2

The interconnect usage from the OMS to the RCS is shown in the following table.

INTERCONNECT USAGE, PERCENT/POUNDS

Parameter	Interconnect usage, %	Interconnect usage, lb
Left interconnect	3.505	453.93
Right interconnect	2.454	317.82
Total Usage	5.959	771.75

Auxiliary Power Unit System

The Auxiliary Power Unit (APU) subsystem performance was nominal throughout the STS-122 mission. One In-flight anomaly was identified from the data analysis and review and it is discussed in a later paragraph of this section.

APU RUN TIMES

APU (S/N)	Ascent, hr:min:sec	FCS Checkout, hr:min:sec	Entry, hr:min:sec	Total time, hr:min:sec
1 (409)	00:20:32	00:00:00	01:00:28	01:21:00
2 (410)	00:20:53	00:00:00	01:28:14	01:49:07
3 (204)	00:21:01	00:04:23	01:00:40	01:26:04

APU FUEL CONSUMPTION

APU (S/N)	Ascent, lb	FCS Checkout, lb	Entry, lb	Total, lb
1 (409)	50	0	104	154
2 (410)	51	0	152	203
3 (204)	53	14	119	183

On FD 3 at approximately 040/08:24 GMT (01/12:38:30 MET), the APU 3 fuel seal cavity drain line A heater began to exhibit thermostat-off set-point shifts (IFA STS-122-V-02). The nominal off set-point for this heater circuit is approximately 67 °F. The shifts were noted on both drain-line temperature sensors. Corresponding shifts in the APU 3 fuel pump seal cavity drain-line pressure sensors were seen indicating the heat input was into the entire drain system. A total of four anomalous heater cycles were seen. The first two cycles as well as the last anomalous cycle had off set-points below the nominal value of approximately 62 °F. The other anomalous cycle had an off set-point above nominal and was at approximately 81 °F. To avoid having a heater failure during a critical period or during the crew-sleep period, the panel A12 APU 3 system A heater circuits were deactivated at 040/13:42:50 GMT and the B heater circuits were activated 10 sec later. No mission impacts were noted from this anomaly. The redundant Fuel

Pump Seal Cavity Drain Line “B” heater circuit operated nominally for the remainder of the mission.

Hydraulics/Water Spray Boiler System

Overall Hydraulic (HYD) and Water Spray Boiler (WSB) system performance during all phases of the mission was nominal: STS-122 was the fifth flight (2nd flight on OV-104) to use the water additive Propylene Glycol Monomethyl Ether (PGME) in all three WSB water tanks to preclude post-ascent freeze-ups in the boiler Heat Exchanger (Core). WSB mission performance was nominal. There were no Hydraulic/WSB related IFA’s generated during the mission.

The HYD system 3 right outboard (ROB) elevon return-line temperature sensor data exhibited an elevated thermal-response over a period of approximately 9 hr. The temperature increased from approximately 9 °F spiking to approximately 31 °F and to approximately 57 °F. The HYD system 1 and 2 return-line temperatures in the same general area did not respond similarly. Following the Flight Control System (FCS) Checkout with APU/HYD system 3, all HYD system 3 return-line temperatures responded as expected. The temperatures increased to above 60 °F and trended as expected through the remainder of the mission. The cause of the ROB Elevon return line temperature sensor excursion is still under investigation. The sensor is located in an area that is difficult to access for repair. Trouble-shooting is not planned at KSC during the current OV-104 Vehicle flow. The HYD System 3 ROB return line temperature sensor will fly as is and will be observed during the next mission.

All File IX requirements were met with exception of Priority Valve Crack/Reseat on HYD System 2. This requirement states that all three priority valves must re-seat at no-greater than 2675 psia. Re-seats on the three systems at APU shutdown (post ascent, FCS checkout and entry) were within the File IX requirement with the exception of system 2 (post ascent). The system 2 bootstrap accumulator priority valve lock-up pressure was approximately 2671 psia.

Water Spray Boiler PGME/Water usage during entry for spray cooling was as follows, calculated by the standard method of 1-percent equals 1.4 lb (specification is no greater than 45 lb/sys):

1. System 1 = 8.1 lb (PGME/Water)
2. System 2 = 30 lb (PGME/Water)
3. System 3 = 16.9 lb (PGME/Water)

Power Reactant Storage and Distribution System

The OV-104 Power Reactant Storage and Distribution (PRSD) system performance was nominal during STS-122. The PRSD system supplied the fuel cells with 2827 lb_m of oxygen and 356 lb_m of hydrogen for the production of 4126 kWh of electrical energy. The average power level for the 306.38-hour mission was 13.5 kW. A 57-hour mission extension was possible at the average power level with the reactants remaining at

touchdown based on the PRSD Oxygen (O₂) (the limiting reactant) tank landing quantities.

The following table shows the tank quantities at loading, lift-off and landing.

PRSD TANK QUANTITIES AT LAUNCH

Oxygen	Tank 1, %	Tank 2, %	Tank 3, %	Tank 4, %	Tank 5, %	Total Mass, lb_m
Loaded	101.8	101.4	100.9	101.8	101.8	3965
Launch	100.5	100.5	100.1	100.5	100.5	3921
Landing	36.1	32.2	23.9	8.1	5.0	922
Hydrogen	Tank 1, %	Tank 2, %	Tank 3, %	Tank 4, %	Tank 5, %	Total Mass, lb_m
Loaded	102.3	101.5	102.8	104.1	103.2	472.8
Launch	99.3	98.4	99.7	100.6	99.7	457.9
Landing	35.1	35.1	38.7	0.7	1.1	101.8

The total oxygen supplied to the Shuttle/ISS Environmental Control and Life Support System (ECLSS) was 272 lb_m of oxygen. The Shuttle ECLSS used 178 lb_m and 94 lb_m of oxygen was transferred to the ISS.

At 038/22:16:51 GMT (00/02:32:21 MET), a 299-psia pressure spike was observed on PRSD Hydrogen (H₂) manifold 1 and a 298-psia spike was observed on H₂ manifold 2. It occurred while H₂ tanks 3 and 4 were supplying the manifolds. The total vehicle power demand had just increased by about 2.5 kW and this placed an increased demand for hydrogen on the nearly full H₂ tanks supplying the manifolds. Cold dense cryogenics from the tanks entered the warmer H₂ manifold, which expanded the state of the gas, which caused the pressure increase. This condition is a relatively common occurrence when high flowrates are demanded from a nearly full cryogenic tank and is an explained condition.

At 039/15:55 GMT (00/20:10 MET), the Oxygen (O₂) tank 1 control valve did not reseat and began to track the O₂ tank 4 heater/pressure cycles. After 11 O₂ tank 4 heater cycles, the valve became fully seated. This occurred when O₂ tanks 1 and 4 were supplying the O₂ manifolds during an ECLSS cabin repressurization. The high O₂ demand from the cabin repressurization dropped the manifold pressure and caused the O₂ tank 1 and O₂ tank 4 heaters to cycle on. When the cabin repressurization ended and the manifold pressure recovered, the H₂ tank 1 pressure rose above its heater control pressure and tracked the manifold and H₂ tank 4 pressures for 11 cycles before fully reseating. This condition was explained as a non-anomalous occurrence.

Fuel Cell System

The overall performance of the OV-104 fuel cell system was nominal. The average electrical power level and load was 13.5 kW and 438 A. The fuel cells produced 3183 lb_m of potable water and 4126 kWh of electrical energy from 2827 lb_m of oxygen and 356 lb_m of hydrogen. Seven fuel cell purges were performed, occurring at approximately 22, 76, 124, 172, 228, 264, and 298 hr MET. One in-flight anomaly was identified and it is discussed in a later paragraph.

The prelaunch baseline Cell Performance Monitor (CPM) values for fuel cell 1 were 16, 18, and 6 mV, for fuel cell 2 were 2, 12, and 32 mV, and for fuel cell 3 were 6, 10, and 48 mV. They were established approximately 7 hr prior to launch and approximately 3 hr after the completion of the fuel cell calibration.

The Fuel Cell Monitoring System (FCMS) was used to monitor individual cell voltages during prelaunch, on-orbit, and postlanding operations. Full-rate on-orbit data were recorded for 12 min approximately 3 hr after lift-off; and no issues were observed. Fuel Cell 2, Cells 37/38 indicated "pin sharing" (cell 37 indicated 771 mV and cell 38 indicated 1178 mV). Their average voltage was near fuel cell 2 mean cell-voltage.

The actual fuel cell voltages (200-Ampere load) at the end of the mission were as predicted for Fuel Cells 1 and 3, and 0.10 V above predicted for fuel cell 2. The voltage margins above the minimum performance curves at 200 amperes at the end of the mission were 0.74 V above minimum for fuel cell 1, 1.06 V above minimum for fuel cell 2, and 1.06 V above minimum for fuel cell 3.

Fuel cell operating times, which are the times accumulated on the fuel cells prelaunch, on-orbit, and postlanding, were 331:28:56 (hr:min:sec) for fuel cell 1, 331:06:31 for fuel cell 2, and 330:05:56 for fuel cell 3. The end-of-mission accumulated operating times for these fuel cells are 2037, 1186, 1130 hr, respectively.

The fuel cell 3 O₂ flowmeter began displaying erratic behavior at 046/10:30:40 GMT (07/14:45:10 MET) (IFA STS-122-V-04). The reading went off-scale low for about two min, then displayed unreliable and erratic data. The flowmeter was considered failed and was inhibited in the Failure Detection and Annunciation (FDA) upper limit. A review of the electrical current did not show any anomalous indication at the time of the failure.

The primary purpose of the flowmeter is to indicate purge flow. Purge flow can be verified by other parameters. Fuel cell flowmeter failures are a common occurrence. No further action was required for this mission. Troubleshooting will be performed at KSC to verify the failure is in the flowmeter.

During Entry, at 051/13:25:38 (11/17:40:08 MET), the fuel cell 1 flowmeter became biased high and erratic. A waiver had allowed the fuel cell to fly with the high bias on the flowmeter, but the in-flight performance exceeded the waiver measurements as well as displaying an erratic output. After landing, the output became stable and continued

with about a 1.2 lbm/hr high bias. Since the bias became stable after landing, no further action will be pursued during vehicle turnaround activities.

Electrical Power Distribution and Control System

The Electrical Power Distribution and Control System (EPDC) performed nominally during all mission phases of STS-122, with the possible exception of the 18-Ampere current spike which resulted in the loss of the Aft RCS heaters (IFA STS-122-V-06). Post-flight troubleshooting confirmed that although the fuse had been blown in the aft Load Control Assembly (LCA) 3, the cause of the current spike was not the result of an internal EPDC hardware failure. The current spike was isolated to a short in the R5D thruster heater circuit.

The data review and analysis of all available EPDC parameters identified no abnormal conditions other than the IFA discussed in the previous paragraph.

As a minimum, the following EPDC parameters are analyzed each mission:

- a. Fuel Cell voltages and currents
- b. Essential bus voltages
- c. Control bus voltages
- d. Forward Power Control Assemblies voltages and currents
- e. Mid Power Control Assemblies voltages and currents
- f. Aft Power Control Assemblies voltages and currents
- g. AC bus voltages and currents
- h. AC bus Monitor/auto switch status and overload/over-voltage alarm
- i. Main bus to Control bus Remote Power Controller (RPC) status
- j. Forward, Mid and Aft Motor Control Assemblies operations status
- k. Fuel Cell to Essential bus switch status
- l. Main bus to Essential Bus RPC and switch status
- m. Drag chute Pyro Controller Functions

In addition, when the SSPTS was in operation, the following parameters were analyzed.

1. Assembly Power Converter Unit (APCU) voltages and currents;
2. Orbital Power Converter Unit (OPCU) voltages and currents;
3. APCU and OPCU temperatures;
4. Main Distribution Control Assembly (MDCA) motor switches status;
5. APCU status bits and trips; and
6. OPCU trips.

Orbiter Docking System

The Orbiter Docking System (ODS) performed satisfactorily, and no IFA's were identified from the review and analysis of the data.

The initial application of power to the ODS and ring extension were performed nominally during FD 2 commencing at 039/22:27:20 GMT (1/02:41:50 MET), and the ODS was activated for 8 min 30 sec, and the avionics hardware was powered for 5 min 54 sec. The system was ready for rendezvous and docking with the ISS.

The application of power for the docking activities was initiated at 040/16:57:04 GMT (01/21:11:34 MET), and the ODS was powered for 43 min 31 sec. The initial contact and capture of the ISS occurred at 040/17:17:16 GMT (01/21:31:46 MET). The initial damping and performance of the “Disable and Release Dampers” procedure was necessary to ensure that any stuck dampers were disengaged. Upon release of the capture latches and completion of the ring retraction, the docking was completed and the ODS power was removed from the system.

In preparation for undocking, the ODS was activated at 049/08:25:19 GMT (010/12:39:49 MET) and the ODS system operated for 46 min 54 sec. The Orbiter was undocked from the ISS at 049/09:24:41 GMT (010/13:39:11 MET).

Atmospheric Revitalization and Active Thermal Control and Airlock Systems

Atmospheric Revitalization System

The Atmospheric Revitalization System (ARS) and the Atmospheric Revitalization Pressure Control System (ARPCS) performance were nominal for the entire mission.

The system 2 Nitrogen (N₂) flow sensor read off-scale high during various stages of the mission. The first occurrence of the flow sensor was on FD 9 and showed that there were three occurrences. On the first occurrence, there were five 2-3 sec spikes, then on the second occurrence there were six 2-3 sec spikes, and last occurrence there were two more 2-3 sec spikes. There was no impact to flight as insight into a Gaseous Nitrogen (GN₂) leak was maintained by monitoring cabin pressure and other sensors. During the post-flight troubleshooting, additional spikes were noted in the system 2 N₂ flow sensor and also in the system 1 N₂ flow sensor. The system 1 spikes were a new occurrence.

During postflight vehicle operations, it was noted that the booster fan bypass ducting was incorrectly stowed during pre-launch operations. The duct elbow was fastened to the wall of the short tunnel extension, while the flex end was attached to the Duct Tee, located in the External airlock. The documentation for the Launch configuration shows the correct configuration.

Active Thermal Control System

The Active Thermal Control System (ATCS) performance was nominal for the entire mission.

During the prelaunch closure of the starboard payload bay door, the starboard aft radiator flexible hose was found to be buckled into an out-of-configuration “omega” shape. During final payload bay door closure, the flexible hose was guided into the stowage container to preclude formation of the buckled omega shape. Flight rationale was developed and the decision was made to fly the hose as-is. No problems were noted during in-flight closure of the both payload bay doors.

During the first Lithium Hydroxide (LiOH) canister change-out, two fresh canisters were installed in the cabin fan assembly. Data showed that the post installation cabin fan power-up Differential Pressure (ΔP) was slightly higher than the ΔP value prior to the fresh canister installation. Because the LiOH canisters in this flight have taped covers over the open annular end of the canister because of LiOH dust concerns, it was suspected that the crew may have inadvertently left a tape cover on one of the canisters. Pre-mission analysis predicted that changes of a few tenths of an in. H₂O in the cabin fan Differential Pressure (ΔP) would result should one canister be installed with the taped cover in place. The suspicion was confirmed a few hours later when Partial Pressure Carbon Oxygen (PPCO₂) levels did not decrease at the nominal rates. The crew was then asked to inspect the installed LiOH canisters and the crew did find one canister with the taped cover still installed, and the taped cover was removed. There were no significant impacts to the mission timeline because of this incident.

During the postlanding operations, the Ammonia Boiler System (ABS) tank-A pressure dipped from 38 psia to 18 psia before returning to baseline values 1 min later. The pressure variation occurred approximately 1 min after ABS tank A was de-activated. It appears that the signature does not indicate a tank A valve opening because the pressure recovered back to the baseline value indicating no mass loss. The pressure stabilized at that baseline. No mission safety or mission success impact resulted from this signature.

Airlock System

All of the Extravehicular Activities (EVA's) were performed from the ISS airlock. As a result, the Airlock was not used during this mission.

Supply and Waste Water Management System

The Supply Water and Waste Management Systems (SWWMS) performed nominally throughout the mission and all of the scheduled in-flight checkout requirements were satisfied. Supply water was managed through the use of the Flash Evaporator System (FES), water transfer to the ISS and the overboard nozzle dump system.

At approximately 040/03:26 GMT (01/07:41 MET) supply water tanks A and B were filled to capacity and the supply water inlet pressure began to increase (42 psi) and the relief/check valve A/B didn't open immediately. The pressure increased greater than the FDA limit of 40 psia, and an alarm was annunciated while the crew was asleep. At that time, the B/C check valve opened and fuel cell water flowed through the alternate

line. In approximately 11 min, the A/B check cracked when supply water pressure reached 42 psia, and pressure dropped to 37 psia. A 44-psia limit was uplinked to the Orbiter to prevent any further nuisance alarm. The initial high opening of check valves is not unexpected when tanks are hard filled. After the first incident, the check valve was opening within the normal range (0.8 to 2.5 psid). This issue had no impact on the mission and no post-flight testing is required.

Three supply-water nozzle dumps were performed simultaneous with waste water and the nominal dump rate of 1.7 percent (2.8 lb/min) was maintained. The line heater A maintained the supply-water dump-line temperature between 110 °F and 80 °F before the heaters were reconfigured to the main B power bus and the thermostat then maintained the supply water dump line between 90 °F and 74 °F throughout the mission. Five wastewater nozzle dumps at an average rate of 1.97 percent/min (3.25 lb/min) were performed nominally. In addition, one Contingency Water Container (CWC) containing Extravehicular Mobility Unit (EMU) iodinated water, five Portable Water Reservoirs (PWR's) and three condensate CWCs were dumped through the waste line. The wastewater dump line temperature was maintained between 62 °F and 71 °F throughout the mission.

A total of 13 CWC's were filled with supply water and transferred to the ISS, for a total of 1213.3 lb_m. In addition, 8 PWRs of iodinated water for a total 172.8 lb_m were filled and transferred to ISS.

At: 047/16:15:21 GMT (08/20:29:51 MET), the supply water tank A quantity sensor exhibited a quantity dropout at a tank quantity of 44 percent. The tank quantity dropped to 18 percent for one sec and recovered. In addition, the tank quantity sensor dropped multiple times at different quantity level during the mission. The tank A quantity sensor was tracked and documented. Such dropouts have been experienced in previous flights and the problem was caused by either contamination on the collector bar and/or a surface defect on the collector bar of the potentiometer, which causes an intermittent break in continuity. These dropouts are understood problems, and no trouble shooting will be required during the turnaround operations.

The vacuum vent line temperature was maintained between 74 °F and 58 °F.

Smoke Detection and Fire Suppression System

The Smoke Detection and Fire Suppression (SDFS) system operated nominally with no issues. The smoke detection test was performed of FD 1. Also, the smoke detector check was accomplished and both smoke detection A and B sensor circuits passed.

Use of the Fire Suppression system was not required.

Flight Software

The flight software performed satisfactorily throughout the mission. No in-flight anomalies were identified during the mission.

Data Processing System Hardware

The data review and analysis of Data Processing System (DPS) parameters have been completed and no in-flight anomalies were identified. The Integrated DPS system performed nominally.

During FD 3 procedures to expand the common set of General Purpose Computers (GPC's) to a Triple G2 set to support rendezvous and docking operations, GPC 3 unexpectedly failed out of the common set. Data from the downlisted dump data of the GPC 1 showed no indication of a hardware or software problem. The condition is documented in a User Note, which results in this issue being an explained condition. Docking was completed with a Dual G2 configuration of GPC 1 and 2. After docking, the GPC set was again contracted to a Single G2 configuration with GPC 1 commanding all strings. Undocking was completed on FD 12 using a Triple G2 set, which included GPC 3, with no issues.

Multifunction Electronics Display System

The Multifunction Electronics Display System (MEDS) performed satisfactorily throughout the mission. One issue was identified and it concerned the Commander (CDR) 2 Multifunction Display Unit (MDU), which had three messages about the "Lamp Fail". The crew did not report any display abnormalities. Also, this condition is covered by a User Note, which explains this condition when it occurs.

Displays and Controls System

The Displays and Controls (D&C) systems, including Lighting, performed nominally during all phases of STS-122, except for one anomaly identified in the payload bay area, which is discussed in the following paragraph.

At 049/15:47 GMT (10/20:02 MET), the crew turned on the six Payload Bay Floodlights, two powered by Main Bus A (MNA) Mid-Power Controller (MPC) 1, two powered by Main Bus B (MNB) MPC 2, and two powered by Main Bus C (MNC) MPC3 (IFA STS-122-V-08). The current increase on MNB was lower than what is expected for two Payload Bay Floodlights. The crew was asked to individually un-power each floodlight on a mark the next time they turned them off. When the crew turned off the mid-port floodlight (no. 3), the current on MNB MPC2 dropped less than the expected amount indicating this light was not working properly. Previous data was reviewed and it indicated that the first time the Mid Port Floodlight was energized, it did not work properly. No impact to mission success or crew safety existed because of failure of floodlight 3. The inability to provide illumination was not critical to crew safety or vehicle

operation. Multiple losses of PLB floodlights could cause the crew to use alternative method (hand-held spotlight) to verify latches during PLB door closure operations. The most probable cause of Floodlight 3 failure was a cracked bulb.

Flight Controls System

The flight controls system performed nominally during the preflight, countdown, ascent, on-orbit, Flight Control System (FCS) checkout, deorbit preparation, entry, landing and post-landing operations.

The FCS hardware/effector systems performed nominally during ascent through APU shutdown. At all times, the SRB thrust vector controller (TVC), MPS TVC, and aerosurface actuators were positioned as commanded with normal driver currents, secondary differential pressures, and elevon primary differential pressures. The rate outputs of the four Orbiter rate gyro assemblies (ORGAs) and four SRB rate gyro assemblies (SRGAs) tracked one another normally, and there were no spin motor rotation detector (SMRD) dropouts. The outputs of the four accelerometer assemblies (AAs) also tracked one another normally. Reaction jet driver (RJD) operation was also normal with no thruster failures or other anomalies noted. Device Driver Unit (DDU) and controller operations were nominal as well. Both the Rotational Hand Controller (RHC) and the Transitional Hand Controller (THC) were used and exhibited normal channel tracking.

The OMS TVC File IX requirements were met, and TVC actuator rates were normal. Flight control actuator temperatures were also normal. Rudder/Speed Brake Power Drive Unit (RSB PDU) motor backdrive did not occur during hydraulic system shutdown.

The FCS hardware checkout in the OPS-8 mode performance was nominal. No anomalies were found in aerosurface drive data, individual channel test data, ORGA and AA test data, nose-wheel steering test data, and DDU/controller data.

Entry performance was nominal from the deorbit maneuver through vehicle touchdown. The pre-Time of Ignition (TIG) OMS gimbal profile was as expected with the OMS actuator active and standby channels reaching nominal drive rates. All aerosurface actuators performed normally. Secondary Differential Pressure (ΔP) for all actuators was well within the equalization threshold, and all actuator positions closely tracked General Purpose Computer (GPC) commands. Entry hydraulic system temperatures were comparable to previous flights with aerosurface actuator temperatures being within the normal limits. The MPS TVC actuator performance was normal, with secondary differential pressures within threshold and TVC actuator positions and GPC commands following each other closely.

Air Data Transducer Assembly

The Air Data Transducer Assemblies (ADTA) performed nominally during preflight, countdown, on-orbit, FCS checkout, deorbit preparation, entry, landing and post landing operations.

All four ADTAs functioned nominally from power-on until nominal data loss at the T-minus-20-min transition on launch day. The ADTA self-tests were performed shortly after power-on with nominal results. No insight into the ADTA performance is available during the ascent phase until after the elevons are parked during the post-insertion period. All ADTA mode/status words were nominal during elevon park activity.

The ADTA performance during the FCS checkout was nominal. Power-on and self-tests were performed with no anomalies. All 16 transducer outputs showed nominal responses.

Entry performance was nominal from deorbit through wheels-stop. All 16 transducers tracked during the pre-probe deployment phase of entry. Air data probes were deployed at approximately Mach 4.7, and deployment timing was within specification at less than 15 sec. ADTA data were incorporated into Guidance, Navigation, and Control (GN&C) at about Mach 2.6. No ADTA dilemmas or RM failures occurred during deployment through wheels-stop. Entry data was retrieved and reviewed, and no anomalies were observed.

Inertial Measurement Unit and Star Tracker System

The Inertial Measurement Unit (IMU) system performed satisfactorily throughout the STS-122 mission. No in-flight anomalies or problems were identified during the analysis of the data. The IMU's required one adjustment of the onboard IMU accelerometer compensations during the mission. Also, two adjustments were performed for the IMU drift compensation values.

The Star Tracker (ST) performed nominally during the STS-122 mission in acquiring navigation-stars. The -Y ST acquired navigation-stars 705 times, and also missed a navigation-star 495 times (41.2 percent) during the mission. This condition did not impact the mission.

The -Z ST acquired a star 76 times and missed a star 23 times (23.2 percent). Data showed that most of these stars were missed during docking and undocking activities. This condition also did not impact the mission.

Global Positioning System Navigation

Nominal Global Positioning System (GPS) performance was observed throughout the mission when the GPS was powered on. The GPS receivers and corresponding pre-

amplifiers were powered off during FD 3 and were repowered on FD 13 as part of a modified Group B Power-Down to conserve power for an extended docked day.

The GPS was powered ON approximately 5 hr prior to launch and remained ON for the mission except for the period identified in the previous paragraph. There were no occurrences of the Y-Code Erroneous Tracking Incident (YETI) or the PPS anomaly on this flight. During entry, the GPS state vector was incorporated into both the Primary Avionics Software System (PASS) and the Backup Flight System (BFS) in Major Mode (MM) 304 after performance confirmation from the high-speed C-band tracking. The PASS and BFS GPS-to-Navigation command was set to Auto at approximately 139,000 ft altitude. The PASS navigation state errors were reduced from approximately 3000 ft to less than 150 ft, and the BFS errors were reduced from approximately 4500 ft to less than 50 ft. Both PASS and BFS navigation states remained consistently less than 100 ft during the GPS incorporation period all the way down to when Microwave Scanning Beam Landing System (MSBLS) was incorporated, when the PASS by design automatically stops taking GPS updates. The design also allows the BFS to continue to incorporate GPS data all the way through rollout. After wheel stop, a number of BFS GPC errors (square root of a negative number) were seen in the error logs. This is a known documented condition, which will be corrected in the next version of the PASS

Communications and Tracking Systems

During STS-122, the Communications and Tracking systems performed nominally. No IFA's were identified from the data review and analysis.

During the initial Ku-Band RADAR self test, the range was 5857 ft (should be between 4820 and 5820 ft). The RADAR Range Data Good and RADAR Range Rate Data Good flags were low and should have been high. In addition, the TRACK flag was missing. This resulted in a self-test failure related to the Electronics Assembly 2 (EA-2). The failure of the RADAR Active test is expected to sometimes occur. The RADAR self-test checkout is performed in the Active (Cooperative Mode) mode of the RADAR system. The failure of this sequence is indicated by the absence of the TRACK flag and the presence of the DETECT flag as well as by the absence of the RADAR Range Data Good and RADAR Range Rate Data Good flags. All four signals should be present during this sequence. The failure of this sequence is a known idiosyncrasy in the self-test software timing during the TRACK mode. However, the difference in this case was the out-of-tolerance range indication.

The failure of the RADAR Active test had no impact on the RADAR Passive test or on Ku-Band communication or radar Passive operations. The Ku-Band operation during Rendezvous (RADAR Passive) was nominal. The Active mode (RADAR Cooperative mode) has never been used operationally.

The Orbiter Ku-Band antenna radiated the ISS while stowing the antenna during FD 4. The S1 truss was radiated for approximately 3 sec. The E-Field at the truss was less than 40 V/m peak. The ISS exposure limit is 125 V/m. Consequently, there was no

issue with the radiation. As a result, an evaluation is discussing the possibility of adding a note in the Ku-Band stowage procedure to verify with the Mission Control Center (MCC) that the Traveling Wave Tube (TWT) is inhibited, if it becomes necessary to stow the Ku-Band antenna while docked with ISS.

Review and evaluation of the Navigation Aids (NAVAIDS) data showed nominal performance and that all File IX requirements were satisfied. In addition, the S-Band system 1 was in operation for 27 hr 10 min, which satisfied the OMRSD Vol. II, File IX requirement to operate the S-Band Backup string continuously for 24 hours \pm 4 hr.

Operational Instrumentation/Modular Auxiliary Data System

The Operational Instrumentation (OI) sensors, signal conditioners and fuel cell monitoring systems performed nominally. Likewise, the Modular Auxiliary Data System (MADS) recorder and Master Measurement Unit (MMU) performed nominally during all phases of STS-122 mission without any issues or problems. No IFA's were identified from the data review and analysis.

The MADS sensors and signal conditioners performed nominally, and more specifically, the MADS Pulse Code Modulation (PCM) ascent and entry data has been reviewed with no issues or concerns identified.

It was noted that the Payload Data Interleaver (PDI) decommutator 1 lost the master frame and word synchronization with the Orbiter Interface Unit (OIU) data at several points in the mission. The Flight Control Instrumentation console switched to decommutator 2 and the PDI continued to lose the master frame and word synchronization with the OIU data at infrequent intervals. This change in configuration exonerated the two PDI decommutators and thus isolated the source of the dropouts to the OIU. This was later determined to be an explained occurrence and due to the fact that the OIU and PDI use different clocks to handle data transfer which are not kept in sync. The PDI decommutator is expected to lose synchronization with the OIU data approximately once every 10 to 14 hr.

Mechanical and Hatch Systems

The Mechanical and Hatches system performed satisfactorily and no IFA's were identified during the review and analysis of the data. One issue was noted, and it is discussed in the following paragraph.

During the Port Manipulator Positioning Mechanism (MPM) stowing operations on FD 12, neither of the 2 aft pedestal limit switches indicated 'Stow' as expected when the motors were deenergized at the end of the MPMs stow travel (IFA STS-122-V-07). The Shuttle Remote Manipulator System (SRMS) MPM stowing was performed in nominal dual motor run time. The stow/deploy motors are controlled by the limit switches located on the shoulder pedestal. The flight rules require only one shoulder indication and one indication at either the mid or aft pedestal is required for entry.

The deployment of the Right-Hand (RH) air data probe exceeded the dual-motor run-time limit of 14 sec. The deployment required 17.1 sec. The first 8.1 sec of drive time, only one motor was operating. After the crew cycled the RH air data probe switch, the remaining 9 sec was completed with both motors operating. The initial single-motor operation is attributed to the switch not being completely in the deploy position, such that the contacts for motor 2 were not closed. The remaining 9 sec had both motors operating.

Landing and Deceleration System

The Landing System performance at KSC was nominal. This assessment included all events from landing gear deployment, main gear touchdown, nose gear touchdown, through roll out, and including drag chute deployment and brake/deceleration. It was the second flight of the nose landing gear tires. They were in good condition and performed nominally. The main landing gear tires appeared nominal. The normal appearance of tread cord materials on areas of the tire's surface is a known expected characteristic of the new tire design. The parachute deployment and jettison occurred nominally. No unexpected affects from the performance of the drag chute occurred. An inspection of the flown parachute at the KSC Parachute Refurbishment Facility indicated no anomalies.

LANDING PARAMETERS

Parameter	From threshold, ft	Time from MLG touchdown, sec	Speed, keas^a	Speed, kgs	Sink rate, ft/sec	Pitch rate, deg/sec
Main Landing gear touchdown	2447.9	0.0	193.0	196.4	-1.00	N/A
Drag Chute Deployment	3300.4	2.91	184.9	186.5	N/A	N/A
Drag Chute Disreef	5084.3	8.84	157.1	159.9	N/A	N/A
Nose Landing Gear Touchdown	5159.9	9.16	154.5	157.2	N/A	-4.16
Brakes On	8564.0	26.18	86.6	90.5	N/A	N/A
Drag Chute Jettison	10029.1	38.47	67	54.1	N/A	N/A
Wheels Stop	10989.1	58.77	0	0	N/A	N/A
Parameter			Data			
Brake Initiation Speed, keas			86.6			
Brake On Time, sec			26.18			
Rollout Distance, ft			8541.2			
Rollout Time, sec			58.77			
Runway Location, Surface and Degrees			KSC/15 Concrete			
Orbiter Weight at Landing, lb			207215			

LANDING PARAMETERS (Concluded)

Parameter	Maximum Brake Pressure, psia	Total Brake Energy, Mft/lb
Left inboard	688.70	14.12
Left outboard	647.38	9.77
Right inboard	599.17	13.22
Right outboard	623.28	12.60

^aKnots equivalent air speed

Aerothermodynamics, Integrated Heating, and Interfaces

Post-flight reports indicated that overall, the Orbiter TPS appeared normal following the STS-122 mission. The lower structural temperature data indicated normal entry heating. The recorded structure temperatures are within the flight experience of OV-104. From the thermocouple data, Boundary Layer Transition (BLT) occurred around Mach 9.4 based on a pre-flight EOM trajectory and centerline location of X/L = 0.6.

The runway report indicated that the chin panel gap filler exhibited 2 breaches (about 2.5-in. at LHS and 0.8-in. at RHS). The starboard OMS pod peeled back blanket corner appeared to be in the same condition as detected during on-orbit imagery. The Port OMS pod stinger missing tile area was still in the same condition as detected on-orbit. A small fray near the centerline detected during on-orbit imagery was on the edge of a patch, not a frayed thermal barrier.

The following table shows the maximum temperatures and maximum temperature rise during entry.

ENTRY MAXIMUM TEMPERATURE AND MAXIMUM TEMPERATURE RISE DATA

Thermal Sensor Location	Maximum Temperature, °F	Maximum Temperature Rise, °F
Lower fuselage forward center (B1)	132.5	121.4
Lower fuselage forward left-hand (B2)	171.9	160.8
Lower fuselage forward mid left-hand (B3)	164.0	170.7
Lower fuselage mid center (B4)	143.0	149.7
Lower fuselage mid aft center (B5)	161.4	160.5
Lower fuselage aft center (B6)	185.1	158.7
Left-wing center (LW)	109.0	133.5
Right wing center (RW)	116.8	131.2
Port side FRCS forward (P1)	132.5	101.0
Port side fuselage forward center (P2)	96.0	90.0
Port side fuselage forward mid center (P3)	85.6	84.7
Port side fuselage mid aft center (P4)	70.1 ^a	87.0 ^a

**ENTRY MAXIMUM TEMPERATURE AND MAXIMUM TEMPERATURE RISE DATA
(Concluded)**

Thermal Sensor Location	Maximum Temperature, °F	Maximum Temperature Rise, °F
Port side fuselage aft center (P5)	77.9	66.8
Starboard side FRCS Forward (S1)	143.0	106.3
Starboard side fuselage forward center (S2)	135.1	121.5
Starboard side fuselage forward mid center (S3)	106.4	85.1
Starboard side fuselage mid-aft center (S4)	75.3	61.6
Starboard side fuselage aft center (S5)	101.2	74.8
Left-hand OMS pod side forward (LP)	70.1	56.5
Right-hand OMS pod side forward (RP)	64.9 ^a	59.0 ^a
Lower body flap center	96.0 ^a	77.3 ^a
Right-hand OMS-pod side forward	64.9 ^a	59.0 ^a
Left-hand OMS-pod side forward	70.1	56.5
Right-hand PLBD forward	62.4 ^a	114.6 ^a
Left-hand PLBD forward	67.5 ^a	129.8 ^a
Right-hand PLBD aft	72.7 ^a	109.8 ^a
Left-hand PLBD aft	72.7 ^a	119.9 ^a
Right wing upper center	90.8 ^a	110.2 ^a
Left wing upper center	90.8 ^a	125.4 ^a
Forward RCS center	98.6 ^a	77.3 ^a
Forward fuselage upper center	70.1	87.0

Note a: Maximum temperature occurred 30 min after wheel stop.

Thermal Control System

All passive Thermal Control System (TCS) temperatures were maintained within acceptable limits with exceptions shown in the following list. None of these issues impacted the safety of the mission.

1. APU system 3 drain line heater cycled inconsistency – item is discussed in the APU section of this report.
2. The Forward RCS propellant tanks approached the Systems Management (SM) alarm limit twice - The FRCS compartment tanks exhibited warm temperatures approaching the 90 °F SM limit. The tanks reached 84 °F on the Oxidizer and 87°F on the fuel while docked and 85 °F on the Ox and 87 °F on the fuel post-undocking. A cold environment due to the attitude and very low forward RCS tank quantities caused a fast response and both heaters to stay on constantly. The attitude was changed to expose the nose to the Sun, which caused the heaters to turn off and prevented the tanks from reaching the 90 °F limit.
3. Four Aft Vernier RCS heaters failed off - item is discussed in the RCS section of this report.

4. Starboard Outboard Elevon Actuator System 3 return line – The hydraulic system 3 right outboard elevon return line temperature sensor exhibited an elevated thermal response over a period of nine hr. Starting at 049/16:13:30 GMT (10/20:28 MET) and ending at 050/01:59:30 GMT (11/06:14 MET), the temperature increased from 9 °F spiking to 31 °F and then to 57 °F. The systems 1 and 2 return lines in the same area did not respond the same as this sensor. It is unlikely to have a 50 °F temperature gradient between systems for no or low flow conditions. The most probable cause is an erratic sensor. The measurement tracked with other systems for rest of flight.

Thermal Protection System

Tile and Blanket Flight Assessment

On FD 2, the Thermal Protection System (TPS) Damage Assessment Team (DAT) reviewed images of blankets on the port and starboard OMS pods that were taken by the crew through the aft flight deck windows. A blanket on the port pod appeared to be slightly lifted and required DAT evaluation (IFA STS-122-V-01). A blanket on the starboard pod appeared to be peeled back to some extent. A recommendation was made to conduct a focused inspection of a blanket on the starboard OMS that was slightly lifted.

On FD 4, the Shuttle crew performed a Focused Inspection of the lifted thermal blanket on the starboard OMS pod using the SRMS and the OBSS without issue. Images were collected with the Laser Camera System (LCS), the Integrated Sensor Inspection System (ISIS) Digital Camera (IDC), and the Intensified Television Camera (ITVC) and the LDRI, and downlinked for ground analysis. Evaluation continued to clear two minor tile damage sites near window 4, as well as the pending analysis of the FD 5 inspection imagery.

By FD 6, the TPS DAT completed the analysis of the two damage sites around the cabin windows and the uplifted blanket on the starboard OMS pod for entry. The TPS DAT presented results of the tile and blanket damage assessment to the MMT. The MMT approved the TPS DAT recommendation and cleared all open TPS items with the exception of the missing tile on the Port OMS Pod RCS stinger.

On FD 7, the TPS DAT completed analysis of the missing tile on the Port OMS pod RCS stinger. The MMT approved the DAT recommendation, and declared the vehicle TPS cleared for entry.

RCC Flight Assessment

On FD 3, a Focused Inspection meeting was held to review DAT recommendations. The Reinforced Carbon-Carbon (RCC) DAT summarized the results of the FD 2 surveys, and cleared the RCC and identified no focused inspection requirements.

On FD 12, following undock and separation, the RCC late inspection of the Starboard and Port Wing Leading Edge and Nose cap were performed using the Orbiter Boom Sensor System (OBSS). The survey began at 049/13:54 GMT (10/18:08 MET) and was completed 3 hr 02 min later, and the survey imagery was successfully down linked for ground analysis.

Post-landing Assessment

The final debris-related tile damage numbers are shown in the following table.

SUMMARY OF IMPACT SITES FOR EACH ORBITER SURFACE

Orbiter Surface	Impacts greater than 1 in.	Total impacts
Lower surface	16	158
Upper Surface/Window	2	25
Right side	-	-
Left side	-	-
Right OMS pod	2	17
Left OMS pod	1	8
Totals	21	208

A post-landing walk-down of the runway was performed. The only unexpected flight hardware found was an Omega label temperature sensor. All components of the drag parachute were recovered. The drag parachute hardware and components appeared to have functioned nominally. Both reefing-line-cutter pyrotechnic devices were expended. One reefing line was found 4500-ft aft of the main parachute, and the other was found 2500-ft aft of the main parachute.

There was a missing tile on the Left-Hand (LH) stinger. This was seen during film review to have occurred during SSME startup and confirmed in on-orbit imagery. A carrier panel bolt head was exposed under the missing tile, and appeared to be undamaged.

The main landing gear and nose landing gear door corner tiles did not have any chips. There was a gap-filler protruding from the LH main landing gear door.

The Orbiter nose cap, LH RCC, and RH RCC panels all appeared to be in nominal condition.

The SSME Dome Mounted Heat Shield (DMHS) blankets all appeared to be in excellent condition, with a very low amount of fraying. The base heat shield tiles had little damage between the engines, although there was a large (6-in. by 6-in.) collection of hits on the +Z of SSME 2.

The LH₂ and LO₂ umbilicals both appeared to be nominal. Both did have 4 clips bent around the perimeter of the External Tank/Orbiter (EO) fittings. There was a light hazing on all of the camera lenses.

Drag-chute induced-tile-damage was noted approximately 0.5-in. in diameter on the LH tile adjacent to the drag parachute door.

There was charred tape residue remaining in 3 tiles.

Windows

Window 2 had hazing on the upper edge. Window 3 appeared to have discoloration in the upper outboard corner approximately 5-in. by 1-in, and Orbiter Processing Facility (OPF) inspection is required to determine the extent of this condition. Window 5 had hazing on the upper half of the window.

Waste Collection System

The Waste Collection System (WCS) performed satisfactorily, and the crewmembers did not report any problems or issues during the flight and systems debriefings.

EXTRAVEHICULAR ACTIVITY

SUMMARY

The three Extravehicular Activities (EVA's) were completed satisfactorily and the total EVA time was 22 hr 08 min. The three crewmembers who performed the EVA's were Rex Walheim, designated as EV 1, who had 22 hr 08 min of extravehicular activity time; Stanley Love, designated as EV2, who had 15 hr 23 min of extravehicular time and Hans Schlegel, designated as EV 3, who had 6 hr 45 min of extravehicular activity time.

FIRST EXTRAVEHICULAR ACTIVITY

EV1 and EV2 conducted the first of three EVAs on FD 5. The EVA was completed satisfactorily, and the total time of the EVA was 7 hr 58 min. The activities began with the EVA preparation tasks required to unberth the Columbus Laboratory. On the way to the Shuttle payload bay, the crewmembers opened the Node 2 Centerline Berthing Camera System (CBCS) hatch cover. Both crewmembers then translated to the Shuttle payload bay. The crew demated the Launch to Activation (LTA) cable from the Columbus Laboratory and installed it on the EVA Cable Stowage Hardware (ECSH). The EV2 crewmember removed the Power and Data Grapple Fixture (PDGF) from the sidewall carrier while the EV1 crewmember removed and stowed one of the Meteor and Debris Panel Shield (MDPS) panels in preparation for the PDGF installation task. Once the PDGF was structurally mounted, the crew removed and stowed a second MDPS Panel to install the PDGF harness. Once the harness was installed, the 2 MDPS panels were then reinstalled. The crew then removed eight Passive Common Berthing Mechanism (PCBM) Covers and stowed the covers in a large EVA Trash bag. With the completion of these EVA tasks, the Columbus Module was ready for unberth. The crew then translated the Orbital Replacement Unit (ORU) Temporary Stowage Device (OTSD) to the external stowage position, and this was a EVA get-ahead task. The crew then translated to P1 to prepare the P1 Nitrogen Tank Assembly (NTA) for removal and replacement on EVA 2. The two tasks performed were to break torque on the bolts and temporarily stow the EVA tools that would be used during the NTA changeout.

Planned tasks that were not completed during the first EVA included the demating of the N₂ lines and electrical connectors and the NTA venting. These tasks were incorporated into the second EVA on FD 7 when the depleted P1 NTA was removed and a new NTA was installed.

Upon ingress, the crew noted a possible Micrometeoroid/Orbital Debris (MMOD) strike on handrail 506 of the ISS Airlock. The Airlock handrail was subsequently inspected and photographed during the third EVA and the crew completed a swatch test over the surface of the handrail. Following the first EVA, the crew photographed the Extra-Vehicular Mobility Unit (EMU) gloves to facilitate assessment by ground specialists.

SECOND EXTRAVEHICULAR ACTIVITY

The EV1 and EV3 crewmembers successfully completed the second EVA on FD 7. The total time of the EVA was 6 hr 45 min. Both EV crewmembers successfully removed and replaced the NTA on EVA 2. The crew began by removing the new NTA from the shuttle payload bay and temporarily stowing it on the Crew and Equipment Translation Aid (CETA) cart. The crew then demated the electrical connectors and uninstalled the P1 truss NTA and also temporarily stowed it on the CETA Cart. The new NTA was then installed on the P1 truss.

The old NTA was then returned to the payload bay and installed on the cargo carrier for return. After completing the NTA removal and replacement, the crew installed the four Columbus Laboratory trunnion covers. Finally, the crewmembers were requested to evaluate the Laboratory MMOD shield repair task. During the evaluation, the crew installed a wire tie to secure the debris shield in place and returned the 3 adjustable tethers and the MMOD tools.

THIRD EXTRAVEHICULAR ACTIVITY

The EV 1 and EV 2 crewmembers completed EVA 3 on FD 9 in 7 hr and 25 min. The first task was to transfer the first of two European Space Agency (ESA) payloads, which was Sun Monitoring on the External Payload Facility of Columbus (SOLAR). The crew ingressed the SSRMS and removed the SOLAR payload from the cargo carrier and transferred it to the Columbus External Payload Facility (EPF). The crew then removed the Control Moment Gyroscope (CMG) from ESP-2 and transferred it to the cargo carrier in the payload bay for return to Earth.

The second of two ESA payloads, European Technology Exposure Facility (EuTEF) was removed from the cargo carrier and transferred to the Columbus EPF. The crew then completed installation of 9 EVA handrails, 2 Worksite Interface (WIFs) on the Columbus Module, and the keel pin Multi-Layer Insulation (MLI) cover. The final task completed was an inspection of the airlock handrail damage site that was first noted on EVA 1. The crew performed a swatch test using a prepared tool with Velcro and over-glove material to determine if the airlock handrail area of interest was a sharp edge.

SHUTTLE REMOTE MANIPULATOR SYSTEM AND ORBITER BOOM SENSOR SYSTEM

STS-122 was the 77th flight of the Shuttle Remote Manipulator System (SRMS), the 26th flight of SRMS S/N 301, the 8th flight of the Orbiter Boom Sensor System (OBSS), and the 4th flight of Inspection Boom Assembly (IBA) S/N 201.

The SRMS on-orbit initialization was performed on Flight Day (FD) 1. The port and starboard Manipulator Positioning Mechanisms (MPMs) were deployed and the SRMS shoulder brace was released.

On FD 2, the SRMS power-up and checkout began at 039/11:24 GMT (00/15:38 MET) followed by OBSS grapple and unberthing of the OBSS. The port and starboard wing leading edge (WLE) Reinforced Carbon-Carbon (RCC) and nose-cap surveys began at 039/14:31 GMT (00/18:45 MET) and were completed 4 hr 42 min later. Following the completion of the surveys, the OBSS was berthed and the SRMS was maneuvered to the pre-cradle position.

On FD 3, The Orbiter docked with the ISS while the SRMS was in the pre-cradle position. After docking, the Space Station Remote Manipulator System (SSRMS) was used to grapple and unberth the OBSS for a hand-off to the SRMS. Following the hand-off, the SRMS was maneuvered to the Columbus viewing position at 040/21:13 GMT (02/01:27 MET).

On FD 4, the crew performed a Focused Inspection of the Starboard Orbital Maneuvering System (OMS) Pod blanket. Following the completion of the Focused Inspection, the SRMS was maneuvered back to the Columbus Viewing position at 041/20:38 GMT (03/00:52 MET).

On FD 5, the SRMS provided viewing support as the SSRMS unberthed and installed the Columbus module during the first Extravehicular Activity (EVA). The SRMS remained at the Columbus Viewing position on FD 6.

On FD 7, the SRMS maneuvered to the second EVA viewing position at 044/12:35 GMT (05/16:49 MET). The SRMS was then maneuvered back to the Columbus Viewing position after the completion of the second EVA.

On FD 9, the SRMS remained in the Columbus Viewing position while the SSRMS supported the third EVA.

On FD 10, a reboost of the ISS using Shuttle vernier Reaction Control System (RCS) thrusters was performed with the SRMS holding the OBSS in the Columbus Viewing position.

On FD 11, the SRMS was maneuvered to the undocking position.

On FD 12, the Orbiter undocked and performed a full flyaround and two separation maneuvers with the SRMS holding the OBSS in the undocked position. The Late Inspection began at 049/13:54 GMT (10/18:08 MET) and was completed 3 hr 02 min later. After performing the Late Inspection, the OBSS was berthed, the SRMS was cradled and latched, and the Manipulator Positioning Mechanisms (MPMs) for both systems were stowed. Powerdown was complete at 049/18:46 GMT (10/23:00 MET). With the latching of the SRMS, no additional SRMS activities were performed for the remainder of the mission.

During the subsequent stowage of the port MPMs, the aft stow microswitch indicators failed to come on. This anomaly was not a constraint to entry. The indicators later came on at 050/04:59:32 GMT (11/09:13:02 MET), approximately 10.5 hr after the Port MPMs were stowed.

WING LEADING EDGE IMPACT DETECTION SYSTEM

ASCENT MONITORING

No real-time Wing Leading Edge (WLE) support was performed for this flight because the Wing Leading Edge Impact Detection System (WLEIDS) sensor side relays would not transmit data, making communication with the sensor units from the onboard laptop computers impossible. This condition was discovered pre-flight, and investigation revealed that the firmware upgrade provided for this flight inadvertently depleted the batteries inside the relays when certain commands were issued during ground testing.

During post-flight operations at Kennedy Space Center, support personnel were able to communicate directly with the sensor units through the Orbiter wing structure using a directional antenna, which enabled bypassing the nonfunctional relays. Using this method, the WLE IDS sensor ascent data was successfully downloaded from the units after landing.

All units triggered and began data recording on Space Shuttle Main Engine (SSME) ignition within 0.2 sec of each other except for Unit 1078, which triggered approximately 0.51 sec early and Unit 1103 that recorded no ascent data. The summary of all probable impact indications above 1.0 Grms for this flight is shown in the following table.

SUSPECTED ASCENT DEBRIS IMPACTS ABOVE 1.0 Grms

Times		Location			Magnitude		Criteria				Impact ^a	
MET	DET	Wing	RCC	Unit-Channel	Max. Grms	Max. G	Transient	Local	Spectral	Shock	In-Flt	Post-Flt
127.6	136.8	Starboard	11-12	1102-J3	4.3	17.40	+	+	+	+	N/A	P
130.7	139.9	Port	13-14	1104-J2	4.2	17.50	+	+	+	+	N/A	P
99.0	108.2	Starboard	6-7	1076-J3	1.5	6.15	+	+	+	+	N/A	P
64.9	74.1	Starboard	19-22	1122-J3	1.2	6.43	+	+	+	+	N/A	P

Notes: Mission Elapsed Time was set to 9.2 seconds behind Data Elapsed Time (MET = DET - 9.2 sec).

[†] P=probable, Q=questionable, N=no, U=unfound

Since no impact-probable cases were reported during the flight because the sensor-side relay transmission anomaly, only post-flight analysis was used to identify the four probable indications above 1.0 Grms that are shown in the previous table.

Automatic scanning of post-flight data acquired from 10-500 sec MET revealed an additional 41 probable ascent debris impact indications on the WLE (15 on the port and 26 on the starboard wing) ranging from 0.1 to 1.0 Grms.

ORBIT MONITORING

In addition to ascent programming, the sensor units were also successfully programmed pre-launch for Micrometeoroid and Orbital Debris (MMOD) monitoring. As previously demonstrated on STS-120, three composite groups (A, B, and C) consisting of combinations of the original seven on-orbit groups were planned for STS-122 to ensure a denser array of accelerometers was monitoring during the highest risk periods.

Monitoring began at approximately 15 hr MET with on-orbit Group A, 36 hr MET with on-orbit Group B, and 204 hr MET with on-orbit Group C. Both on-orbit Groups A and B were programmed to monitor for 18 hr. Group C was Orbiter jacking and leveling operations.

As a result of battery life limitations, continuous on-orbit monitoring of each RCC panel was not possible. The total monitoring time for this mission was about 48 hours for each wing.

For this mission, the WLE IDS recorded 5 valid triggers; all of which satisfied all impact criteria. Four of the five impact indications occurred in the period from initial activation until docking which occurred at approximately 45 hr MET. The summary of all WLE IDS MMOD probable impact indications for this flight is shown in following table.

SUSPECTED MMOD IMPACTS

Times	Location			Magnitude	Criteria				Impact ^a		
	GMT	Wing	RCC		Unit-Channel	Max. G	Transient	Local	Spectral	Shock	In-Flt
39/16:56:33	Port	9:10	1095-J2	0.59	+	+	+	+	+	N/A	P
39/17:03:37	Port	10:11	1093-J2	1.17	+	+	+	+	+	N/A	P
39/17:22:35	Starboard	19:22	1119-J3	0.60	+	+	+	+	+	N/A	P
40/03:57:10	Starboard	16:17	1121-J2	0.65	+	+	+	+	+	N/A	P
47/12:07:04	Starboard	16:19	1122-J2	1.38	+	+	+	+	+	N/A	P

^a P=probable, Q=questionable, N=no, U=unfound

SUPPLEMENTAL DATA COLLECTED

Following the post-flight roll-in of the Orbiter to the Orbiter Processing Facility (OPF), the Orbiter was subjected to standard leveling and jack-stand operations. Prior to performing these operations, the WLE IDS sensor units were placed into the on-orbit monitoring mode to determine if any evidence of vehicle popping could be observed that may result from the load redistribution and subsequent strain energy relief in the structure. A single data acquisition was recorded during these operations, but appeared to be triggered by the background noise. The data did not exhibit impact characteristics.

CONCLUSIONS

The WLE IDS system was not available to support real-time operations for this mission. Post-flight analysis of the ascent data indicated four probable debris impact indications above the 1.0 Grms reporting threshold. Post-flight evaluation of MMOD monitoring data indicated five probable MMOD impact indications. A late mission survey inspection was used to clear the vehicle for entry.

GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

The Government Furnished Equipment (GFE) and Flight Crew Equipment (FCE) performed satisfactorily. Three STS-122 in-flight anomalies were identified as well as a repeat of an STS-117 anomaly and these are discussed in the following paragraphs.

During the Flight Day (FD) 2 Laser Dynamic Range Imager (LDRI) video processing, intermittent occurrences of color that should not have been present were noted (IFA STS-122-V-05). This was subsequently observed in video from other black and white cameras. This presence of color is attributed to chroma noise being injected into the signal before the recording circuit on the DSR-25 recorder. The chroma noise was observed to occur several times, and there is no mission impact.

While viewing downlink video from the middeck, the flight controllers noticed that the video appeared as overexposed (IFA STS-122-V-03). The crew was requested to check the Advanced Video Interface Unit (AVIU) Hi-Z/75 switch to make sure it was in the 75-Ohm position (video will look overexposed if it is in the Hi-Z position). The crew verified the 75-Ohm position, but the video signature remained. The crew mentioned that they were having other issues with that AVIU and replaced it with an AVIU from the flight deck. The change of the AVIU's cleared the problem. The AVIU was returned for post-flight testing.

After about 4 hours of good communications, the Space-to-Space Orbiter Radio (SSOR) no. 1 and Space-to-Space Station Radio (SSSR) no. 2 frame synchronization toggled for 15 min (IFA STS-122-V-09). The frame synchronization was then good for 2 min, after which the crew switched to SSOR no. 2. The frame synchronizations of the SSOR and the SSSR were toggling at the time of the anomaly and the switch to SSOR no.2 prevented any more evaluation of SSOR no.1 and SSSR no. 2 to determine the root cause, as the SSSR no. 2 could also produce the same frame synchronization signature. During the FD 9 overnight troubleshooting, the crew switched back to SSOR no. 1 prior to crew sleep and then back to SSOR no. 2 in support of EVA 3. No anomalies were seen during the troubleshooting. The crew returned to SSOR no. 1 on FD 10 and remained there until FD 12 undocking and no repeat of the problem was identified.

The crew reported a small amount of water around the Mineral/Silver Biocide Injection Port. Upon further discussions with the flight controllers, the crew reported that the water previously observed around the Mineral/Silver Biocide Injection Port was not due to condensation. The entire line segment was the same temperature, and the only observance of water outside the line was near the injection port. The crew described it as a "ball of water," rather than tiny drops that might be associated with condensation. Eleven Contingency Water Containers (CWC's) were filled at the time of the crew report with two CWC's remaining to be filled. The leak was small and did not impact any CWC fills. The crew wrapped a towel around the port to soak up the leaking water. This condition was defined as an in-flight anomaly on STS-117 and thus it carries that flight

designation (IFA STS-117-V-05). The leaking hose will be returned for post-flight evaluation.

DEVELOPMENT TEST OBJECTIVES (DTO)

DTO 805 Crosswind Landing Performance

This DTO was not performed as crosswinds were below the lower limit of 10 knots for the performance of this DTO.

DTO 853 In-Flight Evaluation of Areas of Carbon Dioxide Concentration

The CO₂ Monitor (CDM) activities were assumed to have been executed per the nominal procedures over the duration of the flight.

POSTLAUNCH PAD INSPECTION

The post-launch inspection of Main Launch Platform (MLP) -1, Pad A Fixed Service Structure (FSS), and South side apron of Launch Pad A was conducted on February 7, 2008. No flight hardware was found other than minimal Solid Rocket Booster (SRB) nozzle throat-plug foam and Room Temperature Vulcanizing (RTV) material.

The Orbiter lift-off lateral acceleration data indicated a maximum of 0.12g. Hold-down stud hang-ups are typically noted with lateral accelerations above 0.19g. The results of the inspection of the Hold-Down Posts (HDP's) are as follows:

HDP 1 – The EA934 poured sidewalls were nominal with some acceptable visible voids present. The Phenolic shim was nominal and the two firing lines had approximately 2 ft of length protruding from the HDP. No galling or chatter marks were noted in the chamfer of the through-hole.

HDP 2 – The EA934 poured sidewalls were nominal with acceptable visible voids present with some delamination from the shoe on the East side. The Phenolic shim was nominal with one blister present. Approximately 6-in. of both firing lines was present. The Range Safety System (RSS) cable was present and still coiled to the underside of the aft skirt shoe retainer. No galling or chatter marks were noted in the chamfer of the through-hole.

HDP 3 – The inspection showed nominal indications of erosion on the RTV-coated blast shield with proper closure.

HDP 4 – The inspection showed nominal indications of erosion on the RTV-coated blast shield with proper closure.

HDP 5 – The EA934 poured sidewalls were nominal with some visible voids present and with minor delamination from the shoe on the east side. The Phenolic shim was nominal with one blister present. Approximately 6-in. of both firing lines was present. No galling or chatter marks were noted in the chamfer of the through-hole.

HDP 6 – The EA934 poured sidewalls were nominal with visible voids present and without any delamination from the shoe. The Phenolic shim was nominal without visual blistering. Approximately 6 in. of both firing lines were present. No galling or chatter marks were noted in the chamfer of the through-hole.

HDP 7 – The inspection showed nominal indications of erosion on the RTV-coated blast shield with proper closure.

HDP 8 – The inspection showed typical indications of erosion on the RTV-coated blast shield with proper closure and the RSS cable was missing.

The results of the inspection of the GN₂ purge lines were as follows:

The Left-Hand (LH) probe was erect and slightly bent to the South with about 95-percent of the protective tape layering remaining and no exposed braiding was found.

The Right Hand (RH) probe was erect and slightly bent to the South with about 90-percent of the protective tape layering remaining and no exposed braiding was found.

Both the LH and RH SRB T-0 Ground Carrier Assemblies (GCA's) appeared to be in nominal condition with the proper demate. The electrical connector back-shells had the typical sidewall breaks.

The LO₂ and LH₂ Tail Service Masts (TSM's) appeared undamaged and both bonnets appeared to have closed properly. The LH₂ bonnet had two straps protruding outward from the top of the door.

The MLP deck was in excellent condition. Typical blast erosion was observed in and around the SRB flame holes with an indication of a Northeasterly ascent. All sound suppression shims appeared to be in place.

The Orbiter Access Arm (OAA) at the 195-ft level was intact with no evidence of plume damage. All slidewire baskets were still secured at the 195-ft level with no evidence of damage.

The GH₂ vent line on the Ground Umbilical Carrier Panel (GUCP) at the 215-ft level was latched on the sixth tooth (of eight) of the latching mechanism. The vent line was in between the gimbal struts and slightly north of center in the latching mechanism as seen from the FSS. The External Tank (ET) 7-in GUCP GH₂ Quick-Disconnect (QD) probe was accessible for inspection and appeared to be undamaged. Both the QD probe sealing surface and the poppet valve assembly were in good condition. The deceleration cable was in nominal configuration and the GH₂ vent line blanket was mostly torn away by plume impingement. The ET GUCP exhibited typical blast damage and the pyrotechnic-bolt fired nominally.

The Gaseous Oxygen (GO₂) Vent Arm at the 255-ft level as well as the vent hood, ducts and structure appeared to be in nominal condition. The latch mechanism was locked properly.

Although numerous items were found, the Pad facility was found to be in very good condition. Most notable were the communication boxes on the 115-ft and 135-ft levels, which had the doors blown open with cables exposed. Various pieces of rust-scale were found and catalogued on many levels. The team noted that this pad appeared to be the cleanest since the Return-To-Flight (STS-114).

LAUNCH PHOTOGRAPHY AND TELEVISION ANALYSIS

The ground cameras, both film-type and television, provided very good coverage of the launch and ascent of the STS-122 vehicle. Numerous observations were made and are documented in the NASA Imagery Reporting Database (NIRD). Significant observations and those which were determined to potentially impact the Orbiter included the following.

1. An entire tile was seen falling from the aft end of the port Orbital Maneuvering System (OMS) stinger after Space Shuttle Main Engine (SSME) Startup. The tile was noted in other views as a rectangular-shaped piece of debris seen between SSME 2 and the LH₂ Tail Service Mast (TSM) during SSME startup. The Thermal Protection System (TPS) Damage Assessment Team (DAT) cleared this area of the vehicle for entry at FD7 Mission Management Team (MMT).
2. At 22 sec Mission Elapsed Time (MET), debris from the Port External Tank (ET/Orbiter) Attachment (EO 2) point was observed falling outboard across the underside of the port wing from EO 2. The debris may have impacted the wing but no damage observed in ascent imagery. The TPS DAT reviewed R-bar Pitch Maneuver (RPM) imagery and noted no damage in this area.
3. At 22 sec MET, debris from near the Port ET/Orbiter attachment (EO 2) was observed falling aft from near the EO 2 and may have impacted the underside of the port wing. No evidence of damage was observed in ascent imagery, and the TPS DAT reviewed RPM imagery and noted no damage in this area.
4. At 27 MET sec, a small piece of debris was observed falling aft and impacting the Orbiter belly forward of the starboard Landing Gear Door. No evidence of damage observed in ascent imagery. The TPS DAT assessed RPM imagery and identified some small damages in this location which were within the criteria.
5. At 47 sec MET, debris was observed aft of the starboard Orbiter/External Tank umbilical (EO 3), which may have been purge barrier material. The debris may have impacted the body flap, but no evidence of damage was observed in ascent imagery. The TPS DAT reviewed RPM imagery and noted no damage in this area.
6. At 125 sec MET, multiple pieces of small debris impacted the Orbiter starboard wing during SRB separation. No evidence of damage was observed in ascent imagery, and the TPS DAT reviewed the RPM imagery and noted no damage in this area.
7. Around 133 sec MET, multiple pieces of debris were seen inboard of the LO₂ feedline just aft of the starboard bipod leg. The External Tank reported this as the loss of insulation at Xt 1129 inboard of LO₂ feedline. Impact to the Orbiter was inconclusive, and the TPS DAT reviewed RPM imagery and noted no damage in this area.
8. At 440 sec MET, debris was observed impacting the Orbiter belly and changing direction. The debris appeared to come from area aft of starboard bipod foot. ET reported this as the TPS loss aft of starboard Bipod Foot. The TPS DAT reviewed the RPM imagery and noted no damage in this area.

APPENDIX A

STS-122 MISSION EVENTS

EVENT	DESCRIPTION	ACTUAL GMT
APU Activation	APU-1 Gas Generator Chamber Pressure APU-2 Gas Generator Chamber Pressure APU-3 Gas Generator Chamber Pressure	038/19:40:42.239 038/19:40:43.097 038/19:40:43.822
SRB HPU Activation	LH HPU System A Start Command LH HPU System B Start Command RH HPU System A Start Command RH HPU System B Start Command	038/19:45:02.128 038/19:45:02.288 038/19:45:02.448 038/19:45:02.608
Main Engine Start	SSME-3 Start Command Accepted SSME-2 Start Command Accepted SSME-1 Start Command Accepted	038/19:45:23.424 038/19:45:23.553 038/19:45:23.669
SRB Ignition	SRB Ignition Command	038/19:45:29.988
Throttle Up 104.5 Percent	SSME-1 Command Accepted SSME-2 Command Accepted SSME-3 Command Accepted	038/19:45:34.025 038/19:45:34.049 038/19:45:34.060
Throttle Down to 74 Percent	SSME-2 Command Accepted SSME-3 Command Accepted SSME-1 Command Accepted	038/19:46:06.666 038/19:46:06.690 038/19:46:06.700
Throttle Up to 104.5 Percent	SSME-1 Command Accepted SSME-2 Command Accepted SSME-3 Command Accepted	038/19:46:22.667 038/19:46:22.690 038/19:46:22.700
Maximum Dynamic Pressure (Max Q)	Derived Ascent Dynamic Pressure	038/19:46:33
Both SRMs to less than 50 psi	RH SRM Chamber Pressure LH SRM Chamber Pressure	038/19:47:29.631 038/19:47:29.831
End SRM Action	RH SRM Chamber Pressure LH SRM Chamber Pressure	038/19:47:32.068 038/19:47:33.068
SRB Separation Command	SRB Separation Command Flag	038/19:47:34
SRB Physical Separation	LH APU B Turbine Loss of Signal LH APU A Turbine Loss of Signal RH APU B Turbine Loss of Signal RH APU A Turbine Loss of Signal	038/19:47:34.228 038/19:47:34.228 038/19:47:34.228 038/19:47:34.268
OMS Assist Ignition	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	038/19:47:44.5 038/19:47:44.6
OMS Assist Cutoff	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	038/19:49:37.9 038/19:49:38.0
Throttle Down for 3g	SSME-1 Command Accepted SSME-2 Command Accepted SSME-3 Command Accepted	038/19:52:53.238 038/19:52:53.258 038/19:52:53.265
3G Acceleration	Total Load Factor (g)	038/19:53:20.1
Throttle down to 67 percent for Cutoff	SSME-1 Command Accepted SSME-2 Command Accepted SSME-3 Command Accepted	038/19:53:46.360 038/19:53:46.379 038/19:53:46.385
SSME Shutdown	SSME-1 Command Accepted SSME-2 Command Accepted SSME-3 Command Accepted	038/19:53:52.840 038/19:53:52.860 038/19:53:52.865
Main Engine Cutoff (MECO)	MECO Command Flag MECO Confirmed Flag	038/19:53:53 038/19:53:54
ET Separation	ET Separation Command Flag	038/19:54:15

APPENDIX A

STS-122 MISSION EVENTS

EVENT	DESCRIPTION	
APU Deactivation	APU-1 Gas Generator Chamber Pressure APU-2 Gas Generator Chamber Pressure APU-3 Gas Generator Chamber Pressure	038/20:01:11.268 038/20:01:34.322 038/20:01:42.606
OMS 1 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	N/A
OMS 1 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	N/A
OMS 2 Ignition	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	038/20:23:10.1 038/20:23:10.2
OMS 2 Cutoff	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	038/20:24:54.1 038/20:24:54.2
Payload Bay Doors Open	Right Payload Bay Door Open 1 Left Payload Bay Door Open 1	038/21:35:59 038/21:37:18
OMS 3 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	038/23:22:47.7 038/23:22:47.8
OMS 3 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	038/23:23:02.7 038/23:23:02.8
OMS 4 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	039/12:42:44.2
OMS 4 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	039/12:42:54.2
OMS 5 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	040/12:16:15.8 040/12:16:15.8
OMS 5 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	040/12:17:14.4 040/12:17:14.4
OMS 6 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	040/13:06:11.8 040/13:06:11.8
OMS 6 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	040/13:07:00.2 040/13:07:00.4
OMS 7 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	040/14:37:28.1
OMS 7 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	040/14:37:39.5
Docking	Capture	040/17:17:15
Undocking	Undocking Complete	049/09:24:40
Flight Control System Checkout – APU 1 Start	APU-3 Gas Generator Chamber Pressure	050/10:11:09.626
APU 1 Stop	APU-3 Gas Generator Chamber Pressure	050/10:15:30.946
Payload Bay Door Close	Left Payload Bay Door Close Right Payload Bay door Close	051/10:19:27 051/10:26:31
APU Activation	APU-2 Gas Generator Chamber Pressure APU-1 Gas Generator Chamber Pressure APU-3 Gas Generator Chamber Pressure	051/12:54:51.073 051/13:22:31.379 051/13:22:33.166
Deorbit Maneuver Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	051/12:59:52.2 051/12:59:52.3
Deorbit Maneuver Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	051/13:02:35.5 051/13:02:35.6
Entry Interface	Orbital Altitude Referenced to Ellipsoid	051/13:35:30

APPENDIX A
STS-122 MISSION EVENTS

EVENT	DESCRIPTION	
Blackout End	Data Locked (High Sample Rate)	No Black
Terminal Area Energy Management (TAEM)	Major Mode Code (305)	051/14:00:44
Main Landing Gear Contact	Main Landing Gear Left Hand Tire Pressure Main Landing Gear Right Hand Tire Pressure	051/14:07:08 051/14:07:08
Main Landing Gear Weight on Wheels	Main Landing Gear Right-Hand Weight on Wheels Main Landing Gear Left Hand Weight on Wheels	051/14:07:09 051/14:07:13
Drag Chute Deployment	Drag Chute Deploy 1 CP Volts	051/14:07:10.6
Nose Landing Gear Contact	Nose Landing Gear Left Hand Tire Pressure 1	051/14:07:17
Nose Landing Gear Weight on Wheels	Nose Landing Gear Weight on Wheels	051/14:07:18
Drag Chute Jettison	Drag Chute Jettison 2 CP Volts	051/14:07:46.2
Wheels Stop	Velocity with respect to Runway	051/14:08:10
APU Deactivation	APU-1 Gas Generator Chamber Pressure APU-2 Gas Generator Chamber Pressure APU-3 Gas Generator Chamber Pressure	051/14:22:57.969 051/14:23:03.323 051/14:23:12.387

APPENDIX B STS-122 IN-FLIGHT ANOMALIES

ORBITER ANOMALIES

IFA Number	Title	Comments
STS-122-V-01	TPS Tile and Blanket Anomalies	<p>A complete listing of the TPS Tile, Blanket, and RCC Regions of Interest (ROI) evaluated by the Tile and RCC Damage Assessment Teams are documented in the TPS Imagery Inspection Management System (TIIMS) Database located at: http://isal-web1.jsc.nasa.gov/tiims/TIIMS.htm. A total of 17 items were identified which either exceeded pre-defined screening criteria or for which no criteria exists. Twelve of these items were closed using standard procedures/tools, and the following five required additional analysis and were cleared for entry:</p> <ol style="list-style-type: none"> 1. D-122-AFD-540-001 - Starboard OMS Pod Blanket, X=1411.27, Y=143.07, Z=456.45 (FD 4 Focused inspection). 2. D-122-RPM-140-004 - Tile Damaged Above Window 4. 3. D-122-RPM-140-005 - Tile Damaged Above Window 4 4. D-122-RPM-550-002 - Port OMS Stinger Missing Tile. 5.. D-122-RPM-651-001 - Starboard Inboard Elevon Tile Damage, X=1398.96, Y=234.92, Z=280.68 PR: LP04-30-2702.
STS-122-V-02	APU 3 Drain Line Off-Nominal Heater Cycles	<p>At approximately 040/08:24 GMT, the APU 3 fuel seal cavity drain line heaters began to exhibit heater-off set-point shifts. The nominal off set-point for the APU 3 fuel seal cavity drain line heater circuit is approximately 67 °F. The shifts were noted on both drain-line temperature sensors with corresponding shifts in drain-line pressures seen. A total of four anomalous heater cycles were identified. The first two and last anomalous cycle had off set-points below nominal at approximately 62 °F. The other anomalous cycle had an off set-point above nominal and it was at approximately 81 °F. To avoid a having a heater failure during a crew sleep period, the panel A12 APU 3 tank and line A heaters were deactivated and the B heaters were activated. The thermostat was removed and replaced post-flight.</p>
STS-122-V-03	AVIU Video Overexposed	<p>While viewing downlink video from the middeck, the video appeared to be overexposed. The crew was requested to check the Advanced Video Interface Unit (AVIU) Hi-Z/75 switch to ensure it was in the 75-ohm position (video will look overexposed if it is in the HI-Z position.) The crew verified the 75-ohm position; however, the video signature remained. The crew mentioned that they were having other issues with that AVIU and replaced it with an AVIU from the flight deck. The change-out cleared the problem. The crew marked the AVIU as suspect. At the post-flight crew debrief, one of the crew members said that the AVIU was used later in the mission with no problem.</p>

APPENDIX B STS-122 IN-FLIGHT ANOMALIES

ORBITER ANOMALIES

IFA Number	Title	Comments
STS-122-V-04	Fuel Cell 3 Oxygen Flowmeter Erratic	<p>The Fuel Cell 3 Oxygen (O₂) flowmeter began displaying erratic behavior at 046/10:30:40 GMT (07/14:45:10 MET). The reading went off-scale low for about 2 min, followed by displaying unreliable and erratic data. Flight Control declared the Fuel Cell O₂ flowmeter failed and inhibited the on-board class 3 Fault Detection and Annunciation (FDA) upper limit (11 lb/hr). A review of the electrical bus did not show any anomalous indication at the time of the failure.</p> <p>The primary purpose of the flowmeter is to indicate purge flow. Purge flow can be verified by other parameters (coolant pressure, hydrogen flow, and fuel cell performance). No further action was required during the mission.</p>
TS-124-V-05	CCTV Black and White Video Shows Intermittent Color	<p>During the FD 2 Laser Dynamic Range Imager (LDRI) video processing, intermittent occurrences of color that should not have been present were noted. This was subsequently observed in video from other black and white cameras. This presence of color is attributed to chroma noise being injected into the signal before the recording circuit on the DSR-25 recorder. On FD 12, the Chroma was again observed during the RCC late inspection using the LDRI. This condition did not impact the mission.</p> <p>Post-flight investigation revealed that the noise was being generated by the DTV DSR-25 VTR.</p>
STS-122-V-06	Aft Vernier Heaters Failed	<p>At 11/00:43:39 MET, an electrical current spike on fuel cell 3 of 12 Amps was observed. Within 5 min, the injector temperatures on L5L, L5D, R5D and R5R began decreasing at a rate of approximately 0.75 °F/min indicating their respective thruster heaters had lost power. All 4 heaters are powered by a single Type III Hybrid Driver. The spike observed was consistent with the amperage and duration required to open the 5 A internal fusible link in the Hybrid Driver.</p> <p>Telemetry for the controlling switch, RCS/OMS Heaters Aft RCS Jet 5, indicated good power before the failure and after a subsequent power cycle. Control bus power flows through the switch to the hybrid driver. The driver then supplies Main Bus C ALC3 power to the four vernier thrusters.</p> <p>Post-flight on-vehicle resistance checks identified a short circuit that was isolated to thruster R5D. R5D was subsequently replaced (no pod removal required), and the discrepant thruster was returned to the WSTF Depot for TT&E. In addition, the Load Control Assembly (LCA) in the aft compartment was removed and replaced to repair the Hybrid Driver external fuse.</p>

APPENDIX B STS-122 IN-FLIGHT ANOMALIES

ORBITER ANOMALIES

IFA Number	Title	Comments
STS-122-V-07	Port Aft MPM Stow Indications Delayed	During the Port Manipulator Positioning Mechanism (MPM) stow on FD 12, neither of the two aft-pedestal limit switches indicated 'Stow' as expected when the motors were deenergized at the end of the MPMs stow travel. The port MPM stow had driven in nominal dual motor time. The Stow/Deploy motors are controlled by the limit switches located on the Shoulder pedestal. In accordance with Flight Rules, only 1 shoulder indication and one indication at either the mid or aft pedestal is required for entry. Both Aft MPM close indications came-on approximately 11 hrs later, so the anomaly was of no impact to the flight.
STS-122-V-08	Mid Port Payload Bay Floodlight Not Illuminating	At 049/15:47 GMT (10/20:02 MET), the crew turned on six payload bay floodlights, two powered by Main Bus A Mid Power Controller (MPC) 1, two powered by Main Bus B MPC2, and two powered by Main Bus C MPC 3. The current increase on MNB MPC 2 was lower than what is expected for two payload bay floodlights. The crew was asked to individually remove power from each floodlight on a mark the next time they turned them off. When the crew turned off the MID PORT floodlight, the current on Main Bus B MPC 2 dropped less than the expected amount indicating this light was not working properly. Previous data was reviewed which indicated the first time the this floodlight did not work properly was at 046/17:14 GMT (07/21:29 MET). Post-Flight inspection in the OPF visually confirmed to have a cracked bulb. The light was removed and replaced.
STS-122-V-09	SSOR 1 Intermittent Communication Dropouts	After about 4 hours of good comm, the SSOR and SSSR frame sync toggled for 15 minutes starting at 040/19:45. The frame sync was then good for 2 minutes, after which the crew switched to SSOR #2. Note that the frame syncs of the SSOR and the SSSR were toggling at the time of the anomaly, and therefore it is not certain that SSOR 1 was the root cause. An issue with SSSR 1 could also produce the same frame sync signature. During FN 8 overnight troubleshooting, the crew switched back to SSOR #1 prior to crew sleep and then back to SSOR #2 in support of EVA 3. No anomalies were seen during the troubleshooting. The crew returned to SSOR #1 on FD 10 and remained there until FD 12 undocking. No repeat of the problem was seen. Post-flight, the intermittent comm dropouts were not duplicated

**APPENDIX B
STS-122 IN-FLIGHT ANOMALIES**

SOLID ROCKET BOOSTER ANOMALIES

IFA Number	Title	Comments
STS-122-B-001	One of Three Main Parachutes on LH SRB showed Significant Damage in the Canopy	<p>During deployment of left-hand main parachutes, one of three main parachutes showed evidence of significant damage in the canopy. The parachute was never able to inflate. Consequently, the left SRB's water impact velocity was significantly higher than normal (approximately 92 ft/sec vs. 75 ft/sec nominal). There was significant damage to the aft skirt structure and internal components.</p> <p>Inspection of main parachute canopy revealed that one gore (no. 22) was torn for about 25 ft, extending from above the vent band down to ripstop 180. The tear extended through the vent band, through ripstops 283, 263, 246, 229, to ripstop 205 where the ribbon only detached. The tear terminated at ripstop 180. There were no other significant damage sites.</p>

APPENDIX B
STS-122 IN-FLIGHT ANOMALIES

REUSABLE SOLID ROCKET MOTOR ANOMALIES

IFA Number	Title	Comments
STS-122-M-001	Missing Piece of Forward Factory Joint Weatherseal (RSRM 99B)	<p>During post flight inspection of RSRM-99B, a missing section of cap ply insulation was noted on the forward segment cylinder-to-cylinder factory joint weatherseal. The missing section was located at approximately 195 deg and measured approximately 2 inches circumferential by 3 inches axial. The radial thickness of the missing section was approximately 0.06 inches. Material resembling brown poly backing was visible on the surface of the remaining Weatherseal, beneath the missing cap ply insulation. Fingerprinting analysis has confirmed that the suspicious material was indeed poly backing. Uncured insulation cap plies have poly backing on both surfaces that should be removed as part of the normal fabrication sequence. It has since been concluded that the poly backing on the underneath side of the cap ply was inadvertently left in place during the build process.</p> <p>No special process changes associated with the application of the cap ply insulation indicate a special cause for RSRM-99B; therefore, this condition may exist on other assembled/delivered flight motors. This finding results in an unsatisfactory condition.</p> <p>Investigation team has determined cause, identified flight rationale and corrective actions. Post-flight process evaluation of the cap ply installation procedure revealed corrective actions that would greatly improve process controls to preclude failure to remove poly backing. Corrective actions were processed per CR00021015.</p>
STS-122-M-002	Gas Penetration through RTV, Nozzle Joint 5, RSRM-99A	<p>During the post-fire inspection of RSRM-99A, a gas path was observed through a Room Temperature Vulcanizing (RTV) non-contact area at 204 deg. No heat effects were observed to the RTV, phenolics, metal, or O-rings.</p> <p>Gas penetration through the joint 5 RTV is not consistent with original design intent, but is not unexpected at this point in the program with the accumulated flight experience. This phenomenon is well understood and each occurrence is carefully evaluated for any challenge to flight rationale and level of risk assessment. 0 Joint 5 has experienced gas path/penetration through the RTV 22 times. This non-optimum performance of the RTV thermal barrier constitutes an unsatisfactory condition. Air entrapped in the RTV during assembly resulted in a gas path during motor operation is the most probable cause.</p> <p>Post-flight assessment indicated that replacing the RTV with carbon fiber rope has been qualified and is to be implemented on flight on RSRM-101. No corrective actions have been identified for RSRM-93 thru RSRM-100.</p>

APPENDIX B STS-122 IN-FLIGHT ANOMALIES

REUSABLE SOLID ROCKET MOTOR ANOMALIES

IFA Number	Title	Comments
STS-122-M-003	Gas Penetrations Through Nozzle Joint 2 RTV (RSRM-99A and B)	<p>LEFT HAND: Non-distinct gas penetrations were observed in Joint 2 around the full circumference through the RTV on both RSRM-99 A and B nozzles. Gas penetration through Joint 2 RTV is not consistent with original design intent, but is not unexpected at this point in the program with the accumulated flight experience. This phenomenon is well understood and each occurrence is carefully evaluated for any challenge to flight rationale and level of risk assessment. This non-optimum performance of the RTV thermal barrier constitutes an unsatisfactory condition.</p> <p>RIGHT HAND: Intermittent, non-distinct gas penetrations were observed around the full circumference through the Joint 2 RTV. Soot to the primary O-ring was observed intermittent full circumference. No heat-affected RTV, GCP, virgin CCP, SCP, adhesive, metal, or paint were observed in the joint. No heat effects were observed on the nose inlet or flex bearing flange paint, joint metal surfaces or adhesive. It should be noted that both gas penetrations documented on RSRM-99 are well understood and are within previous joint 2 occurrences.</p> <p>BOTH MOTORS: At motor ignition and Joint 2 pressurization, the deflections of the three metal structural housings (nose inlet housing, forward end ring and cowl housing) result in either a close or static condition at both the primary and secondary O-ring seal locations. However, radially outboard of the metal housings, the Joint 2 RTV filled gap tends to have an opening motion that causes a high volumetric strain condition in the RTV. Static test instrumentation response and RTV characterization testing has shown this strain state is near the limit of the RTV capability. The volumetric strain condition has been established as the cause of gas penetrations in the Joint 2 RTV. Failure of the RTV generally causes non-distinct gas penetrations around the circumference of the joint. For this type of gas penetration, there is little thermal energy that penetrates the RTV since the small closed end volume fills quickly in a dispersed manner. Occasionally, individual gas penetrations form that charge the joint volume such that the thermal energy is focused along a narrow path.</p> <p>Extensive post-flight thermal analysis subscale testing and full-scale post flight observation concluded that no primary O-ring erosion is predicted for a worst-case localized leak path. In addition, only localized thermal impact is predicted on metal housings. No flight safety or structural concerns are predicted but nose inlet housing aluminum and forward end ring steel temperatures could be high enough to result in metal hardware re-use issues.</p>

APPENDIX B STS-122 IN-FLIGHT ANOMALIES

EXTERNAL TANK ANOMALIES

IFA Number	Title	Comments
STS-122-T-001	Post-Launch Camera and Film Review Showed TPS Losses at the Intertank-to- LH2 Flange Closeout at 2 Locations	<p>Post-launch camera and film review showed TPS losses at the Intertank to LH2 flange closeout at two locations.</p> <p>First Location: At XT 1115 located between the 5th or 6th stringer +Z of the -Y thrust panel (Stringer 5 Panel 2 or Stringer 6 Panel 2).</p> <p>Second Location: At XT 1120 located in the 3rd stringer valley +Z of the +Y thrust panel (between Stringer 15 Panel 3 and Stringer 16 Panel 3 or Stringer 16 Panel 3 and Stringer 17 Panel 3).</p> <p>Dimensions were estimated to be 11.4 in. long by 3 in. wide by 0.9 in. deep at the first location and 8.5 in. long by 2.5 in. wide by 0.9 in. deep at the second location.</p> <p>Video review of all pocket, injection, upper and lower BX-265 foam applications for ET-126 LH2-I/T Flange C/O process has been completed. Review verified that required spray schedules were well followed and no non-conformances were noted. Evaluation indicated a top quality product was provided and was ready for flight. In addition, no defects were noted from these sprays <u>high fidelity mock-up dissections</u>.</p>
STS-122-T-002	Foam Loss in LH2 Acreage Forward of Station 1129 LO2 Feedline Bracket Base on ET-125/STS-122	<p>Post-launch camera and film review showed loss of foam XT 1136, LH2 Acreage adjacent to XT 1129 LO2 feedline base fitting closeout. The dimensions of the foam loss event adjacent to station 1129 were 6.0 in. long by 5.5 in. wide by 0.50 in. deep, with a total mass of 0.012 lbm, which violates the current requirements of NSTS 60559 before 135 seconds.</p>
STS-122-T-003	Post-launch Camera and Film Review Showed LH2 Acreage Foam Loss at Station 1145 During Launch	<p>Post-launch camera and film review showed LH2 acreage foam loss at station 1145 during launch. The size of the foam loss was determined to be: 7.5 in. by 4.5 in. by 1.29 in. (Depth based on as-built thickness), which calculates to a mass of 0.020 lbm. Video evidence shows the foam loss occurring at 440 sec. MET with possible Orbiter impact.</p>
STS-122-T-004	Foam Loss in LO2 Umbilical Cable Tray on ET-125/STS-122	<p>Post-launch camera and film review showed loss of foam at the LO2 Umbilical Cable Tray. Dimensions of the foam loss event are 9.0 in. long by 8.4 in. wide by 0.25 in. deep with a mass of 0.097 lb/ft³. This foam loss occurred at approximately 93 seconds MET and violates the NSTS 60559 requirement of 0.066 lb/ft³ ≤ 135 seconds MET. A post-flight corrective action was to evaluate an improvement of the LO₂ umbilical tray mold hold-down.</p>
STS-122-T-005	A Crack in the +Y Longeron Closeout was observed during the post-drain walk down following ET-125 Tanking Test on 12/18/07	<p>A crack, approximately 7in. in length, in the +Y Longeron Closeout (C/O) was observed during the post-drain walk down after the ET-125 tanking test on 12/18/2007. The crack was located in the fwd side of the C/O in between the ribs.</p>

APPENDIX B STS-122 IN-FLIGHT ANOMALIES

EXTERNAL TANK ANOMALIES

IFA Number	Title	Comments
STS-122-T-006	Crack at +Y Vertical Strut Fairing Closeout-to-LH2 Aft Dome Interface Noted on 12/18/2007 During Post-Tanking Inspection on ET-125	A crack at the +Y Vertical Strut (VS) fairing closeout-to-LH2 Aft Dome interface was noted on 12/18/2007 during the post-tanking inspection. The crack was measured at 6 in. long with a 1/32 inch offset.
STS-122-T-007	A Crack in the +Y SRB PAL Ramp was observed prior to the ET-125 Tanking Test on 12/18/2007.	A crack in the +Y SRB PAL Ramp was observed on 12/18/2007 prior to the ET-125 tanking test. The crack was observed following the 2nd tanking performed on 12/09/2007 and prior to the tanking test performed on 12/18/2007. The crack was detected on 12/17/2007 by personnel performing ET-125's J-Box Removal Trim Area layout from the Pad A RH SRB IEA platform. The crack was approximately 4 inches in length with little to no offset noted. Frost was observed on the +Z edge of the crack during tanking test (3rd tanking) and the frost increased to the entire length of the crack during the de-tanking.
STS-122-T-008	During the First Launch Attempt of ET-123 on December 6th, 2007, ECO's no. 3 and no. 4 Failed Wet	During the first Launch attempt of ET-125 on December 6th, 2007, Engine Cutoff's (ECO's) no.3 and no. 4 failed wet. During a second launch attempt on December 9th, 2007, ECO no. 3 failed wet. During a Tanking Test held December 18th, 2007, ECO no. 1 failed wet, and later in the Test, ECO no, 3 failed. Through TDR (Time Domain Reflectometry) troubleshooting performed during the Tanking Test, the failure of ECO no. 1 was tracked to the Feedthrough Connector assembly. For ET-125 and ET-126, the external sockets were soldered to the feedthrough pins to eliminate the known failure mode at the external Feedthrough Connector.

APPENDIX B
STS-122 IN-FLIGHT ANOMALIES

SPACE SHUTTLE MAIN ENGINE ANOMALIES

No IFA's have been identified for the SSME

APPENDIX B STS-122 IN-FLIGHT ANOMALIES

SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-122-I-001	Stinger tile observed falling after SSME startup	<p>During the STS-122 launch at -3.463 sec prior to liftoff, a tile located on the port OMS pod vernier access door carrier panel failed at the densification layer and separated from the Orbiter after Main Engine Ignition (MEI). The failed tile was a LI-900 9lb substrate tile, which was 1.19 in thick and installed on 0.090 Strain Isolator Pad (SIP). A review of flight history showed that tile was installed July 15, 1993, and had accumulated 16 flights prior to its failure. Post-flight inspection of the cavity and failure analysis of the tile remnants and the adjacent damaged tile identified no structural issues and revealed no foreign debris. Flight acoustics environments noted a SSME Ignition Over-Pressure (IOP) that was out-of-family from flight experience, but within design specification. During routine Orbiter processing and inspections prior to STS-122 roll out to the pad, no TPS conditions in this region were reported as anomalous.</p> <p>As a result, the TPS Problem Resolution Team (PRT) initiated stinger tile inspections prior to each every flight and elevated the priority for the attrition replacement of the 0.090 SIP /9 lb tile configurations.</p>
STS-122-I-002	Ku Band radiated in Hi power	<p>During the rendezvous checklist callout, the crew asked the ground to take control of the Ku-band antenna and switch to Low power mode via ground command. At that time, the Information and Communication Officer (INCO) took control of the Ku-band antenna control in the Communications mode via ground command, and the crew skipped the checklist action to take the Ku-band antenna output to Low power. After the manual stow procedure on FD 5, the crew resumed control of the Ku-band system and the system returned to the configuration on the hardware panel switches, causing the Ku-band antenna to radiate in the RADAR mode. INCO quickly asked that the crew take the Ku-band antenna output switch to Low to stop radiating in RADAR high-power mode and commanded the Traveling Wave Tube (TWT) to stop all Ku-band radiation. This sequence of events violated Flight Rule 1E-C11-2 and radiated the ISS S1 truss for three seconds at a power level causing no hardware damage. Analysis determined this occurrence was not an issue for the ISS.</p>

APPENDIX B STS-122 IN-FLIGHT ANOMALIES

SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-122-I-003	Unexpected Debris / Expected Debris Exceeding Mass Allowable Prior to Pad Clearance (Lift-off Debris)	<p>Risk Assessment indicated that given the proposed mitigations, observed debris poses no appreciable increase in risk. Debris release mitigated for identified potential sources of critical debris:</p> <ol style="list-style-type: none"> 1. Removed items, and 2. Added inspections of system level components. <p>On-going mitigations include FOD awareness, attrition-based removal of unistrut clamp hardware, routine inspections and monitoring for facility corrosion. Two updates to NSTS 60559 were recommended as part of this IIFA closure:</p> <ol style="list-style-type: none"> 1. Broken/degraded tie wrap and 2. Strain relief spring from vertical cable trays on side 3 of FSS. <p>A presentation was made to the Space Station Integration Control Board that provided the rationale for closure of STS-122-I-003.</p>
STS-122-I-004	LH ₂ acreage loss adjacent to Xt 1129 LO ₂ feedline base closeout	<p>During STS-122 ascent, a debris event was observed on the LH₂ tank acreage inboard of the LO₂ feedline bracket base closeout. The total mass of the liberated foam was 0.017 lbm from Xt 1135. The NSTS 60559 debris mass allowables for LH₂ tank acreage are 0.004 lbm before 135 sec MET, and 0.015 lbm at or after 135 sec MET. Although it is obvious from film review that the foam liberated in multiple small pieces, the loss will be assessed as a single release for a conservative estimate. The ET Post Flight Assessment Team (EPAT) identified the most probable cause of this debris event as cryopumping. (Ref: IFA STS-122-T-002)</p> <p>Post-flight, a Probabilistic Risk Assessment (PRA) was performed to assess LH₂ acreage losses inboard of the LO₂ Feedline PDL closeout for the cryopumping failure mode. The risk was 1/2,500 for Tile, and 1/10,000 for RCC, Special Tile, and Tile shear. This Integrated IFA was closed based on the accepted risk posture for LH₂ acreage TPS losses inboard of the LOX feedline brackets due to cryopumping.</p>

APPENDIX B STS-122 IN-FLIGHT ANOMALIES

SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-122-I-005	LH2 Acreage Loss At of +Y Bipod	<p>During STS-122 ascent, a foam-loss event was observed on the LH2 tank acreage below the +Y bipod fitting. This debris loss of 0.019 lbm occurred at 440 sec MET from Xt 1145. The NSTS 60559 debris mass allowables for LH2 tank acreage are 0.004 lbm before 135 sec MET, and 0.015 lbm at or after 135 sec MET. The ET Post Flight Assessment Team (EPAT) identified the most probable cause of this debris event as a combination of cryopumping and Differential Pressure (ΔP) loading due to induced damage during tank processing. A PDL repair was performed adjacent to this location, and may have also contributed to the divot by providing a leak path. A Probabilistic Risk Assessment (PRA) was performed to assess LH2 acreage losses from Xt 1130 to Xt 1200 for the cryogenic-pumping failure mode. The risk was 1/10,000 for Reinforced Carbon-Carbon (RCC), Tile, and Special Tile; 1/5,000 for Tile-shear. SE&I determined that the LH2 acreage TPS losses due to cryogenic-pumping were within the Space Shuttle Program (SSP) risk assessment.</p>
STS-122-I-006	Intertank to LH2 Flange Closeout Foam Loss	<p>The Umbilical Well camera showed the LH2 Intertank Flange foam losses observed at ET Separation at the -55 deg and 62 deg phi positions. The estimated masses of the two losses were 0.023 lbm for the -55 deg loss and 0.012 lbm for the 62 deg loss. The consequence of recurrence includes the worst-case. The LH2 Intertank (IT) Flange losses on STS-122 represent an increase in risk for this debris source. The damage reconstruction for the -55 deg phi loss (0.023 lbm) showed a risk of approximately 1/500 to Tile and approximately 1/180 to RCC at 85 sec. The damage reconstruction for the 62 deg phi loss (0.012 lbm) showed a peak risk of approximately 1/500 to Tile and no risk to RCC at the worst time of approximately 105 sec. The External Tank project concluded that the most likely failure mechanism for both the LH2 IT Flange losses was due to Cryogenic Ingestion. The Version 1.0 PRA Model was updated as follows:</p> <ol style="list-style-type: none"> 1. Refined Orbiter Tile Allowable Map (441 grids compared to 32 grids); 2. Updated threshold velocity model due to completed Small Foam on Tile Impact Testing; and 3. Computed the lift simultaneously with drag to capture some coupling, which is likely a small effect compared to the other two changes.

APPENDIX B STS-122 IN-FLIGHT ANOMALIES

SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-122-I-007	Two locations of Red Foreign Material Located on SRB	<p>During the SRB post-flight assessment, a piece of red vinyl tape was found on the Right-Hand (RH) forward skirt system tunnel cover below the feed-through cover. The material appeared to be less than 1 in². A second piece of red vinyl tape, which appears to be less than .0625 in², was found on the system tunnel closeout. Painting RT455 with Acrymax has been required since STS-114. In the process of closure of the Integrated IFA STS-121-I-014, workmanship problems were identified and addressed, regarding the painting of the red vinyl masking tape such that it cannot be detected for removal.</p> <p>A Technical Awareness Bulletin was issued and, as a result of this detailed painting instruction, red vinyl tape should be more easily recognized and removed following the painting process. The new mitigation strategy is to remove the red vinyl tape after the RT455 installation and prior to Acrymax paint application, thus eliminating the possibility of painting over this tape. With the implementation of this mitigation strategy, this debris source will maintain its unexpected debris classification.</p>
STS-122-I-008	Missing/Peeled SF-EPDM on RH Forward Segment Factory Joint	<p>During the Reusable Solid Rocket Motor (RSRM) Post Flight Assessment (PFA), a 3.24 in. by 2.14 in by 0.060 in. piece of Silica Filled Ethylene Propylene Diene Monomer (SF-EPDM) weather seal cap ply insulation was observed missing from the right hand (RH) forward segment factory joint (Xt station 691 Booster Coordinates) at approximately 195 deg circumferential location. Laboratory testing of the weather-seal butt-joints with cap ply poly film inclusions subjected to simulated ascent and entry heating profiles demonstrated that for the cap ply in the location specific to the STS-122/RSRM-99B loss, the thermal environment is not sufficient to cause blistering on ascent. Blistering was determined to be a necessary but not sufficient condition for cap ply SF-EPDM to be liberated. Therefore, the SF-EPDM weather seal material for STS-122/RSRM-99B could not have been liberated during ascent. Effective on RSRM-103/STS-125 and RSRM-104/STS-126, all cap plies on the aft dome in critical locations will be inspected by Infra-Red Thermography.</p>

APPENDIX B STS-122 IN-FLIGHT ANOMALIES

SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-122-I-009	LO2 umbilical cable tray foam loss (aft of Xt-2058)	<p>At 93 seconds MET, a 0.097 lbm piece of foam was observed to liberate from the LO₂ Umbilical Cable tray at Xt 2077. The foam appeared to liberate in one piece and exceeded the risk assessment mass of 0.066 lbm documented in NSTS 60559. This foam material is required for ice/frost prevention during prelaunch operations. The underlying ablator material is adequate to protect the structural temperature limits if the foam liberates during launch. Releases below the 0.066 lbm risk assessment mass are no threat to the vehicle as they are past the aft limit. Releases above this mass only pose a threat to the Tile Shear failure mode. The External Tank project concluded that the most probable cause is a combination of Void ΔP and Bond Adhesion failure stemming from mold movement during the closeout pour. Since the liberated mass was above the risk assessment mass, a conditional probability reconstruction was performed to ensure the "past the aft limit" was still applicable, which it was. The External Tank Project will reassess the mold closeout procedure for process improvement.</p>
STS-122-I-010	STS-122 LH2 ECO Failure	<p>During the STS-122 first launch attempt, the LH₂ Engine Cutoff (ECO) circuits 3 and 4 failed wet shortly after the initiation of fast fill. During the drain for the firsts launch attempt, LH₂ ECO circuit 1 also failed wet. A second launch attempt was made and LH₂ ECO circuit 3 again failed wet after the initiation of fast fill. Instrumentation installed during the STS-122 tanking test isolated the anomaly to the feed-through connector location on ET-125. The most probable failure mechanism was identified as an open-circuit condition caused by contamination and movement between the external plug sockets and the feed-through connector pins. The failure mechanism was eliminated by soldering the pin and socket connections between the external plug and the feed-through connector. The repair was implemented for the February 7, 2008, STS-122 launch and all four LH₂ ECO circuits performed nominally. The same design change was implemented for the next two External Tanks (ET-126 and ET-128). Additional design enhancements may be implemented on future ET's after the long-term team investigating the previous ECO anomalies completes its research and testing.</p>

APPENDIX B STS-122 IN-FLIGHT ANOMALIES

FLIGHT SOFTWARE ANOMALIES

IFA Number	Title	Comments
STS-122-S-01	Suspect PGSC 3Com Network Card	On FD11, Orbiter Communications Adapter (OCA) officer reported an intermittent problem with the KFX Payload General Support Computer (PGSC) dropping off the network. Problem persisted until the Ethernet PCMCIA (3Com) card was swapped and system rebooted. Operation restored after card replaced. Starting with STS-123, new wireless access points will replace 3Com network hardware
STS-122-S-02	Backup RPOP not receiving TCS Data during undock	During rendezvous and docking operations, the HHL was operational but its data was not downloaded to the Rendezvous Proximity Operators Program (RPOP) PGSC. Post-docking analysis of downlinked RPOP and Trajectory Control Sensor (TCS) data indicated that the backup RPOP/TCS laptop did not receive TCS data during rendezvous. The problem was reproduced during rendezvous tools checkout on FD11, and the RS-422 Quatech card was replaced to restore proper operation.
STS-122-S-03	RPOP not receiving HHL data during docking	During rendezvous and docking operations, the HHL was operational but its data was not downloaded to the Rendezvous Proximity Operators Program (RPOP) Payload General Support Computer (PGSC). During rendezvous tools checkout on FD11, the RS-232 HHL interface cable was replaced in the course of completing the checkout procedure and verifying proper operation

**APPENDIX B
STS-122 IN-FLIGHT ANOMALIES**

FLIGHT OPERATIONS AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-122-N-01	Suspect Launch to Activation (LTA) Cable Position	During EVA 1, the LTA cable was not secured as expected on the EVA Cable Stowage Hardware (ECSH). The crew secured the LTA cable per training and the pre-flight Crew Equipment Interface Test (CEIT) configuration, however, the cargo integration team had a different stowage configuration. An analysis of the “as stowed” configuration was performed and positive margins were demonstrated.

APPENDIX B STS-122 IN-FLIGHT ANOMALIES

MOD ANOMALIES

IFA Number	Title	Comments
STS-122-D-01	Ku Band Radar Radiated While Docked to ISS	During Ku band stow while docked on FD05 in prep for Columbus unberth and installation, the Ku band radar radiated, in violation of Flight Rule 1E_C11-2 – Radiation of ISS S1 Truss for ~ 3 seconds at > 4 watts. The preliminary corrective action was to add a note to crew procedures to verify that MCC has inhibited the TWT if docked; the long term plan was for the OFTP/GJOP to review Shuttle and Joint Shuttle-ISS Ku band system Flight Rules and ground and flight procedures
STS-122-D-02	High-speed Tracking Data Dropouts	There were 4 occurrences of high-speed tracking data dropouts, each ~ 4 sec. duration – 2 just prior to lift-off, 2 during ascent. The cause of the dropouts was attributed to data processing delays in the MCC Ground-to-Ground FEP due to inactive ATV data route in the active routing table. The preliminary corrective action was to scan for and remove inactive data routes from the GTG FEP active routing table before high speed tracking data phases.
STS-122-D-03	Trajectory Server GPS Time Misconfiguration	At the prelaunch initialization of Trajectory Server navigation ground filter processing (038/19:37:28 GMT), GPS-to-Orbiter state vector comparison data was missing from all displays. The cause was due to incorrect “GPS Offset Days” initialization parameter defined for a 2008 STS-122 launch. There was no impact to the launch countdown. Troubleshooting quickly identified the cause and a corrected parameter was loaded, resulting in correct processing and display of GPS Orbiter state vector data. The preliminary corrective action was to implement a pre-launch GPS vector validation activity for STS-123 and subs, and to review current procedures and training plans and revise as needed.

APPENDIX C

STS-122 DOCUMENT SOURCES

MER DAILY REPORTS

The following STS-122 MER Daily Reports by David S. Moyer, Lead MER Manager:

First Daily Report (Ascent Plus 2-Hour Report), dated February 7, 2008
Second Daily Report, dated February 8, 2008
Third Daily Report, dated February 9, 2008
Fourth Daily Report, dated February 10, 2008
Fifth Daily Report, dated February 11, 2008
Sixth Daily Report, dated February 12, 2008
Seventh Daily Report, dated February 13, 2008
Eighth Daily Report, dated February 14, 2008
Ninth Daily Report, dated February 15, 2008
Tenth Daily Report, dated February 16, 2008
Eleventh Daily Report, dated February 17, 2008
Twelfth Daily Report, dated February 18, 2008
Thirteenth Daily Report, dated February 19, 2008
Landing Plus 2 Hour Report, dated February 20, 2008
Landing Plus 2 Day Report, dated February 25, 2008

ET/SRB/RSRM/SSME REPORTS

STS-122 Preliminary Event Times, David W. Morr, MSFC-USA, dated February 7, 2008
STS-122 Console Flash Report Final, David W. Morr, MSFC-USA, dated February 7, 2008
STS-122 Final Event Times, Jeffrey A. Hixson MSFC-USA, February 15, 2008
STS-122 (360W099) RSRM Flash Report, Glen A. Ricks, NASA-MSFC, dated March 13, 2008
STS-122 MSFC Element IFA's, David W. Morr, MSFC-USA, April 9, 2008

ORBITER REPORTS

STS-122 Landing and Deceleration Summary Report, Chip C. Heinol, Boeing-Houston, March 7, 2008
STS-122 ADTA Report, Howard A. Damoff, Boeing-Kennedy Space Center, February 26, 2008
STS-122 Flight Control System, Donald E. Marquith, Boeing-Houston, February 26, 2008
STS-122 Communications and Tracking Report and NAVAIDS, Charles J. Stafford, Boeing-Houston, March 3, 2008
STS-122 Displays and Controls and Lighting Report, Q. P. Ngo, Boeing-Houston, March 6, 2008
STS-122 Shuttle Remote Manipulator System, Nik Doshewnek MDA-Houston, March 7, 2008
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APPENDIX D

ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/Abbreviation	Explanation
AA	Accelerometer Assembly
ABS	Ammonia Boiler System
AC	Alternating current
ACBM	Active Common Berthing System
ACTEX	Iodine Filter
ADTA	Air Data Transducer Assembly
AGT	Adaptive Guidance Throttling
AHMS	Advanced Health Monitoring System
A/L	Airlock
AMEC	Advanced Master Events Controller
APCU	Auxiliary Power Converter Unit
APU	Auxiliary Power Unit
ARIS	Active Rack Isolation System
ARS	Atmospheric Revitalization System
ARPCS	Atmospheric Revitalization Pressure Control System
ATCS	Active Thermal Control System
AVIU	Audio Visual Interface Unit
BBA	Baseplate Ballast Assembly
BFS	Backup Flight System
BLT	Boundary Layer Transition
BMRRM	Bearing Motor Roll Ring Module
CBM	Common Berthing System
CCS	Command and Control System (Columbus)
C&DH	Command and Data Handling
CDM	Carbon Dioxide Monitor
CBM	Centerline Berthing Camera System
CDR	Commander
CDT	Central Daylight Time
CEI	Contract End Item
CETA	Crew Equipment Transition Aid
CMG	Control Moment Gyroscope
C/O	Closeout
CO ₂	Carbon Dioxide
CPM	Cell Performance Monitor
CSLM-SPU	Coarsening in Solid Liquid Mixture Sample Processing Unit
CWC	Contingency Water Container
DAP	Digital Autopilot
DAT	Damage Assessment Team
D&C	Display and Control
DC	Digital Camera
DDU	Data Display Unit
DLA	Drive Lock Assembly
DMC	Data Management Computer

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ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/Abbreviation	Explanation
DMHS	Dome Mounted Heat Shield
DPS	Data Processing System
DTO	Development Test Objective
ΔP	Differential Pressure
ΔV	Differential Velocity
ECLSS	Environmental Control and Life Support System
ECO	Engine Cutoff
EDR	European Drawer Rack
EDT	Eastern Daylight Time
EI	Entry Interface
EMCS	European Modular Cultivation System
EMEC	Enhanced Master Events Controller
EMU	Extravehicular Mobility Unit
E/O	External Tank/Orbiter
EOM	End of Mission
EPDC	Electrical Power Distribution and Control
EPF	External Payload Facility
EPM	European Physiology Module
ESA	European Space Agency
ESCH	EVA Cable Stowage Device
ESP	External Stowage Platform
ET	External Tank
ETCS	External Thermal Control System
EuTEF	European Technology Exposure Facility
EV	Extravehicular (Crewmember)
EVA	Extravehicular Activity
FBMBT	Flexible Bearing Mean Bulk Temperature
FCE	Flight Crew Equipment
FCMS	Fuel Cell Monitoring System
FCS	Flight Control System
FCV	Flow Control Valve
FD	Flight Day
FDA	Fault Detection and Annunciation
FE	Flight Engineer
FES	Flash Evaporation System
FID	Failure Identifier
FN	Flight Night
FRCS	Forward Reaction Control System
FSL	Fluid Science Laboratory
FSS	Service Structure
G	Gravity
GCA	Ground Carrier Assembly
GEI	Ground Environmental Instrumentation

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ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/Abbreviation	Explanation
GFE	Government Furnished Equipment
GG	Gas Generator
GGVM	Gas Generator Valve Module
GH ₂	Gaseous Hydrogen
GLA	General Luminaire Assembly
GMT	Greenwich Mean Time
GN&C	Guidance, Navigation and Control
GN ₂	Gaseous Nitrogen
GO ₂	Gaseous Oxygen
GPC	General Purpose Computer
GPS	Global Positioning System
Grms	Gravity root mean square
GUCP	Ground Umbilical Carrier Plate
HDP	Holddown Post
He	Helium
HPFTP	High Pressure Fuel Turbopump
HPGT	High Pressure Gas Tank
HPOTP	High Pressure Oxidizer Turbopump
Hyd/HYD	Hydraulic
IBA	Inspection Boom Assembly
ICC-L	Integrated Cargo Carrier-Light
IDCS	ISIS Digital Camera
IELK	Individual Equipment Liner Kit
IFA	In-flight Anomaly
IFHX	Interface Heat Exchanger
IMU	Inertial Measurement Unit
IMV	Inter-Module Ventilation
ISIS	Integrated Sensor Inspection System
ISPR	International Payload Rack
ISS	International Space Station
ITVC	Intensified Television Camera
IWIS	ISS Wireless Instrumentation System
JIN	JSC Internet Network
JSC	Johnson Space Center
KBAR	Knee Brace Assembly Replacement
KFX	K-Band file transfer
KSC	Kennedy Space Center
LCA	Load Control Assembly
LCC	Launch Commit Criteria
LCS	Laser Camera System
LDRI	Laser Dynamic Range Imager
LESS	Leading Edge Structure System
LH	Left Hand

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ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/Abbreviation	Explanation
LHA	Lamp[Housing Assembly
LH ₂	Liquid Hydrogen
LHS	Left Hand Side
LiOH	Lithium Hydroxide
LLTD	Launch and Landing Tracking Data
LO ₂	Liquid Oxygen
LPOTP	Low Pressure Oxidizer Turbopump
LTA	Launch to Activation
MADS	Modular Auxiliary Data System
MAUI	Maui Analysis of Upper atmosphere Injections
MC	Midcourse Correction
MCC	Mission Control Center
MDM	Multiplexer/Demultiplexer
MDCA	Main Distribution Control Assembly
MDPS	Meteor and Debris Panel Shield
MDU	Multifunction Display Unit
MEC	Main Engine Controller
MECO	Main Engine Cutoff
MEDS	Multifunction Electronic Display System
MELFI	Minus Eighty Laboratory Freezer
MET	Mission Elapsed Time
MIS	Medical Information System
MISSE	Materials International Space Station Experiment
MLI	Multi-Layer Insulation
MLP	Mobile Launch Platform
MLS	Microwave Landing System
MM	Momentum Manager
MMC	Mission Management Computer (Columbus)
MMOD	Micro Meteoroid Orbital Debris
MMT	Mission Management Team
MMU	Master Measurement Unit
MN	Main Bus
MOD	Mission Operations Directorate
MPC	Multi-Protocol Converter/Mid Power Controller
MPM	Manipulator Positioning Mechanism
MPS	Main Propulsion System
MRL	Manipulator Retention Latch
MSFC	Marshal Space Flight Center
MSBLS	Microwave Scanning Beam Landing System
MTL	Moderate Temperature Loop
N ₂	Nitrogen
NASA	National Aeronautics and Space Administration
NAVAIDS	Navigation Aids

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ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/Abbreviation	Explanation
NC	Nominal Correction (Maneuver)
NCC	Nominal Corrective Combination (Maneuver)
NH	Nominal Height (Maneuver)
NIRD	NASA Imagery Reporting Database
NPC	Nominal Phase Correction (Maneuver)
NTA	Nitrogen Tank Assembly
NPRV	Negative Pressure Relief Valve
O ₂	Oxygen
O ₂ /H ₂	Oxygen/Hydrogen
OAA	Orbiter Access Arm
OBSS	Orbiter Boom Sensor System
OCA	Orbiter Communications Adapter
ODS	Orbiter Docking System
OFI	Operational Flight Instrumentation
OI	Operational Instrumentation
OIU	Orbiter Interface Unit
OME	Orbital Maneuvering Engine
OMRS	Operational Maintenance and Requirements Specification
OMRSD	Operational Maintenance and Requirements Specification Document
OMS	Orbital Maneuvering System
OPCU	Orbiter Power Converter Unit
OPF	Orbiter Processing Facility
OPO	Orbiter Project Office
ORCA	Oxygen Recharge Compressor Assembly
ORGA	Orbiter Rate Gyro Assembly
ORU	Orbital Replacement Unit
ORZS	Optimization of Root Zone Substrates
OTSD	ORU Temporary Stowage Device
OV	Orbiter Vehicle
P	Port
PAL	Protuberance Airload
PAO	Public Affairs Office
PASS	Primary Avionics Software System
PCBM	Passive Common Berthing System
PCM	Pulse Code Modulation
PCVP	Pump and Control Valve Package
PDGF	Power and Data Grapple Fixture
PDI	Payload Data Interleaver
PDU	Power Distribution Unit
PGME	Propylene Glycol Monomethyl Ether
PGSC	Payload and General Support Computer

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ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/Abbreviation	Explanation
PLB	Payload Bay
PLBD	Payload Bay Door
PMA	Pressurized Mating Adapter
PMBT	Propellant Mean Bulk Temperature
PMZ	Promethazine
PPCO ₂	Partial Pressure Carbon Dioxide
PRSD	Power Reactant Storage and Distribution System
PRT	Problem Resolution Team
PV&D	Purge, Vent and Drain
PWR	Payload Water Reservoir
QD	Quick Disconnect
RCC	Reinforced Carbon-Carbon
RCS	Reaction Control System
RH	Right Hand
RHC	Rotational Hand Controller
RHS	Rehydration Station
RJD	Reaction Jet Driver
RM	Redundancy Management
ROB	Right Outboard
ROI	Region of Interest
RPC	Remote Power Controller
RPM	R-Bar Pitch Maneuver
RPOP	Rendezvous Proximity Operations Program
RSB	Rudder Speed Brake
RSRM	Reusable Solid Rocket Motor
RSS	Range Safety System
RTV	Room Temperature Vulcanizing (material)
S&A	Safe and Arm
SARJ	Solar Alpha Rotary Joint
SDBI	Short Duration Bioastronautics Investigation
SDFS	Smoke Detection and Fire Suppression
SIMO	Simultaneous
SIP	Strain Isolation Pad
SLWT	Super Lightweight Tank
SM	System Management
SMIA	Station Multiplex Interface Adapter
SMRD	Spin Motor Rotation Detector
S/N	Serial Number
SODB	Shuttle Operational Data Book
SOLAR	External Payload Facility of Columbus
SRB	Solid Rocket Booster
SRGA	Station Rate Gyro Assembly
SRMS	Shuttle Remote Manipulator System

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ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/Abbreviation	Explanation
SRSS	Shuttle Range Safety System
SSME	Space Shuttle Main Engine
SSOR	Space-to-Space Orbiter Radio
SSP	Space Shuttle Program
SSRMS	Space Station Remote Manipulator System
SSSR	Space-to-Space Station Radio
ST	Star Tracker
Stability	Stability of Pharmacotherapeutic and Nutritional Compounds
	Starboard
Stbd/STBD	Space Transportation System
STS	Supply and Waste Water Management System
SWWMS	Thermal Control System/Trajectory Control Sensor
TCS	Time Domain Reflectometry
TDR	Translational Hand Controller
THC	Torque Equilibrium Attitude
TEA	Terminal Phase Initiation/Transfer Initiation
TI	Time of Ignition
TIG	TPS Imagery Inspections Management System
TIMMS	Table Maintenance Block Update
TMBU	Transfer Priority List
TPL	Thermal Protection System
TPS	Thermal Radiator Rotary Joint
TRRJ	Tail Service Mast
TSM	Thrust Vector Controller
TVC	Travelling Wave Tube
TWT	Ultrahigh Frequency
UHF	United States Air Force
USAF	
VDT	Vehicle Data Table
VS	Vertical Strut
WAICO	Waiving and Coiling response of Arabidopsis Roots
WCS	Waste Collection System
WIF	Worksite Interface Fixtures
WLEIDS	Wing Leading Edge Impact Detection System
WLE	Wing Leading Edge
WSB	Water Spray Boiler
YETI	Y-Code Erroroneous Tracking Incident

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ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Unit of Measure	Explanation
A	Ampere
a.m.	Morning hours
°C	Degree Centigrade
°F	Degrees Fahrenheit
deg	degree
deg/sec	degree per second
ft	feet
ft/sec	feet per second
g/G	Gravity
Grms	Gravity root mean square
hr	hour
in	inch
keas	knots estimated air speed
kW	Kilowatt
kWh	Kilowatt hour
lb	pound
lb/hr	Pound per hour
lbm/lb _m	Pound Mass
lb/min	Pounds Per Minute
Mach	Speed of Sound
Max Q	Maximum Dynamic Pressure
min	minute
Mlbf	Million pound force
mmHg	Millimeters Mercury
mph	miles per hour
Msec	Millisecond
mv	millivolt
nmi	nautical mile
%	percent
ppCO ₂	partial pressure Carbon Dioxide
psi	pounds per square inch
psia	pounds per square inch absolute
psid	pounds per square inch differential
scim	standard cubic inches per minute
sec	second
σ	Sigma
V	Volt