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# **STS-115 SPACE SHUTTLE MISSION REPORT**

May 2007



**National Aeronautics and  
Space Administration**

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

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# **STS-115**

## **SPACE SHUTTLE MISSION REPORT**

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# STS-115 SPACE SHUTTLE MISSION REPORT

## INTRODUCTION

The Space Transportation System (STS) -115 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 this 116<sup>th</sup> mission of the Space Shuttle Program. STS-115 delivered and integrated the P3/P4 Truss Segment as well as delivered supplies to the International Space Station (ISS)

STS-115 was 19<sup>th</sup> mission to the ISS, and the third mission following the loss of the STS-107 Orbiter and crew. STS-115 was also the 27<sup>th</sup> flight of the OV-104 *Atlantis* vehicle.

The flight vehicle consisted of the OV-104 Orbiter; the External Tank (ET), which was a super lightweight tank (SLWT) designated ET-118; three Block II SSMEs that were designated as serial numbers (S/Ns) 2044, 2048, and 2047 in positions 1, 2, and 3, respectively; and two SRBs that were designated B1-127. The two RSRMs were designated flight set RSRM-94. The individual RSRMs were S/N 360W094A and S/N360W094B. Launch pad 39B and Mobile Launch Platform (MLP) -2 were used as the platform for launch of the STS-115 mission.

The primary objectives of the STS-115 mission were to

1. Perform inspections of the Orbiter Reinforced Carbon Carbon (RCC) panels and Thermal Protection System (TPS) tiles.
2. Deliver and install Integrated Truss Segment (ITS) P3/P4 to ITS P1.
3. Activate ITS P3/P4 systems to receive internal power.
4. Transfer water from the Shuttle to the ISS.
5. Transfer logistical assets and supplies to the ISS.
6. Configure P4 for power generation and deploy solar arrays
7. Deploy the Solar Alpha Rotary Joint (SARJ) Drive Lock Assemblies (DLA)
8. Deploy the P4 Photovoltaic Radiator (PVR)
9. Complete planned tasks and get-ahead tasks during three successful Extravehicular Activities (EVAs), including those tasks necessary to enable Mobile Transporter (MT) translation and relocation.

The P4 Photovoltaic (PV) Module (PVM) contained two beta gimbal /PV array assemblies, two Beta Gimbal Transition Structures (BGTS's), one Integrated Equipment Assembly (IEA)I, and associated cabling. The cargo element also included 6 battery sets, PV radiator, 2



Unpressurized Cargo Carrier Attach Systems (UCCAS), SARJ and pre-integrated Space Vision System (SVS) targets.

The Ram Burn Observation (RAMBO) payload was flown as a secondary payload. The RAMBO payload did not require any dedicated Orbital Maneuvering System (OMS) firing, but did require state vectors. Also, the Maui Analysis of Upper-Atmospheric Injections (MAUI) payload was flown as a payload of opportunity and did not require any dedicated OMS firings.

The STS-115 vehicle included capabilities to monitor for released debris during ascent and any subsequent impacts to the Orbiter TPS. The monitoring capabilities included ground-based cameras, ET-based cameras, radar, and wing leading edge (WLE) impact detection instrumentation. This was the third flight of the Orbiter Boom Sensor System (OBSS), which enabled robotic on-orbit inspections of all areas of the Orbiter TPS. In addition, an R-bar pitch maneuver (RPM) was performed during the rendezvous with the ISS so that the ISS crew could photograph the Orbiter.

The STS-115 mission was planned to be an 11-day plus 1 day plus 2-contingency-day flight with 7 docked days. The plus 1 day was used after undocking to evaluate the debris that was noted by the crew and this is discussed later in the report. Two contingency days were available for landing weather avoidance or other Orbiter contingencies. None of the contingency days were used because landing occurred on the first day landing attempt at Kennedy Space Center (KSC).

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, RSRM, ET, SSME, System Engineering and Integration, and Flight Operations and Integration (Payload) in-flight anomalies (IFA's) 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 and abbreviations and definition as used throughout this report.

The six crewmembers that were on the STS-115 flight were Brent W. Jett, Captain, U. S. Navy, Commander; Christopher J. Ferguson, Captain, U. S. Navy, Pilot; Joseph R. Tanner, Civilian, Mission Specialist 1; Daniel C. Burbank, Captain, U. S. Coast Guard, Mission Specialist 2; Heidimarie M. Stefanyshyn-Piper, Commander, U. S. Navy, Mission Specialist 3; and Steven Glenwood MacLean, PhD, Civilian, Canadian Space Agency, Mission Specialist 4.

STS-115 was the fourth flight for the Commander and Mission Specialist 1, the second space flight for Mission Specialist 2 and Mission Specialist 4, and the first space flight for the Pilot, and Mission Specialist 3.

## **MISSION SUMMARY**

### **Pre-Launch**

The launch of STS-115 was delayed four times. The first launch was scheduled for August 27, 2006. During pad operations while preparing the vehicle for launch, a lightning bolt struck the pad and a small power transient was observed on the Orbiter instrumentation. As a result, the countdown was stopped so that each of the elements could verify that the vehicle systems were not damaged as a result of the lightning. To allow all elements time to clear their vehicles, the launch date was delayed two days to August 29, 2006.

Hurricane Ernesto then threatened the East coast of Florida and a decision was made to roll the vehicle stack back to the Vehicle Assembly Building (VAB). While rolling the stack back, weather forecasts indicated that the Hurricane would be downgraded to a Tropical Storm. Consequently, the decision was made to stop the roll-back and return the stack to the launch pad. The countdown for the launch was begun again on September 3, 2006, for a planned launch of September 6, 2006.

During the countdown, power to the Fuel Cell 1 Coolant Pump alternating current (AC) 1 phase A was lost (STS-115-V-02). The remaining two AC phases on the pump motor were determined to be acceptable for flight, and the circuit breaker for that bus was pulled to isolate the failure from the vehicle. In addition, the Forward Reaction Control System (FRCS) thruster F3L Tyvek cover detached during a rain storm. After determining that the loss of the Tyvek cover posed no threat of water within the Reaction Control System (RCS) cavity becoming an ice debris source, the launch date was changed to September 8, 2006.

While filling the External Tank (ET) during the morning of September 8, 2006, Liquid Hydrogen (LH<sub>2</sub>) Engine Cutoff (ECO) sensor no. 3 indicated dry when it should have been wet (STS-115-I-004). A decision was made to scrub the launch for 24 hr to September 9, 2006. Also, during prelaunch operations, the Headset Interface Unit (HIU) for the MS4 crewmember was not operating properly (STS-115-V-06). The power on the HIU was cycled, but the problem was still present. The HIU from the Astronaut Support Person (ASP) was substituted and it worked properly throughout the mission.

### **Ascent and Flight Day 1**

During the subsequent ET tanking, the ECO sensor worked properly and the countdown to launch was satisfactorily completed on September 9, 2006.

At 4 min 38 sec prior to liftoff, hydraulic system 3 Thrust Vector Controller (TVC) pitch actuator switching valve measurement did not indicate proper switching position (STS-115-V-12). The switching valve indication remained in the primary position when the standby hydraulic system 2 was pressurized for prelaunch circulation pump and main

pump activation. The prelaunch slew-test performance was nominal. All indications were that the switching valve was operating properly and the most likely cause of the anomaly was the indication-sensor circuitry. This anomaly did not impact the mission.

The STS-115 mission was launched at 252/15:14:55.008 GMT on a 51.6-degree launch azimuth. An Orbital Maneuvering System (OMS) assist maneuver was performed following separation of the SRB's. Ignition for the Assist maneuver occurred at 252/15:17:07.833 GMT [00/00:02:12.825 (Mission Elapsed Time (MET)], and the maneuver was 172.4 sec in duration. Main Engine Cutoff (MECO) occurred at 252:15:23:21 GMT (00:00:08:26 MET). The Orbiter separated from the ET at 252/15:23:40 GMT (00/00:08:45 MET). ET separation was clearly visible from the ET-mounted camera.

Some debris liberation events were noted during ascent. These were subsequently evaluated by the Damage Assessment Team and no issues were identified.

All Orbiter subsystems performed nominally during ascent and post-insertion with the following problems noted.

Brief periods of intermittent dropouts of the Auxiliary Power Unit (APU) 2 X-axis accelerometer to zero g peak-to-peak were seen from liftoff + 4 sec to liftoff + 46 sec, after which it returned to nominal performance for the remainder of the ascent (STS-115-V-15). During entry, the accelerometer again had brief periods of intermittent operation that was consistent with ascent operation. This condition did not affect APU operation during the mission.

At 14 sec after liftoff, speed-brake driver current in Flight Control System (FCS) Aerosurface Actuator (ASA) channel 3 became erratic but was no impact to the flight (STS-115-V-02).

Ground imagery indicated that the Tyvek rain cover on FRCS thruster F4D released 16.4 sec after liftoff at an approximate velocity of 354 ft/sec or 240 mph, which was 70 mph above the release certification requirements (STS-115-V-05). No recontact with the Orbiter was observed and this condition did not impact the mission.

Starting approximately 1 min 32 sec after liftoff, the Flash Evaporator System (FES) experienced significant pre-evaporative cooling that resulted in a FES shutdown (STS-115-V-10) during ascent. The FES was restarted by the crew and subsequently performed satisfactorily throughout ascent and the remainder of the mission. The cause of the shutdown was the significant amount of pre-evaporative cooling resulting from a large amount of condensate in the FES high-load core that accumulated during prelaunch. Condensate formation was expected to be high because the weather condition in the days prior to launch were ideal for forming high moisture conditions inside the FES cores.

At 7 min 52 sec into ascent, Water Spray Boiler (WSB) -3 Gaseous Nitrogen (GN<sub>2</sub>) pressure regulator/relief valve slightly violated the 28.0 psig reseal pressure when it closed at 27.93 psig (STS-115-V-07). This condition did not impact the mission.

In conjunction with MECO, the Backup Flight System (BFS) Cabin Differential Pressure/Differential Temperature ( $\Delta p/\Delta t$ ) 0.12-psi/min alarm limit was exceeded due to cabin pressure toggling between 14.73 and 14.81 psia. This is a known condition.

It was noted while dumping the Modular Auxiliary Data System (MADS) Pulse Code Modulation (PCM) ascent data that the data were good up to liftoff. At liftoff, the recorded data began experiencing data dropouts (STS-115-V-04). The data dropouts did not clear until after MECO.

Also noted in the MADS data, just prior to launch, at T-4 seconds, the Left OMS Low-Temperature Reusable Insulation (LRSI) measurement started ramping up from a near nominal ambient temperature of 87.8 °F to an Off-Scale High (OSH) value during ascent (STS-115-V-32). The measurement, which is used for thermal trend analysis, remained OSH post-flight.

After the starboard Payload Bay Door (PLBD) was opened in a nominal manner, the aft close indication remained on and should have been off (IFA STS-115-V-03). Also, during port PLBD bulkhead latch opening, a premature loss of the forward closed indication caused an out-of configuration software condition which stopped the door opening sequence (STS-115-V-09). The door was opened manually by the crew with no problem.

The OMS-2 maneuver was performed at 252/15:52:15.833 GMT (00/00:37:10.825 MET) and was 144.2 sec in duration. The Differential Velocity ( $\Delta V$ ) was 144.27 ft/sec, and the orbit achieved was 123.7 by 154.1 nmi.

The Remote Manipulator System (RMS) was powered on and the RMS was checked out and placed in the pre-cradle position near the close of Flight Day (FD) 1.

The OMS-3 (NC-1) maneuver was performed nominally at 252/18:11:30.033 GMT (00/:56:45.025 MET), and the maneuver was 52 sec in duration. The  $\Delta V$  was 90.6 ft/sec and the resulting orbit was 152.5 by 171.1 nmi.

A fuel cell purge was performed beginning at 252/19:59:21 GMT (00/04:49:26 MET), and resulted in an H<sub>2</sub> manifold pressure spike which may have caused the manifold relief valve to open. The pressure spike occurred because a single H<sub>2</sub> tank was feeding all 3 fuel cells along with the purge flow, which results in extremely cold cryogenic H<sub>2</sub> entering the manifold and rapidly expanding.

## Flight Day 2

The OMS-4 (NC-2) circularization maneuver was performed nominally at 253/07:07:39.633 GMT (00/15:52:45.625 MET), and the maneuver was 33 sec in duration. The  $\Delta V$  was 51.5 ft/sec and the resulting orbit was 171.3 by 181.2 nmi.

The Orbiter Boom Sensor System (OBSS) was unberthed at 253/07:30 GMT (00/16:15 MET) and the Thermal Protection System (TPS) Reinforced Carbon Carbon (RCC) survey began at 253/09:01 GMT (00/17:46 MET). A new OBSS flat-field procedure was up-linked to the crew, which not only saved about 15 min of on-orbit crew time, but also resulted in better data than were available on previous flights.

The Laser Dynamic Range Imager (LDRI) scanning proceeded nominally. The Laser Camera System (LCS) and Integrated Sensor Inspection System (ISIS) Digital Camera (IDC) both operated satisfactorily. The IDC data were collected along one pass of the starboard wing while the LDRI collected primary data. The IDC data were down-linked and were of excellent quality. All LDRI data were down-linked.

The OBSS inspection surveys of the starboard wing, nose cap and port wing RCC were completed and the OBSS was berthed at 253/14:45 GMT (00/23:30 MET). During latching of the OBSS into the Manipulator Positioning Mechanism (MPM), the aft pedestal Manipulator Retention Latch (MRL) System 2 latch indication did not come 'ON' (MER-14). The System 1 latch time was nominal. This condition repeated during the subsequent latching of the OBSS, and was of no impact to the mission.

The left OMS fuel propellant tank temperature sensor was indicating a peak temperature of 92 °F with the B heaters controlling (MER-19). Also the Differential Temperature ( $\Delta T$ ) between the minimum and maximum was approximately 12 °F for both heater strings. Historically, the  $\Delta T$  is 6 to 8 °F. There was no mission impact from this condition.

The Orbiter Docking System (ODS) was activated at 253/16:58:47 GMT (01/01:43:52 MET) and was deactivated after the avionics had operated for 6 min, 43 sec. Ring extension to the initial position was nominal, operating for a total time of 3 min, 25 sec (dual motor time).

The NC-3 rendezvous maneuver was a +X RCS firing with an ignition time of 253/18:29:25 GMT (01/03:14:30 MET) and the maneuver ended at 253/18:29:53 GMT (01/03:14:40 MET). The firing time was 27.2 sec with a  $\Delta V$  of 6.5 ft/sec. The resulting orbit was 175.1 by 181.1 nmi. RCS performance was nominal.

## Flight Day 3

Following the completion of the simultaneous water dump at 254/05:46 GMT (01/14:31 MET), the supply water dump line A heater began cycling at the over-temperature range (IFA STS-115-V-11). At heater activation, the first complete heater

cycle was similar to the last flight of this vehicle (STS-112), except that the peak was 11 °F higher, which exceeded the nominal upper limit. The heater dithered until the simultaneous water dump was complete. Following the dump, the heater stopped dithering and began to cycle between the lower limit and the over-temperature limit. The crew was requested to switch to the B heater, which controlled satisfactorily. This condition did not impact the mission.

The OMS-5 (NC-4) maneuver was a right-engine OMS firing with an ignition time of 254/06:36:29 GMT and cutoff time of 254/06:36:44 GMT. The firing time was 15.0 sec with a  $\Delta V$  of 11.4 ft/sec. The resulting orbit was 180.5 by 182.8 nmi. Engine performance was nominal.

The left-engine OMS-6 Target Intercept (TI) rendezvous maneuver had an ignition time of 254/08:08:08.233 GMT (01/16:53:13.225 MET). The firing time was 11.02 sec with a  $\Delta V$  of 8.1 ft/sec. The resulting orbit was 181.1 by 187.5 nmi. The OMS performance was nominal.

The Ku-Band pre-rendezvous radar self-test was performed and the system was placed in the radar mode. The system immediately acquired and locked on to the ISS at a range of 139,313 ft (approximately 23.0 nmi). As expected, the Ku-Band radar lost lock during the R-Bar Pitch Maneuver (RPM) at 254/09:42 GMT (01/18:27 MET) and the crew reconfigured the system to communication mode 7 min later. The Ku-Band radar performance was nominal.

The RPM maneuver started at 254/09:38:00 GMT (01/18:13:05 MET) and ended 9 min later. The peak pitch rate during the maneuver was approximately 0.70 deg/sec and the maximum roll error reached approximately 0.5 deg. During the RPM maneuver, the ISS crew members took digital photographs of the Orbiter throughout its rotation, and downlinked these photos for ground analysis.

The ODS was powered and was active for a total time of 57 min 35 sec during the docking operations. The ISS was captured at 254/10:48:28 GMT (01/19:33:33 MET). The ring drive-in operation ran for approximately 5 sec when it was stopped in accordance with the disable-and-release-dampers procedure. The system was allowed to dampen out, and regained alignment after approximately 45 sec. The stuck dampers are an explained condition and were subsequently cleared. The final ring-drive-in command was issued and ring retraction proceeded nominally with good ring alignment for approximately 3 min 23 sec using dual motors. The hooks were driven closed nominally and final ring extension was performed, releasing the capture latches. The ODS was powered off at 254/11:05:53 GMT (01/19:49:58 MET).

After commanding the Ku-Band antenna to "on" at 254/13:38:00 GMT (01/22:24:05 MET), the antenna failed to slew as expected (continued to point at the previously designated angles) (MER-18). Subsequent commands did not correct the problem. The Ku-Band antenna power was cycled, and the system began operating

properly. The failure to slew was later determined to be an explainable procedural condition due to the logic-power switch configuration.

The Shuttle RMS successfully unberthed the P3/P4 Truss and maneuvered it to the handoff position at 254/14:32 GMT (01/19:17 MET). The P3/P4 Truss was handed off to the Space Station Remote Manipulator System (SSRMS) and ungrappling of the truss was completed at 254/15:02 GMT (01/23:47 MET). The RMS was maneuvered to the Space Vision System/RMS Sideview Camera (SVS/RSC) viewing position in preparation for providing photography for ground assessment of SVS targets.

The downlinked photos from the RPM maneuver identified isolated cases of tile damage and blanket damage (IFA STS-115-V-08). Analysis of a protrusion of approximately 1.7 in on the port External Tank Door (ETD) indicated that it was shim stock. A small gap filler protrusion was also identified on the starboard ETD.

#### **Flight Day 4**

The P3/P4 truss was successfully berthed to the ISS by the SSRMS and latched.

The first Extravehicular Activity (EVA) was performed satisfactorily with all mechanical and electrical hardware connections completed. During the first EVA, a Solar-Array Rotary-Joint Cover-21 inboard bolt and washer were lost overboard. The bolt and washer left the area in the zenith and V-bar directions, respectively. The preliminary analysis predicted a slow opening rate to approximately 10 miles by FD 6.

The RMS Sideview Camera provided photographic coverage of the EVA operations from the planned viewing position.

The second on-orbit fuel cell purge was performed at 255/04:50 GMT (02/13:43 MET). During the 57-hour purge interval, the approximate voltage decay was 0.13 Vdc in fuel cell 1, 0.14 Vdc in fuel cell 2, and 0.14 Vdc in fuel cell 3.

The Damage Assessment Team completed evaluation of the ascent debris imagery, the FD 2 OBSS inspection imagery, and the FD 3 RPM maneuver imagery. Their analysis concluded that no focused inspections were required, and they recommended that the Orbiter be cleared for entry with no significant ascent TPS damage. A planned Micro Meteoroid Orbital Debris (MMOD) survey remained to be completed on FD 10.

#### **Flight Day 5**

The second EVA was performed satisfactorily with all remaining P3/P4 Solar Alpha Rotary Joint pre-rotation preparation activities successfully accomplished. The Solar Alpha Rotary Joint (SARJ) was successfully commanded to rotate 180 degrees. Troubleshooting of the failure of Drive Lock Assembly 2 to engage was successfully completed.

Also during the second EVA, the Extravehicular Mobility Unit (EMU) Radio Frequency (RF) Camera Assembly (ERCA) video and telemetry were not transmitting from the EV2 EMU (MER-20). EV2 was informed that the ERCA 18 video was lost and to cycle power on the ERCA. When the system was power cycled, the green Light Emitting Diode (LED) was off, indicating that the ERCA was not getting power. As a result, no video was available from EV2 for the remainder of the EVA.

An intermittent data dropout when transmitting on the lower right S-Band antenna was evaluated (STS-115-V-18). The on-board instrumentation indicated nominal performance of the S-band system. Subsequent evaluation after undocking confirmed a problem with the lower right antenna.

The simultaneous water dump 2 and condensate CWC dump 1 were successfully completed. A total of 45 lb of waste water and 102 lb of supply water were dumped during the 45-minute dump operation.

Hydraulic circulation pump runs on systems 1 and 3 were activated via ground command due to the circulation pump body temperatures approaching the start-up low limit of 20 °F. The circulation pump 1 and 3 runs were performed at 256/19:42:15 and 256/19:48:51 GMT (04/04:27:10 and 04/04:33:56 MET), respectively. Each circulation pump run was approximately 5 min in length.

A cold Orbiter port-side thermal attitude was initiated at approximately 256/20:00 GMT (04/04:45 MET), resulting in increased APU 1 and 2 fuel-system heater duty cycles and higher fuel supply and drain system temperatures. To eliminate a nuisance alarm, the upper Fault Detection and Annunciation (FDA) limit for the APU 2 fuel service line temperature was raised from 150 °F to 155 °F.

The ISS P3/P4 Solar Arrays 4A and 2A were fully deployed after recovering from a Drive Lock Assembly 2 failure. Attitude control was handed over to the Orbiter during the final portion of Solar Array 2A deployment operations.

## **Flight Day 6**

Onboard troubleshooting for the EV 2 crewmember's Wireless Video System ERCA anomaly was completed and determined that the power connector was not connected. Troubleshooting confirmed nominal power to the system, and the ERCA was used for the third EVA and operated satisfactorily.

The third on-orbit fuel-cell purge was performed at 257/09:32 GMT (04/18:17 MET). During the 53-hour purge interval, the nominal voltage decay was 0.11 Vdc in fuel cell 1, 0.11 Vdc in fuel cell 2, and 0.10 Vdc in fuel cell 3. The fuel cell 1 hydrogen (H<sub>2</sub>) pump-motor status sensor output voltage gradually increased from 3.26 to 3.40 V over the 53-hour period. The fuel cell 2 H<sub>2</sub> pump motor status signature closely followed the previous period between fuel cell purges 1 and 2.



## **Flight Day 7**

The start of the third EVA was delayed due to an open in the Remote Power Controller (RPC) powering the airlock repressurization pump, which caused a problem in depressurizing the ISS airlock. No electrical short was observed, and the RPC was successfully reset, and the pump recovered. The EVA began 1.5 hr later than planned. The third EVA was completed with all activities accomplished.

The APU 1 Gas Generator (GG) bed-heater lower-cycle set point shifted approximately 15 °F higher, but the temperatures remain within the operating specification (MER-25). This condition did not impact the mission.

A request was submitted to Flight Control to troubleshoot the International Space Station (ISS)/Orbiter docked Air-to-Ground (A/G) 1 interfaces which failed a day after docking (STS-115-V-17). Power cycling attempts were not successful in regaining the communications capability.

## **Flight Day 8**

Flight Day 8 was an off-duty day for the crew.

The fourth on-orbit fuel cell purge was performed at 259/05:40 GMT (06/14:25 MET). During the 44-hour purge interval, the approximate voltage decay was 0.12 Vdc in fuel cell 1, 0.08 Vdc in fuel cell 2, and 0.06 Vdc in fuel cell 3. The fuel cell 1 coolant pump and hydrogen (H<sub>2</sub>) pump continued to operate nominally on two phases. Flight Control initiated fuel cell purges earlier than typical due to the operation of the fuel cell 1 H<sub>2</sub> pump motor on two phases. The two-phase H<sub>2</sub> pump motor status measurement limit is set for 3.5 Vdc. To keep the load on the pump to a minimum for this flight, the purges occurred when this measurement reached 3.4 Vdc.

At 259/14:00 GMT (06/22:45 MET), the Sequential Still Video (SSV) failed to provide video when power was applied to the unit (STS-115-V-14). Numerous attempts were made to power the unit on, but none were successful. As a result, no initial camera views to determine the correct sensor pointing during surveys were available for the remainder of the mission.

The crew reported a slight Payload Water Reservoir (PWR) leak during the filling of PWR 4. It was later determined that the bag was only slightly wet, and not leaking sufficiently to impact the cabin. The crew double-bagged the PWR, and the water was dumped overboard after the Orbiter undocked from the ISS.

## **Flight Day 9**

All planned transfers were completed, including the filling and transfer of 11 Contingency Water Containers (CWC's). The Orbiter was undocked from the ISS at 260/12:49:55 GMT (07/21:35:00 MET). The Orbiter separated from the ISS to a distance of approximately 600 feet, and the flyaround maneuver was performed

satisfactorily. The first separation maneuver was performed satisfactorily at 260/13:59:55 GMT (07/22:45:00 MET). The second separation maneuver was performed using the RCS and the  $\Delta V$  was approximately 1.5 ft/sec.

### **Flight Day 10**

The planned inspections of the nose cap, starboard wing, and port wing RCC for MMOD damage using the LDRI on the tip of the OBSS were completed satisfactorily.

The SSV was not recovered prior to the start of the inspections and, as a result, the SSV was not available for the Mission Control Center (MCC) to aide the crew in pointing the LDRI during the inspections of the RCC. This was not an issue in the performance of the inspections.

### **Flight Day 11**

The results of the FD 10 RCC inspection imagery analysis were presented at the Flight Day 11 MMT meeting, and the vehicle was cleared for entry.

The FCS checkout was performed satisfactorily at 262/05:12 GMT (09/13:57 MET) using APU 1/Hydraulics (HYD) system 1. The total run time was 4 min and 32 sec with a total fuel consumption of 14 lb.

The ASA 3 Speed Brake channel 3 did not show any intermittent or other anomalous behavior during the checkout. The power to ASA 3 was left on to continue providing insight.

Following the FCS checkout, the Rudder Speed Brake (RSB) Power Drive Unit (PDU) body temperature appeared to flat-line while in the  $-ZLV -XVV$  attitude (MER-28). In essentially the same attitude on STS-112 (previous flight of this Orbiter), this same temperature exhibited a definite cooling trend following the FCS checkout. This condition did not impact the vehicle or mission.

The RCS Hot Fire was also performed satisfactorily. All of the thrusters were fired at least once; however, the Hot Fire procedure was not performed completely in that one group of the RCS thrusters were not fired twice.

Late on FD 11, an object was observed by the MCC traveling parallel to the Orbiter (MER-27). As a result of this debris observation and due to forecasted weather violations at KSC for the planned entry day, entry preparations were delayed for 24 hr, to FD 13, to allow additional imagery of the Payload Bay, Leading Edge Subsystem (LESS) and TPS to be obtained.

## Flight Day 12

The RMS and OBSS MPM's were deployed. The RMS was powered up, and surveys of the vehicle underside were performed using existing procedures. To obtain better imagery of the aft portion of the vehicle, the RMS grappled and unberthed the OBSS for additional underside surveys.

All the survey imagery was downlinked and evaluated by the Damage Assessment Team. The analysis of all imagery showed no problem areas, and the MMT cleared the vehicle for entry.

The OBSS and RMS were berthed and the port and starboard MPM's were stowed.

## Flight Day 13

The Payload Bay Doors (PLBD's) were closed at 264/06:33:50.8 GMT (11/15:18:55.7 MET) in preparation for the first landing opportunity at KSC. The operation of the doors was nominal.

The MADS recorder initially failed to start recording when commanded on one hour prior to the OMS deorbit maneuver (STS-115-V-22). However, repeated commands resulted in clearing the problem and the recorder did record during entry.

The deorbit firing for the first landing opportunity at KSC, a dual-engine straight-feed firing, was performed on orbit 186 at 264/09:14:23.233 GMT (11/17:59:28.225 MET). The duration of the deorbit firing was 161.40 sec and the  $\Delta V$  was 308.1 ft/sec. The orbit following the deorbit firing was 192.2 by 23.6 nmi.

Entry interface occurred at 264/09:49:44 GMT (11/18:34:49 MET).

During entry, the MADS Frequency Division Multiplexer (FDM) 2 Multiplexer 4 annunciated a Built-In Test Equipment (BITE) indication (STS-115-V-20). Multiplexer 4 returned to normal operation after landing. This problem did not impact the entry.

After the planned inhibit of the FES and approximately 6 min before landing, the left-duct temperature sensor on the FES Topping system began to show erratic readings that continued through landing (STS-115-V-19).

Entry was completed satisfactorily. The main landing gear touchdown occurred on concrete runway 33 at 264/10:21:25 GMT (11/19:06:30 MET) on September 21, 2006. The drag chute was deployed at 264/10:21:26.4 GMT (11/19:06:31.3 MET). Nose-gear touchdown occurred at 264/10:21:32 GMT (11/19:06:37 MET). Wheels stop occurred at 264/10:22.15 GMT (11/19:08:00 MET). The rollout was normal in all respects.

The flight duration was 11 days 19 hr 06 min 30 sec. All aspects of the landing were completed in a very satisfactory manner. The shut down of the last APU occurred at 264/10:39:13.766 GMT (17 min 48 sec after landing).

## **PAYLOADS AND EXPERIMENTS**

### **FLIGHT OBJECTIVES**

The primary objective of the STS-115 flight was to deliver, install, and activate the P3/P4 Integrated Truss Segment (ITS) of the ISS 12A Launch Package. The P4 Photovoltaic (PV) Module (PVM) contained two beta gimbal/PV array assemblies, two Beta Gimbal Transition Structures (BGTS's), one Integrated Equipment Assembly (IEA), and associated cabling. The cargo element also included 6 battery sets, PV Radiator (PVR), 2 Unpressurized Cargo Carrier Attach Systems (UCCAS), Solar Alpha Rotating Joint (SARJ), and pre-integrated Space Vision System (SVS) targets.

The ISSP Utilization payloads flown in the middeck were European Modular Cultivation System (Tropi), Microbe, Yeast Gene Expression in Microgravity - Group Activation Pack (Yeast GAP), and Short Duration Bioastronautics Investigations (SDBIs) for Latent Virus, PMZ (Promethazine), and Sleep.

The Ram Burn Observation (RAMBO) payload and the Maui Analysis of Upper-Atmospheric Injections (MAUI) payload were flown as payloads of opportunity.

Mission success criteria were met by completion of the following primary objectives:

1. Perform Orbiter Flight Day 2 Thermal Protection System (TPS) Inspections.
2. Perform R-bar Pitch Maneuver (RPM) during rendezvous and docking for Orbiter TPS tile inspection using ISS imagery.
3. Install Integrated Truss Segment (ITS) P3/P4 to ITS P1.
4. Activate ITS P3/P4 systems to receive survival power from P6.
5. Transfer mandatory quantities of water from the Orbiter to the ISS.
6. Transfer critical items per the Flight 12A Transfer Priority List.

A detailed list of the major mission priorities and the completion status is provided later in this section.

### **CREW ACTIVITIES**

There were three scheduled ISS airlock-based Extravehicular Activities (EVAs) planned for the mission, and all were performed. Following the unberth, maneuver, and berthing of the P3/P4 segment to the ISS, the crew successfully completed the first EVA on Flight Day 4. Tasks included connecting segment P1-to-P3 umbilicals, preparing the

two P4 Solar Array Wings (SAW) for deployment, preparing the Solar Alpha Rotary Joint (SARJ) for activation/deactivation, and removing Electronics Control Unit (ECU) and Sequential Shunt Unit (SSU) covers. They also completed get-ahead tasks for the EVA 2.

During the second EVA on Flight Day 5, the crew successfully completed the tasks required to prepare the SARJ for rotation by removing the remaining 14 launch locks and 6 launch restraints. They also completed get-ahead tasks for the EVA 3. For the third EVA on Flight Day 7, the crew successfully completed planned tasks including Photovoltaic Radiator (PVR) Deployment, removal and replacement of the S-band Antenna Subassembly (SASA) and the Baseband Signal Processor (BSP), installation of the P6 Beta Gimbal Assembly (BGA) shoulder clip, and other tasks. Further details of these EVA activities are listed in the Extravehicular Activity section later in this report.

The following table summarizes the completion status of the tasks assigned to Flight 12A in the Mission Integration Plan (MIP) plus real-time processes:

**MIP AND REAL-TIME TASK ACCOMPLISHMENT**

Source of Tasks	Approved	Completed	Withdrawn	Deferred	Not Complete
MIP Baseline	57	46	6	0	5
Added in Real Time	0	0	0	0	0
Totals	57	46	6	0	5

A. Tasks completed in addition to the MIP requirements:

1. None

B. Tasks Withdrawn:

1. ISS Reboost - not required.
2. MAUI – Maui Analysis of Upper Atmosphere Injections (MAUI) - not performed.
3. RAMBO – Ram Burn Observation (RAMBO) - no opportunity to perform.
4. Install S1 Crew Equipment Translation Aid (CETA) light – completed prior to STS-115.
5. Install Non-Propulsive Vent (NPV) on Laboratory - completed prior to STS-115.
6. Perform DTO 851, IR Camera Objective 2 (if not performed before 12A) - completed prior to STS-115.

C. Tasks Deferred:

1. None

D. Orbiter consumables transferred to the ISS were:

1. Water – A total of 11 CWCs were transferred.
2. Nitrogen – No Nitrogen was transferred.
3. Lithium Hydroxide (LiOH) – No canisters were transferred from the Orbiter to the ISS. 3 canisters were transferred from the ISS to the Orbiter.

### **TRANSFER WEIGHT SUMMARY**

A total of 100 percent of transfers were completed during this mission. The weight summary for ISS pressurized cargo and consumable items that was transferred between both vehicles during the mission is shown in the following tables:

#### **Part 1 (Ascent)**

<b>Transferred from Orbiter to ISS</b>	<b>Planned, lbm</b>	<b>Actual, lbm</b>
Middeck	1,126	1,126
Water (via Contingency Water Containers)	~1,043 (11 CWC)	~1,043 (11 CWC)
Oxygen (via Oxygen Recharge Compressor Assembly (ORCA))	103	103
Nitrogen	0	0

#### **Part 2 (Return)**

<b>Transferred from ISS To Orbiter</b>	<b>Planned, lbm</b>	<b>Actual, lbm</b>
Middeck	1,084	1,084

Approximately 200 lb of launch locks, launch restraints and other hardware deemed to be trash that were removed from the P3/P4 truss during the extravehicular activities were placed in the Progress vehicle for disposal.

### **SIGNIFICANT FIRSTS**

The significant firsts for the STS-115 mission are:

1. First flight of the OV-104 vehicle since the STS-107 accident.
2. A high Qα trajectory design with the ET PAL ramp.
3. The entire late TPS inspection was performed after undocking.
4. The first uses of the ISS Airlock Campout Protocol for the EVA prebreathe.
5. The first checkout and rotation of the P3 Solar Alpha Rotary Joint to support the P4 Solar Array Wing and Photovoltaic Radiator deployment.

## MAUI ANALYSIS OF UPPER-ATMOSPHERIC INJECTIONS (MAUI)

MAUI was manifested as a payload of opportunity. A data collection opportunity utilizing the OMS maneuver on FD11 was planned but was forfeited when NASA requested Department of Defense (DOD) assistance in imaging the Orbiter in the early efforts to identify debris observed drifting away from the Orbiter following FCS checkout. The optical telescope sensors and all-sky imagers at the Air Force Maui Optical and Supercomputing Site (AMOS) were utilized for this effort. None of the imagery collected satisfied MAUI science objectives.

### MAJOR ISS MISSION PRIORITIES COMPLETED

The table on the following pages lists the Mission Priorities that were completed.

Mission Priority	Task	Status
1	Perform Flight Day 2 Thermal Protection System (TPS) inspections	Completed
2	Perform R-bar Pitch Maneuver (RPM) during rendezvous and docking for Orbiter TPS tile inspection using ISS imagery	Completed
3	Install Integrated Truss Segment (ITS) P3/P4 to ITS P1	Completed
4	Activate ITS P3/P4 systems to receive survival power from P6	Completed
5	Transfer mandatory quantities of water from Orbiter to ISS	Completed
6	Transfer critical items per Flight 12A Transfer Priority List	Completed
7	Configure P4 for power generation and deploy P4 (Channel 4A/2A) Solar Array Wings (SAWs)	Completed
8	Deploy Solar Alpha rotary Joint (SARJ) Drive Lock Assemblies (DLA)	Completed
9	Install all four Alpha Joint Interface Structure (AJIS) Struts	Completed
10	Remove launch locks and restraints, and activate and checkout the SARJ	Completed
11	Install all SARJ Brace Beams	Completed
12	Deploy P4 Photovoltaic Radiator (PVR)	Completed
13	Complete EVA tasks necessary to enable Mobile Transporter (MT) translation to Work Site (WS) No. 8:	--
	a. Rotate P1 MT stop	Completed
	b. Remove P3 Space Vision System (SVS) target - Face 1	Completed
	c. Remove and stow keel pin and drag link	Completed
	d. Remove P3 Remote Power Distribution Assembly (RPDA) covers	Completed
	e. Position Articulating Portable Foot Restraints (APFRs) to clear face 1	Completed
14	Remove Circuit Interrupt Devices (CIDs) 6 and 8	Completed
15	Remove and replace S-Band String 1 S-band Antenna Support Assembly (SASA)	Partial Only 1 of 4 gimbal locks engaged

## MAJOR ISS MISSION PRIORITIES PERFORMED (CONTINUED)

Mission Priority	Task	Status
16	Perform Late Orbiter Reinforced Carbon Carbon (RCC) inspection of the wing leading edge (WLE) of both wings and nose cap prior to deorbit and landing to detect Micrometeoroid Orbital Debris (MMOD) damage and downlink the sensor data to the ground for evaluation	Completed
17	Relocate MT in preparation for Flight 12A.1 Space Station Remote Manipulator System (SSRMS) assembly activities and checkout Mobile Servicing System (MSS) WS No. 8	Completed
18	Transfer remaining items per Flight 12A TPL	Completed
19	Remove and replace starboard S-band base band signal processor (BSP) and transponder	Completed
20	Install eight P6 Beta Gimbal Assembly (BGA) shoulder bolt retainers	Completed
21	Retrieve Materials International Space Station Experiment (MISSE) Passive Experiment Container (PEC) 5	Completed
22	Install EVA Temporary Rail Stop (ETRS), stow P3 MT stop and EVA Shuttle tether stop	Completed
23	Transfer a minimum of 25 lb of oxygen to ISS High Pressure Gas Tanks (HPGT's)	103 lb transferred
24	Perform middeck payload operations:	
	a. Microbe (payload of opportunity)	Completed
	b. Short Duration Bioastronautics Investigation (SDBI) 1493 - Latent Virus - Monitoring latent virus reactivation and shedding in astronauts	Completed
	c. SDBI 1490B - PMZ - Bioavailability and performance effects of promethazine during spaceflight	Completed
	d. SDBI 1634 - Sleep - Sleep wake actigraphy and light exposure during spaceflight	Completed
	e. Yeast Gap (Payload of opportunity)	Completed
25	Perform U.S. On-orbit Segment (USOS)/Russian daily ISS payload status checks as required	Completed
26	Perform Internal Thermal Control System (ITCS) water sample	Completed
27	Perform defibrillator checkout	Completed
28	Set the soft capture latches for P5 install (12A.1 get-ahead task)	Completed
29	Manual Rocketdyne Truss Attachment System (MRTAS) visual inspection and Foreign Object Debris (FOD) check (12A.1 get ahead)	Completed
30	Install Ku-band Antenna Group Interface Tube (AGIT) Heat Shield (12A.1 get-ahead task)	Completed
31	Engage P6 BGA hinge lock (get-ahead task)	Unable to engage
32	Reboost ISS with Orbiter to maintain altitude and rendezvous requirements, if propellant available	Not required
33	Perform imagery survey of the ISS exterior during Orbiter flyaround after undocking, if propellant available	Completed
34	Perform Maui Analysis of Upper Atmosphere Injections (MAUI) (payload of opportunity)	Not performed



**MAJOR ISS MISSION PRIORITIES PERFORMED (CONTINUED)**

<b>Mission Priority</b>	<b>Task</b>	<b>Status</b>
35	Perform Ram Burn Observation (RAMBO) (payload of opportunity)	No opportunity available
36	Perform SDTO 15003-U, ISS Microgravity Environment Definition, for the SARJ Checkout	Completed
37	Perform SDTO 12004-U, Shuttle Booster Fan Bypass	Completed
38	Perform SDTO 13005-U, ISS Structural Life Validation and Extension, for SAW Deploy (IWIS required)	Not performed
39	Perform SDTO 13005-U, ISS Structural Life Validation and Extension, for P3/P4 installation (IWIS required)	Completed
40	Perform SDTO 13005-U, ISS Structural Life Validation and Extension, for the 12A Orbiter Undocking (IWIS desired)	Completed
41	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 was trained and ready to perform should the opportunity arise. EVA Mission Operations Directorate (MOD) had the flexibility to change the order and number of tasks to be completed based on efficiencies gained in performing the already scheduled tasks	
	a. Retrieve Quick Disconnect vent tool	Completed
	b. Perform DTO 851 Infrared (IR) Camera Objective 1 daylight imagery of the WLE	Completed
	c. Release P4 IEA MMOD shield bolt torque	Completed
	d. Position APFR for 12A.1 EVA 1 (12A.1 get-ahead task)	Completed
	e. Install External Wireless Instrumentation System (EWIS) antennas and cable on U.S. Lab	Not performed
	f. Install S1 Crew Equipment Translation Aid (CETA) light	Performed prior to STS-115
	g. Install Non-Propulsive Vent (NPV) on Laboratory	Performed prior to STS-115
	h. Mate P1/P3 fluid umbilical	Not performed
	i. Perform DTO 851, IR Camera Objective 2 (if not performed before 12A)	Performed prior to STS-115

## **VEHICLE PERFORMANCE**

### **PRELAUNCH LIGHTNING STRIKE AND ADDITIONAL LAUNCH SCRUBS**

On Friday, August 25, 2006, at 13:49:17 EDT, Launch Complex 39B was struck by lightning. The lightning attached to the Catenary Wire System (CWS). The instrumentation system for the CWS recorded values of 96 kA at the North coil and 110 kA at the South coil; these values resulted in peak amplitudes between 146 kA – 206 kA. This was the highest peak amplitude lightning strike ever recorded at Launch Complex 39B. This lightning strike resulted in scrubbing the launch for 24 hr and then the launch was again scrubbed for further evaluation of system effects because of the lightning strike.

A review was conducted of sensor data from a variety of sources on and around the vehicle following the strike. Analysis of the induced environments on the Solid Rocket Boosters (SRB's) and Reusable Solid Rocket Motors (RSRM's) showed that these two elements did not see significant effects from the lightning strike and these elements were cleared for flight.

An analysis of the affects of the lightning strike was also conducted on the Orbiter vehicle. The results of that analysis showed that no significant problems occurred and the Orbiter was cleared for flight.

The planned launch on August 29<sup>th</sup> was deferred because of a forecasted hurricane that was on a track to the launch site. As a result, the decision was made to rollback the vehicle to the Vehicle Assembly Building (VAB). The rollback was initiated and when the vehicle was about half-way to the VAB, a positive weather forecast allowed the vehicle rollback to be stopped. The vehicle was returned to the Launch Pad and no weather-related problems were reported after the hurricane remnants passed the launch site. As a result, the launch was scheduled for September 6, but the launch was scrubbed because of a fuel cell problem following activation. The launch was postponed to September 8 to complete the evaluation of the fuel cell problem, which is discussed in the Fuel Cell Section of this report.

The scheduled launch on September 8 was scrubbed for 24 hr because of the Space Shuttle Main Engine (SSME) hydrogen Engine Cutoff (ECO) sensor that appeared to fail after tanking was completed. The launch was completed satisfactorily on September 9, 2006.

### **SOLID ROCKET BOOSTERS**

.All Solid Rocket Booster (SRB) systems performed nominally during launch countdown and ascent. Data also indicate that SRB separation was nominal. The SRB separation

time was T+122.53 sec. The SRB pre-launch countdown was nominal and no SRB in-flight anomalies were identified. No SRB Launch Commit Criteria (LCC) or Operational Maintenance Requirements and Specification Document (OMRSD) waivers or exceptions were written during the countdown. No SRB LCC or OMRSD violations occurred.

This was this first flight of the following design changes for the SRB:

1. A new External Tank Attach (ETA) Ring material was flown, the 4340 steel replaced 4130 steel
2. Modifications were made to the Aft Skirt Booster Separation Motor (BSM) Triple Mount Thermal Protection System (TPS).
3. Use of new adhesive (TIGA 321) for entire nozzle on both boosters

Both SRBs were successfully separated from the External Tank (ET) and reports from the recovery area, based on visual sightings, indicated that the deceleration subsystem performed as designed. Both SRBs were observed during descent, and were retrieved and returned to KSC for inspection and disassembly.

## **RESUSABLE SOLID ROCKET MOTORS**

The Reusable Solid Rocket Motors (RSRM's) performed nominally with no violations of the RSRM LCC. Data indicate that the flight performance of both RSRMs was well within the allowable performance envelopes and typical of the performance observed on previous flights. The delivered burn rates at 80 °F Propellant Mean Bulk Temperature (PMBT) and 625 psia were 0.3750 and 0.3763 in/sec for the left and right motors, respectively.

The motor performance parameters were within the Contract End Item Specification limits for this flight. The delivered burn rates at 80 °F PMBT were nominal. Adaptive guidance throttling (AGT) did not make any corrections that were due to off-nominal thrust.

The ambient temperatures recorded during the 187 hr prior to launch varied from 73 °F to 87 °F. The data recorded during this time frame were in the  $\pm 1.0\sigma$  range from historical September average hourly temperatures. At the time of launch, the ambient temperature was 83 °F, which is the historical ambient temperature for the time of launch for the month of September.

The field joint heaters operated for 13-hr 53-min during the launch countdown. Power was applied to the heating elements 26 percent of the time, which is average, to maintain the field joints in the normal operating range during the LCC time-frame of the countdown.

The igniter joint heaters operated for 13-hr 44-min during the launch countdown. Power was applied to the heating elements 38 percent of the time, which is average, to

maintain the igniter joints in the normal operating range during the LCC time-frame of the countdown.

The aft skirt purge was activated once during the final countdown for 4 hr 7 min. The total activation time during the recorded 187 hr of the multiple countdowns was 12 hr 6 min. It was not necessary to thermally condition the aft skirt region prior to launch to achieve the nozzle/case joint seals minimum LCC temperature of 75 ° F. Neither was it 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 motor nozzle/case joint sensor temperatures ranged from 80 °F to 84 °F and 80 °F to 85 °F, respectively. The final Flex Bearing Mean Bulk Temperature (FBMBT) was calculated to be 82 °F.

Reconstructed motor performance parameters adjusted to a 60 °F PMBT are shown in the following table. The calculated PMBT at launch was 80 °F. The maximum trace shape variation of pressure vs. time during the 16- to 30-sec timeframe was calculated to be 1.257 percent at 72.5 sec for the left motor and 0.817 percent at 78.5-sec for the right motor. These values were within the 3.2 percent allowable limits.

#### 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	110.6	110.4
Action time, sec	115.2 – 131.2	122.5	122.8
Head end pressure, psia	847.9 – 965.7	915.1	916.2
Maximum sea level thrust, Mlbf	2.88 – 3.26	3.06	3.06
Web time average pressure, psia	629.9 – 700.5	667.2	668.0
Web time average vacuum thrust, Mlbf	2.46 – 2.74	2.61	2.62
Web time total impulse, Mlbf sec	285.8 – 291.6	288.8	288.7
Action time impulse, Mlbf sec	293.7 – 299.7	296.7	296.6
ISP average delivered, lbf sec/lbm	266.5 – 270.3	268.6	268.5
Loaded propellant weight, lbm	>1103840	1105331	1105186

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

All ground environmental instrumentation (GEI) and operational flight instrumentation (OFI) performed within established requirements. Analysis showed that all sensors operated as expected. No significant hardware problems or concerns occurred during the final countdown.

Beginning with STS-115, the outboard case acreage sensors at the 45- and 135-degree locations became LCC sensors. This launch was also the first use of the

instrumentation change to the igniter joints, field joints, nozzle-to-case joints and case acreage; changing from a variety of temperature ranges to one standard temperature range (10.2 °F to 135.2 °F). With these and other changes to the temperature measurement system, this launch was the cleanest to date as far as measurement tightness (minimal-gauge-to-gauge variation/error) in the RSRM Program.

The predicted and actual propulsion system performances are shown in the following table.

### RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 72 °		Right motor, 72 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10 <sup>6</sup> lbf-sec	66.17	66.06	66.24	65.92
I-60, 10 <sup>6</sup> lbf-sec	176.82	176.34	176.98	176.49
I-AT, 10 <sup>6</sup> lbf-sec	296.92	297.11	296.88	297.00
Vacuum Isp, lbf-sec/lbm	268.6	268.8	268.6	268.7
Burn rate, in./sec @ 60 °F at 625 psia	0.3694	0.3689	0.3697	0.3695
Event times, sec <sup>a</sup>	0.232	N/A	0.232	N/A
Ignition interval	107.9	108.3	107.8	108.1
Web time <sup>b</sup>	117.9	117.9	117.7	117.6
50 psia cue time	120.1	120.0	119.9	120.3
Action time <sup>b</sup>	122.3		122.3	
Separation command				
PMBT, °F	80	80	80	80
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	3.7
Tailoff impulse imbalance differential <sup>c</sup>	Predicted N/A		Actual 342.5	

<sup>a</sup>All times are referenced to ignition command time except where noted by footnote b.

<sup>b</sup>Referenced to liftoff time (ignition interval).

<sup>c</sup>Impulse imbalance = integral of the absolute value of the left motor thrust minus right motor thrust from web time to action time.

### EXTERNAL TANK

External Tank (ET) -118 performed satisfactorily during the ascent phase of the mission. All objectives and requirements associated with propellant loading and flight operations were met however, five in-flight anomalies were identified and these are discussed in

Appendix B. 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 during the final countdown to the successful launch; however, one LCC violation occurred during the first launch attempt.

Developmental Flight Instrumentation was flown in both the Liquid Oxygen (LO<sub>2</sub>) and Liquid Hydrogen (LH<sub>2</sub>) cable trays to provide understanding into the performance of the Protuberance Air Load (PAL) Ramp removal redesigns. These data were recorded on data acquisition located in both SRBs and was available after SRB recovery was complete.

Heavy condensate was noted on the entire ET. Temperatures ranged from 55 to 74 °F. No ET acreage frost or ice was noted. All ice/frost formations were within prelaunch documentation limits.

MECO occurred within the expected tolerances and ET separation was nominal. The ET impacted within the predicted footprint 97 nmi uprange from the preflight predicted impact point. The coordinates of the impact point were 37.565 deg S latitude and 160.163 deg W longitude.

The LO<sub>2</sub> and LH<sub>2</sub> tank ullage-pressures were at predicted levels during the flight. All 49 ET measurements performed satisfactorily. Main Engine Cutoff (MECO) occurred at approximately 504.5 sec MET with ET separation occurring at approximately 526.5 sec MET.

A LCC violation occurred during LH<sub>2</sub> tanking during the Engine Cut-Off (ECO) sensor checkout (STS-115-T-01). The sensor checkout results indicated that the LH<sub>2</sub> ECO sensor no.3 failed with both the Wet and Dry simulation commands. There were no malfunctions of the point-sensor box. A system poll showed nominal activity when the sensor failed, thus the indication was that the Multiplexer/Demultiplexer was functioning properly and the monoball measurements were valid.

After the LH<sub>2</sub> tank was drained and warmed up to 77 °F, ECO sensor no. 3 went Dry for 8 sec. The other three ECO sensors went Dry and remained Dry. ECO sensor no. 3 then transitioned back to Wet for 178 sec and then returned to Dry. The sensor responded nominally to the automated checkout. All four ECO sensors performed nominally during the Main Propulsion System (MPS) level sensor checks during tanking for the STS-115 launch.

Several changes were made to the Main Launch Platform (MLP) -2 Helium (He) prepressurization system to improve as well as bring the system performance and hardware more in line with MLP-1 and MLP-3 He systems.

As a result of these changes, three observations were made regarding interaction of the ET LH<sub>2</sub> tank and the He prepressurization supply:

1. When comparisons with previous Super Light Weight Tank (SLWT) MLP-2 He Supply Pressures, STS-115 represents an approximately 140 psig increase over the previous average. The increase in supply pressure results in an increased He mass flow rate delivered to the ET.
2. The LH<sub>2</sub> Tank Ullage Temperature for STS-115 showed a drop of approximately 20-40 °F during the initial rise into the prepressurization band, as compared to STS-121.
3. The LH<sub>2</sub> Tank Ullage Pressure rise-rate during the initial rise into the control band rose faster than observed for STS-121 and STS-114. This rise rate is higher than any previous MLP-2 SLWT prepressurization. A combination of the affects of slower-than-expected switch timing for the prepressurization Valve (0.510 sec actual versus 0.485 sec expected), and a higher He prepressurization supply pressure resulted in an approximately 20-percent increase in He mass per burst delivered to the tank as compared to STS-121. As the He mass flow rate into the ET increases, the number of prepressurization bursts required to maintain pressure decreases. For STS-115, this was accomplished by the combination of higher-than-typical MLP-2 He supply pressure, and slower-than-expected prepressurization valve timing.

## **SPACE SHUTTLE MAIN ENGINES**

All Space Shuttle Main Engine (SSME) parameters were nominal throughout the pre-launch countdown and were typical of previous flights. There were no LCC or OMRSD SSME violations. Engine "Ready" was achieved at the proper time, all LCC's were met, and thrust build up was nominal.

This was the first flight for the high pressure fuel turbopump (HPFTP) single-piece speed sensors (flown on engines 2044 and 2047) and the fastener modification to small line clamping (flown on engine 2047).

Flight data indicate that SSME performance during mainstage, throttling, shutdown, and propellant dump operations was nominal. The high pressure oxidizer turbopump (HPOTP) and HPFTP temperatures appeared to be well within specifications throughout engine operation. MECO occurred approximately 512 sec after engine start. The commanded Maximum Dynamic Pressure (max Q) throttle-down was performed in one-step to 72-percent thrust. There were two anomalies identified, and these are discussed in the following paragraphs.

At SSME start plus 255 sec, the HPFTP Channel B Speed Sensor became hashy (STS-115-E-01). This same anomaly occurred on STS-111, and as a result, discriminator logic was implemented for all future flights. Redundant sensor channel and pump/engine performance data confirmed nominal engine and pump performance. The HPFTP shaft speed is monitored from SSME start plus 1.40 sec to Engine start plus 1.44 sec for ignition confirm redline.

A 30-degree (approximately 0.75 percent) shift in the HPOTP turbine discharge temperature was noted prior to Max Q throttle-down (STS-115-E-02). This reduction resulted in lower-than-expected fuel consumption. The engine flow meter returned to as-expected Kf performance when the SSME entered the 72 percent power level bucket at 41 sec. The ICD limit is  $\pm 1$  percent error; however, the practice is to remove the duct and fuel flow meter from the flight program with  $\leq 0.5$  percent shift during mainstage operations.

## **SHUTTLE RANGE SAFETY SYSTEM**

The Shuttle Range Safety System (SRSS) closed-loop testing was completed during the launch countdown. There were no OMRSD or LCC violations.

All SRSS Safe and Arm (S&A) devices were armed and system inhibits 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

The Main Propulsion System (MPS) performed satisfactorily throughout the STS-115 mission. One prelaunch anomaly and one in-flight anomaly occurred. The in-flight anomaly did not impact the operation of the MPS during ascent. Both of these anomalies are discussed in later paragraphs in the section of the report.

The maximum hydrogen concentration in the Orbiter aft compartment, with the normally elevated system back-pressure used for fastfill, was 119 ppm (uncorrected). This compares favorably with previous data for this vehicle. Data indicate that the LO<sub>2</sub> system performed as planned. The LH<sub>2</sub> pre-pressurization cycle count was 8 cycles with 13 being the maximum allowed. The engine inlet net positive suction pressure requirements were met throughout the flight.

The overall GH<sub>2</sub> system in-flight performance was nominal. All three flow control valves performed nominally. The cycle count was Space Shuttle Main Engine (SSME) 1 was 11 cycles, SSME 2 was 1 cycle and SSME 3 was 10 cycles. These levels were within the specification limits.

The GO<sub>2</sub> fixed-orifice pressurization system performed as predicted. Reconstructed data from engine and MPS parameters was within  $\pm 0.8$  psi of the actual ET ullage pressure measurements except for a momentary excursion during start-up, which is considered acceptable.

Helium system performance for the SSME and pneumatic Helium (He) systems was nominal except for the Pneumatic He tank pressure which "flatlined" approximately two min after the post-launch dump was stopped. It continued for 13 min and then recovered and operated nominally for the duration of the mission. The data are being evaluated to determine the cause of the erratic transducer behavior. Helium mass leakage while on-orbit was very low compared to the File IX requirement.

Entry helium usage was 59.9 lbm which is within the File IX requirement. All other parameters were nominal.

Thirty valve timing discrete File IX requirements were violated when compared against current requirements. The failures, however, were all due to software updates that changed the timing of the valve.

During the first launch attempt LH<sub>2</sub> loading operations LH<sub>2</sub> Engine Cut-Off (ECO) circuit no. 3 failed to the WET state with all Engine Cut-off sensors indicating the DRY state while Sensor Interface Module (SIM) commands were continuously applied (STS-115-I-004), and as a result, the launch was scrubbed for 24 hr. This event occurred 37 min after the ECO sensors first failed to the WET state and 11 min after the SIM commands were applied. Troubleshooting was performed, and the associated circuit

hardware functioned nominally; with the exception of ECO circuit no. 3. The associated LH<sub>2</sub> monoball signals had no anomalies, and there was no evidence of any power-up/power down events that contributed to the anomaly. The LH<sub>2</sub> ECO circuit no. 3 remained in the failed WET state throughout the detanking operations. The sensor eventually recovered to the “DRY” state approximately 5 hr later. The other three LH<sub>2</sub> ECO sensors functioned nominally during all operations.

During the second launch attempt, the LH<sub>2</sub> ECO circuit no. 3 functioned nominally. All OMRSD system checkout results were nominal, and all four LH<sub>2</sub> ECO sensors performed satisfactorily. The postflight checkout of the Orbiter circuitry confirmed nominal system performance from the monoball to the point sensor box.

The SSME 2 LO<sub>2</sub> inlet pressure transducer read 17 psi lower than the Low Pressure Oxidizer Turbopump (LPOTP) discharge pressure throughout tanking (STS-115-V-23). The reading was also 4 psi lower than observed on the previous 4 flights and 12-16 psi lower than the other feedline pressures. It exceeded the 3-percent accuracy of 9 psi.

### **Hazardous Gas Concentrations**

The aft hazardous gas concentrations during the loadings for the two launch attempts were nominal. They are summarized as follows:

#### **HAZARD GAS CONCENTRATIONS DURING LAUNCH ATTEMPTS**

<b>First Launch Attempt</b>		
<b>Parameter</b>	<b>Peak (ppm)</b>	<b>Steady State (ppm)</b>
Helium	12,082	6,800
Hydrogen	118	15
Oxygen	14	10
LD54/55	3,200	400

<b>Second Launch Attempt (Launch)</b>		
<b>Parameter</b>	<b>Peak (ppm)</b>	<b>Steady State (ppm)</b>
Helium	11,452	6,400
Hydrogen	130	12
Oxygen	20	10
LD54/55	n/a	n/a

### **Gas Sample Analysis**

The measured sample bottle pressures indicated the Orbiter aft fuselage Gas Sampler System collected samples from all six bottles. It was the third flight for RH1, LH1, LH3, RH3 and the second flight for LH2 and RH2. Results of the gas chemical analysis from the Kennedy Space Center Materials and Chemical Analysis Branch laboratory are included in the table on the following page.

### AFT FUSELAGE SAMPLE BOTTLE GAS ANALYSIS

S/N	Position	Actual pressure, torr	Ar, %	Air from Ar, %	He, %	CO, %	CH <sub>4</sub> , %	CO <sub>2</sub> , %	O <sub>2</sub> from air, %	O <sub>2</sub> found %	H <sub>2</sub> , %	H <sub>2</sub> pyro-corrected, %
1091 FLT-3	RH1	178.26	0.08	8.35	0.65	<0.01 N/A	<0.01 N/A	<0.01	1.75	1.99	0.06	0.06
1076 FLT-3	LH1	760	0.60 <sub>a</sub>	0.60 N/A	0.03	0.01	<0.01 N/A	0.05	N/A	18.49	0.01	0.00
1095 FLT-2	RH2	637	0.59 <sub>a</sub>	0.59	0.06	0.01	<0.01 N/A	0.05	N/A	18.06	0.01	0.01
1079 FLT-2	LH2	40.90	0.13	14.24	0.71	0.01	<0.01 N/A	0.08	2.99	3.72	0.11	0.11
1089 FLT-3	RH3	9.22	0.06	6.21	0.78	0.05	<0.01 N/A	<0.01	1.30	1.28	0.29	0.26
1101 FLT-3	LH3	3.27	0.05	5.35	1.91	0.12	<0.01 N/A	<0.01	1.12	1.10	0.57	0.50
Lab Air	-	760	0.69	-	<0.01	<0.01	<0.01	0.07	N/A	23.97	<0.01	N/A

Two bottles, 1076 (LH1) and 1095 (RH2), did not hold the gas samples as reported in the KSC Gas Sample Analysis Report (STS-115-V-25). The bottles were returned to the vendor for Helium leak checks to determine the leak source. No leaks were identified in the bottles. The bottles were also leak tested and JSC following the vendor checks and no leaks were identified. During the last 45 flights, only one bottle failure has been recorded. Based on this analysis, post-flight handling or processing of the bottles was the most likely cause of the lost samples.

A summary of bottle pressure and gas concentration for STS-115 is given in the following table.

### SUMMARY OF BOTTLE PRESSURES AND GAS CONCENTRATIONS

Number	Position	Pressure, psia	Helium, %	Measured oxygen, %	Hydrogen, %
1	RH1	3.45	0.65	1.99	0.06
2	LH1	14.70	0.03	18.49	0.00
3	RH2	12.32	0.06	18.06	0.01
4	LH2	0.79	0.71	3.72	0.11
5	LH3	0.18	0.78	1.28	0.26
6	RH3	0.06	1.91	1.10	0.50

The Ascent Hazard Analysis indicates the maximum hydrogen firing leak rate for STS-115, the 27th flight of OV-104, was 2,950 SCIM. The maximum allowable firing leak rate on ascent is 57,000 SCIM. The estimated firing leak rates for all sample bottle data from this flight are summarized below.

### ESTIMATED FIRING LEAK RATES FOR SAMPLE BOTTLE DATA

Number	Position	Hydrogen firing leak rate, scim
1	RH1	2950
2	LH1	N/A
3	RH2	N/A
4	LH2	1830
5	LH3	1200
6	RH3	885

### Purge, Vent and Drain

The Purge, Vent, and Drain (PV&D) System performed nominally throughout the mission, with no anomalies noted in the review of the prelaunch and postlanding data.

The PV&D System is not active during the mission. Postlanding purge of the PV&D System was initiated 60 min after touchdown and 27 min after the Upper Level Safety Assessment was completed. No problems were noted as a result of the delay. A data trend notification (DTN) was generated for not having the purge initiated within 45 min of touchdown.

### Reaction Control System

The Reaction Control System (RCS) performed nominally. The Tyvek cover for the thruster F3L was missing prior to launch, and the F4D thruster cover came off late at a speed of 244 mph (IFA STS-115-V-05). The remaining 12 thruster covers came off nominally between 52 and 157 mph.

The RCS window-protect maneuver was initiated at 252/15:16:56 GMT (00/00:02:01 MET) for a duration of 2.08 sec. During the maneuver thruster F1U, F2U, and F3U were fired. The intent of the window-protect maneuver was to deflect the exhaust from the SRB separation motors away from the windows during SRB separation. The ET separation maneuver was performed at 252/15:23:40 GMT (00/00:08:45 MET) and was a 6 sec, 10-thruster translation. The ET photo maneuver was performed at 252/15:23:50.4 GMT (00/00:08:55.375 MET). RCS firings, times initiated,  $\Delta V$ s, and firing times are listed in the table on the following page.

The RCS preflight propellant load was 4348 lb of oxidizer and 2868 lb of fuel, for a total of 7416 lb of propellant loaded for the mission. The residual propellants, as calculated by the Primary Avionics Software System (PASS), were 2082.4 lb. The propellant used was 4919.4, which included 499.7 lb used from the OMS during RCS interconnect operations.

## RCS MANEUVERS AND FIRING DATA

Firing	Time of Ignition, GMT	$\Delta V$ , ft/sec	Firing Time, sec
RCS Window Protect	252/15:17:18	N/A	2.1
ET Sep	252/15:23:40	N/A	6.0
ET Photo Maneuver	252/15:23:50	N/A	11.0
NC3	253/18:29:25	6.5	27.2
NCC	254/07:10:26	2.2	4.7
MC1	254/08:28:15	1.11	6.1
Out of Plane Null	254/08:41:27		1.9
MC2	254/08:55:21	0.41	5.6
MC3	254/09:12:12	0.67	3.4
MC4	254/09:22:13	1.54	6.4
ISS Undock	260/12:49:59		
ISS Fly Around - Full	260/13:13:30		
Sep 1	260/13:59:55		5.6
Sep 2 (Final Sep)	260/14:27:36	1.0	4.4
RCS Hotfire	262/06:07:36	N/A	36 thrusters at least two 0.320 sec pulses and 2 thrusters at least 0.240 sec pulses
MAUI Burn	262/15:16:12	N/A	Not performed (debris assessment)
FRCS Dump	264/09:24:48		84.4

As part of the undocking preparations, thrusters F1U, F2U, and F3U were reselected at 260/12:02:58 GMT (07/20:46:03 MET). Undocking was initiated with a +Z pulse at 260/12:49:59 GMT (07/21:35:04 MET). ISS undocking was nominal. The flyaround and separation from the ISS were accomplished nominally. Data for the two separation maneuvers is shown in the above table.

The RCS hotfire was completed satisfactorily, and 36 thrusters were fired at least twice for at least 0.320 sec on each pulse and two thrusters were fired at least two 0.240 sec pulses. No problems were detected during hotfire.

Attitude control responsibilities between the ISS and Shuttle are summarized in the table on the following page.

## CONTROL RESPONSIBILITIES BETWEEN ISS AND SHUTTLE

Control Responsibility	Control Start, GMT	Control End, GMT	Elapsed Time, hr:min:sec	Comments
Docking (ISS)	254/10:48:27	254/11:08:04	00:19:37	DAP to Free Drift
Shuttle	254/11:08:04	254/11:17:58	00:09:54	Vernier Maneuver

## CONTROL RESPONSIBILITIES BETWEEN ISS AND SHUTTLE (CONCLUDED)

Control Responsibility	Control Start, GMT	Control End, GMT	Elapsed Time, hr:min:sec	Comments
Station	254/11:17:58	254/11:18:37	00:00:39	DAP to Free Drift
<b>Shuttle</b>	<b>254/11:18:37</b>	<b>254/11:28:57</b>	<b>00:10:20</b>	DAP to Auto
Station	254/11:28:57	254/11:29:04	00:00:07	DAP to Free Drift
<b>Shuttle</b>	<b>254/11:29:04</b>	<b>254/11:41:55</b>	<b>00:12:51</b>	DAP to Auto
Station	254/11:41:55	256/16:17:57	02/04:36:02	DAP to Free Drift
<b>Shuttle</b>	<b>256/16:17:57</b>	<b>256/19:55:56</b>	<b>03:37:59</b>	DAP to Auto - EVA Activities
ISS	256/19:55:56	257/12:09:37	16:13:41	DAP to Free Drift
<b>Shuttle</b>	<b>257/12:09:37</b>	<b>257/12:38:01</b>	<b>0028:24</b>	DAP to Auto - Deploy 4A Mast Array
ISS	257/12:38:01	257/12:48:35	08/02:06:14	DAP to Free Drift
<b>Shuttle</b>	<b>257/12:48:35</b>	<b>257/13:47:51</b>	<b>00:59:16</b>	DAP configured to Auto - Deploy 2A Mast Array
ISS	257/13:47:51	260/10:31:55	02/20:44:04	
<b>Shuttle</b>	<b>260/10:31:55</b>	<b>260/11:30:10</b>	<b>00:58:15</b>	
ISS	260/11:30:10	260/11:31:03	00:00:53	
<b>Shuttle</b>	<b>260/11:31:03</b>	<b>260/12:24:30</b>	<b>00:53:27</b>	
ISS	260/12:24:30	260/12:25:37	00:01:07	
<b>Shuttle</b>	<b>260/12:25:37</b>	<b>EOM</b>	<b>N/A</b>	Undocking
Total Mated Attitude Control Time		ISS: <b>Shuttle:</b>	04/18:06:44 <b>00/7:30:26</b>	

The RCS pressurization and propellant isolation valves were configured for entry. After the planned landing waveoff, the RCS pressurization and propellant isolation valves were reconfigured for on-orbit operation.

The RCS pressurization and propellant isolation valves were again configured for entry. The FRCS dump (four thrusters) was satisfactory and lasted 88.44 sec. The dump consumed 1040.3 lb of forward RCS propellant.

The postflight Redundant Circuit Verification Test was completed, and there were no anomalies. All valves and switches were exercised, as required.

The primary thrusters were fired 3518 times, for a total firing time of 1470.02 sec. The vernier thrusters were fired 12,132 times, with a firing time of 15129.498 sec.

During entry, about 25 min before touchdown, the heater on RCS thruster R4R failed ON (STS-115-V-24). There was no mission impact as the peak injector temperature was near 138 °F.

## Orbital Maneuvering System

The OMS functioned satisfactorily throughout the mission, with one instrumentation condition noted that did not impact or alter mission operations. No in-flight anomalies were identified during the review and evaluation of the data. The standard OMS configuration is provided in the following table.

### OMS CONFIGURATION

Vehicle/equipment	Flight	Orbital Maneuvering Engine (OME)	Ancillary data
OV-104	27 <sup>th</sup>		
Left Pod (LP) 04	27 <sup>th</sup>	L-OME S/N 108	25 <sup>th</sup> flight
Right Pod (RP) 01	34 <sup>th</sup>	R-OME S/N 109	6 <sup>th</sup> rebuilt flight, 23 <sup>rd</sup> flight

The OMS firings and interconnect operations are given in the following table.

### OMS MANEUVERS

Maneuver designation	Configuration	Time of ignition, GMT	Firing time, sec	$\Delta V$ , ft/sec or interconnect usage, %
Assist	Dual OME	252/15:17:07.8	172.3	N/A
OMS-2	Dual OME	252/15:52:15.8	145.3	220.9
OMS-3 (NC1)	Dual OME	252/18:11:29.9	52.0	80.4
OMS-4 (NC2)	Dual OME	253/07:07:39.6	33.0	51.3
OMS-5 (NC4)	Right OME	254/06:36:29.4	15.0	11.4
OMS-6 (TI)	Left OME	254/08:08:08.2	11.0	8.1
DOB (D/O)	Dual OME	264/09:14:23.2	161.4	308.1
Left interconnect				2.269 %
Right interconnect				1.589 %

The engine inlet pressure, chamber pressure, and regeneration jacket temperatures for both engines were as expected. OMS firing times and propellant consumption were consistent with predictions and verified proper performance.

The left-hand OMS fuel-propellant tank temperature was noted to peak at 92 °F with the system B pod heaters controlling. Three thermal cycles peaked above 90 °F, all occurring while being controlled by the system B thermostat. This condition was noted on previous flights; however, the temperature range between minimum and maximum

was approximately 12 °F for both the system heater systems. Historically, the temperature range has been 6 to 8 °F. There was no mission impact from this condition as this sensor provides insight into the OMS fuel propellant tank temperature and does not affect heater operation.

Official propellant residuals should be taken from the following table.

### PROPELLANT DATA

Parameters	Left OMS pod		Right OMS pod	
	Oxidizer	Fuel	Oxidizer	Fuel
Loaded, lbm	7700	4688	7699	4689
Residual, lbm (aft gage)	572	357	588	514
Residual, lbm (burn time integration)	713	427	695	386
Residual, lbm (Engineering estimate)	N/A	N/A	N/A	N/A
Residual, lbm (SODB flow rate)	620	435	643	407

### Auxiliary Power Unit System

The Auxiliary Power Unit (APU) System performance was nominal throughout the STS-115 mission. Two in-flight anomalies were recorded on the APU System, and these are discussed later in this section.

The run times and fuel consumption for the APUs, including the S/N of each, during STS-115 are summarized in the following tables.

### 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)	00:19:01	00:04:34	01:02:19	01:25:54
2 (410)	00:19:18	00:00:00	01:29:46	01:49:04
3 (204)	00:19:25	00:00:00	01:02:29	01:21:54

### APU FUEL CONSUMPTION

APU (S/N)	Ascent, lb	FCS Checkout, lb	Entry, Lb	Total, lb
1 (409)	47	14	109	170
2 (410)	50	0	161	211
3 (204)	51	0	131	182



The following APU in-flight anomalies occurred during STS-115.

In the review of the APU ascent data, brief periods of intermittent operation were observed on the APU 2 X-Axis accelerometer that started at lift-off + 4 sec and were present until approximately liftoff + 45 sec (STS-115-V-15). Intermittent drops to zero-g peak-to-peak occurred before returning to nominal performance. It was also noted that this accelerometer also was showing zero g peak-to-peak for the first 10 sec of APU operation. Similar APU 2 behavior was also observed during entry. This had no effect on APU performance or mission impact.

During entry, the APU 2 Turbine Exhaust Gas Temperature No. 1 (EGT 1) was erratic before returning to normal after the vehicle entered Terminal Area Energy Management (TAEM) prior to landing (STS-115-V-16). These sensors are in a high-vibration high-temperature environment and have a history of failing by exhibiting an erratic signature. This anomaly had no mission impact or effect on APU performance.

Approximately 3 min after APU start for launch, the APU 3 Turbine Exhaust Gas Temperature No. 2 (EGT 2) became erratic and continued to be for the duration of APU operation. Review of the trace showed that the erratic indications centered around the value that the transducer should be reading, giving the implication that it may be signal noise, and not a sensor failure. A survey of previous EGT failures was conducted and it was noted that some flights had similar erratic traces to the one seen during ascent, which resulted in sensor failure during the subsequent APU run on the same flights. This problem did not impact the flight.

### **Hydraulics/Water Spray Boiler System**

Overall, the performance of the Hydraulics (HYD) and Water Spray Boiler (WSB) System during STS-115 was nominal. STS-115 was the third flight of the Space Shuttle Program as well as the first flight for OV-104 to use Propylene Glycol Monomethyl Ether (PGME) water additive in the WSB system no. 3 water tank to preclude post-ascent freezing in the boiler container. Two in-flight anomalies were identified and these are discussed in this section.

The HYD System 3 Thrust Vector Controller (TVC) pitch actuator switching valve did not indicate the proper switching indication (STS-115-V-12), thus failing the File IX requirement. The switching valve indication stayed in the primary position when standby HYD System 2 was pressurized for both pre-launch circulation pump and main pump activation. The data review, which included the secondary differential pressure on the TVC 3 pitch actuator, showed proper response to HYD system 2 activation followed by indication of switching back to primary HYD system 3. Ground tests will be conducted during the turnaround operations at KSC.

During Ascent, the WSB 3 GN<sub>2</sub> regulator/relief valve open pressure was 32.03 psig and the valve re-seated at a pressure of 27.93 psig, failing the File IX requirement by 0.07 psig (IFA STS-115-V-07). The File IX requirement states that all three WSB GN<sub>2</sub>

regulator/relief valves are required to open at no more than (NMT) 33.5 psig and re-seat at no less than 28.0 psig. The GN<sub>2</sub> pressure transducer functioned nominally during the mission and the re-seat was effective. The on-orbit GN<sub>2</sub> decay rate was well within the specification limit of no-more-than (NMT) 0.06 psi/hour. Five GN<sub>2</sub> relief valve open and re-seats will be performed per the OMRSD. The data from these tests will be evaluated to determine if the GN<sub>2</sub> relief valve operation is within the OMRSD requirements.

WSB heater activation was confirmed with vent nozzle temperatures maintained above the 130 °F minimum and exhibited nominal cycling. The WSB 1, 2 and 3 vent heater temperatures reached the 122 °F minimum temperature indication in a nominal time period.

HYD circulation pump 1 was operated to perform the elevon park while on-orbit. Nine additional circulation pump runs were performed for thermal conditioning to protect against the lower start-up temperature limit of 20 °F at the circulation pump inlet. All thermal runs were commanded from the ground and nominally the pump runs were approximately 5 min in duration. No accumulator recharges were required during this mission.

Following the FCS checkout with APU/HYD System 1, the Rudder Speedbrake (RSB) Power Drive Unit (PDU) body temperature appeared to be non-responsive and tended to flat-line in a -ZLV -XVV, Beta minus 43-degree Orbiter attitude. This condition was observed in almost the identical attitude on the previous flight of this vehicle when performing FCS checkout with APU/HYD System 1. There was no impact to the vehicle or mission. The RSB PDU body temperature functioned perfectly during the entire on-orbit period and perfectly tracked the heater ON/OFF set-point ranges during the five RSB PDU heater cycles which occurred while docked to the ISS. Also, the FCS checkout with APU/HYD System 1 was nominal in all respects.

Water & PGME/H<sub>2</sub>O usage during Ascent for spray cooling was as follows (specification is no-greater-than 8 lb/sys):

1. System 1 = 2.0 lb
2. System 2 = 2.5 lb
3. System 3 = 4.5 lb (PGME/Water)

Water Spray Boiler usage during entry for spray cooling was as follows (specification is no-greater-than 45 lb/sys):

1. System 1 = 4.2 lb
2. System 2 = 19.0 lb
3. System 3 = 13.7 lb (PGME/Water)

Following touchdown, a rust-colored flow pattern was observed on the Orbiter TPS Advanced Flexible Reusable Surface Insulation (AFRSI) blanket around the WSB 3 vent on the vehicle starboard side. This staining was similar to that observed following the STS-121 touchdown, but to a much lesser extent. The light amount of staining seen on STS-115 is thought to be "carry-over", which consists of a residual amount of saturated liquid PGME/H<sub>2</sub>O in the PGME/H<sub>2</sub>O vapor as it exits the vent nozzle post landing.

## Power Reactant Storage and Distribution System

The STS-115 Power Reactant Storage and Distribution (PRSD) system performance was nominal. No in-flight anomalies occurred, and all but one OMRSD File IX requirements was satisfied. The five PRSD tank sets were loaded on September 4, 2006. The tank quantities at the end of loading, launch, and landing are listed in the following table.

**PRSD TANK QUANTITIES**

<b>Oxygen</b>	<b>Tank 1, %</b>	<b>Tank 2, %</b>	<b>Tank 3, %</b>	<b>Tank 4, %</b>	<b>Tank 5, %</b>	<b>Total Mass, Lb<sub>m</sub></b>
Loaded	101.8	101.8	100.9	101.4	101.8	3968
Launch	98.7	98.7	98.3	99.2	98.7	3855
Landing	44.9	39.2	28.7	5.5	5.9	970
<b>Hydrogen</b>	<b>Tank 1, %</b>	<b>Tank 2, %</b>	<b>Tank 3, %</b>	<b>Tank 4, %</b>	<b>Tank 5, %</b>	<b>Total Mass, Lb<sub>m</sub></b>
Loaded	101.9	101.5	102.8	104.1	102.8	472.1
Launch	93.9	93.5	94.8	95.7	93.9	423.1
Landing	36.5	30.3	47.5	1.1	1.1	107.2

The PRSD system supplied the fuel cells with 2595 lbm of oxygen and 327 lbm of hydrogen for the production of 3810 kWh of electrical energy. The average power level for the 283.12-hr mission was 13.5 kW. A 71-hour mission extension was possible at the average power level with the reactants remaining at touchdown. At an extension day power level of 12.48 kW, a 76-hour mission extension was available. Oxygen and hydrogen tank sets 4 and 5 were depleted to residual quantities.

The Environmental Control and Life Support System (ECLSS) was supplied with 290 lbm of oxygen. The O<sub>2</sub>/H<sub>2</sub> manifold isolation valves were cycled for the crew sleep periods, which satisfied the OMRSD File IX In-flight Checkout requirement.

The oxygen (O<sub>2</sub>) tank 2 check valve failed to reseat for one heater cycle of O<sub>2</sub> tank 3 late in the mission. The O<sub>2</sub> tank 2 check valve reseated on the next O<sub>2</sub> tank 3 heater cycle and did not fail to reseat for the remainder of the flight. The most likely cause of this single failure to reseat was transient contamination between the seat and poppet. The failure to reseat resulted in the associated File IX requirement for check valves seating not being satisfied.

## Fuel Cell System

The overall performance of the Fuel Cell System was nominal for STS-115, except for the loss of AC 1, phase A current on fuel cell 1 coolant pump shortly after the initial fuel cell 1 start-up (STS-115-V-01). This anomaly is discussed later in this section. The average electrical power level and load was 13.5 kW and 435 A. The fuel cells

produced 2922 lb of potable water and 3810 kWh of electrical energy from 2595 lb of oxygen and 327 lb of hydrogen.

The final fuel cell startup for launch was initiated on September 5, 2006. Startup and prelaunch operations were nominal. Fuel cell operating times, which are the times accumulated for prelaunch, on-orbit, and postlanding, were 383:38:47 (hr:min:sec) for fuel cell 1, 384:51:45 for fuel cell 2, and 381:37:46 for fuel cell 3. The end-of-mission accumulated operating times for these fuel cells are 1862, 392, and 680 hr for the three fuel cells, respectively.

Seven purges of the fuel cells were performed, occurring at approximately 5, 62, 114, 158, 204, 251 and 275 hr MET. The actual fuel cell voltages at the end of the mission were 0.12 V above that predicted for fuel cell 1 and 0.15 V above that predicted for fuel cells 2 and 0.20 V above that predicted for fuel cell 3. The voltage margins above the minimum performance curves at 200 A at the end of the mission were 0.70 V above the minimum for fuel cell 1, 1.20 V above the minimum for fuel cell 2, and 1.20 V above the minimum for fuel cell 3.

The overall thermal performance of the fuel cell water relief, water line, and reactant purge heater systems was nominal. All of the water system heaters were cycled to satisfy the File IX checkout requirements, except for the fuel-cell 2 alternate water line heater when operating on the B heaters due to leakage from the fuel cell 2 alternate water check valve.

The Fuel Cell Monitoring System (FCMS) was used to monitor individual cell voltages during prelaunch, on orbit, and postlanding. Full-rate on-orbit data were recorded for 12 min early in the mission. Other than pins-sharing on fuel cell 2 (cells 79-80), all voltages were nominal.

During prelaunch operations prior to the second scrub, the hydrogen (H<sub>2</sub>) pump-motor status experienced a step increase from 0.48 to 0.64 Vdc. This corresponded to a spike in the AC 1 phase A current from 4.32 to 5.20 A (0.10-sec duration), followed by a decrease to 3.76 A (STS-115-V-01). Phase B current increased 0.2 A and phase C current increased 0.10 A. The H<sub>2</sub> pump-motor status measurement indicated that the H<sub>2</sub> pump was still operating on all three phases. Fuel cell 1 was shutdown and the drop in the AC1 phase currents were observed. The pump-off stop command was issued. The AC 1 phases B and C decreased about 1 A while phase A current decreased only 0.3 A, verifying that phase A was not powering the coolant pump.

The data indicated that the coolant pump was operating on two phases instead of three. Because of the concern of an additional short, the AC1 phase A bus circuit breaker was opened. With the circuit breaker open, the Fuel Cell (FC) 1 H<sub>2</sub> pump-motor voltage measurement increased from 0.66 Vdc to 3.38 Vdc. The operating range for this measurement with the H<sub>2</sub> pump operating on two phases is 3.2 to 3.5 Vdc.

Two-phase operation of the coolant pump results in a 25-percent decrease in the coolant flow. To determine if this reduced flow rate would provide sufficient cooling for the heat generated at high loads, the Orbiter load was increased to over 21 kW. The FC 1 stack-exit temperature increased from 196 °F to about 204 °F. The stack inlet temperature and condenser exit temperature remained stable at around 181 and 155 ° F, respectively. Small changes in the electrolyte concentration were similar in each fuel cell. The concentration levels were consistent before and after the 1-hour high load test. The H<sub>2</sub> pump-motor status remained steady at 3.38 to 3.40 Vdc. These parameters verified that there is no affect on the overall performance of the fuel cell with the coolant pump and the H<sub>2</sub> pump operating on two phases.

The FC 1 coolant and H<sub>2</sub> pumps operated throughout the entire flight on 2 phases with no adverse observed conditions. The H<sub>2</sub> pump-motor status would gradually increase from about 3.28 Vdc to about 3.4 Vdc over about a 50 hour-period between purges. Most likely explanation was the build-up of inert gases in the hydrogen flow through the H<sub>2</sub> pump caused a slight increase in resistance which was indicated by the increase in the H<sub>2</sub> pump-motor status measurement.

### **Electrical Power Distribution and Control System**

The Electrical Power Distribution and Control (EPDC) system performed nominally during all STS-115 mission phases. The data review and analysis of all available EPDC parameters have been completed and there were no EPDC failures or anomalies on this flight of the vehicle. All File IX requirements were met.

As a minimum, the following EPDC parameters were analyzed

1. Fuel Cell voltages and currents;
2. Essential bus voltages;
3. Control bus voltages;
4. Forward Power Control Assemblies voltages and currents;
5. Mid Power Control Assemblies voltages and currents
6. Aft Power Control Assemblies voltages and currents
7. AC bus voltages and currents
8. AC bus Monitor/auto switch status and overload/over-voltage alarm
9. Main bus to Control bus RPC status
10. Forward, Mid and Aft Motor Control Assemblies ops status
11. Fuel Cell to Essential bus switch status
12. Main bus to Essential Bus RPC and switch status
13. Drag chute Pyro Controller Functions

During prelaunch operations at 237/17:49:17 GMT, there was a lightning strike on the pad. The strike was approximately 80 msec in duration. Essential bus voltage jumped up to 38.2 V, but remained within the specification limit of 38.5 V. All EPDC data were nominal and no anomalies were noted.

During the countdown operations at 249/01:34:55 GMT, phase A of the AC 1 bus experience a current spike that was measured between 4.32 to 5.2 A (approximately 0.9 A) for 0.1 sec, followed by a decrease to 3.76 A (STS-115-V-01). The phase B current increased by 0.20 A and phase C current increased by 0.10 A. The current spike was traced to the Fuel Cell 1 Coolant Pump and the data were indicative of a coolant pump operating on only 2 phases. The AC1 phase A circuit breaker to FC1 coolant and hydrogen pumps was opened to isolate the lost phase, and both motors were operated on 2 phases for the duration of the mission.

### **Orbiter Docking System**

The Orbiter Docking System (ODS) performed satisfactorily with no in-flight anomalies identified in the data.

The ODS Docking Control Panel (DCP) circuit breakers were activated on FD 3 at 254/10:08:18 GMT (01/18:53:23 MET) for a total time of 57 min and 35 sec. (including power to Avionic Instrumentation).

The Shuttle captured the ISS at 254/10:48:28 GMT (01/19:33:33: MET). Ring Drive (Ring In) began at 3 min 16 sec later and ran approximately 5 sec. The system was stopped to allow dampening of any movement, and alignment was regained after approximately 45 sec. A Ring Drive (Ring Out) command was given for 5 sec until the stuck damper was cleared, using established procedures. Final Ring Drive (Ring In) command was issued 7 min 7 sec after capture and ring retraction proceeded nominally with good ring alignment for 3 min, 23 sec using with dual motors. During ring retraction prior to hard mating, which occurs at 5 percent ball-screw linear advancement, ring alignment was momentarily lost for approximately 5 sec, and then regained. This behavior has been seen on the previous 2 flights and is not a problem.

The hooks were driven closed nominally and the final ring extension was performed, and docking was completed satisfactorily.

On FD 9, the Orbiter undocking from the ISS began with powerup at 260/12:21:48 GMT (07/21:06:53 MET) and hook release at 260/12:47:37 GMT (07/21:32:42 MET). The Orbiter completed the undocking sequence from the ISS 2 min 13 sec later, and ODS powerdown was at 260/12:59:54 GMT (07/21:44:59 MET).

### **Atmospheric Revitalization, Atmospheric Revitalization Pressure Control, and Airlock Systems**

The Atmospheric Revitalization System (ARS) performed satisfactorily throughout the mission. No in-flight anomalies were identified in the analysis of the data. The cabin air temperature was maintained within the Flight Rule temperature limits.

During ascent, the cabin air temperature peaked to 73 °F and while on orbit the temperature peaked to 78.5 °F, both of which are within the Flight Rule limit of 80 °F.

During descent, cabin air temperature peaked to 71.3 °F, which is below the Flight Rule limit of 75 °F. Cabin humidity averaged approximately 34-percent during the mission; however, the humidity peaked to 53-percent during the radiator-bypass FES checkout.

At approximately 258/04:24 GMT (05/12:29 MET) during the post-sleep period of FD 7, the crew reported symptoms of headache and stuffiness (STS-115-N-01). These symptoms are analogous with exposure to high concentration levels of Carbon Dioxide (CO<sub>2</sub>). Those experiencing the symptoms indicated having had the symptoms during previous post-sleep periods. Review of Partial Pressure Carbon Dioxide (ppCO<sub>2</sub>) sensor data for the periods of concern showed the levels of ppCO<sub>2</sub> were 3.2, 4.37 and 4.1 mmHg. These ppCO<sub>2</sub> levels are within the 7.6 mmHg Flight Rule limit and below the 5.3 mmHg long-term exposure Spacecraft Maximum Allowable Concentration (SMAC) limit. However, the indicated values represent crew compartment general levels of ppCO<sub>2</sub> and not the ppCO<sub>2</sub> concentration within a localized area. The ppCO<sub>2</sub> sensor is mounted to the cabin fan assembly and the sensing device/head is located in the fan outlet air stream. The sensor measures CO<sub>2</sub> in the air drawn in by the cabin fan from the flight deck and mid-deck, so the sensor provides a general CO<sub>2</sub> measurement of the environment in the cabin volume. To eliminate the post-sleep symptoms, the crew modified the Lithium Hydroxide (LiOH) change-out schedule to lower the overall crew compartment levels of ppCO<sub>2</sub> and stowed the inner-deck access light shield. The light shield had been drawn closed during the sleep periods of the crew with the CO<sub>2</sub> exposure symptoms. With the light shield drawn in the port inter-deck access, the air-flow circulation between the mid deck and flight deck is reduced. This in combination with six crewmembers sleeping on the mid-deck further compounds the CO<sub>2</sub> concentration level in the mid-deck area.

The Atmospheric Revitalization Pressure Control System (ARPCS) and Airlock System performed nominally throughout the mission. ARPCS 1 was configured and was used for the entire mission, and there were no Orbiter-based Extravehicular Activities. The Vestibule was leak and pressure verified for docking operations. An Orbiter-to-ISS tank-to-tank oxygen transfer was performed with a total of 102 lb of oxygen transferred. In addition, the Orbiter provided oxygen for the three ISS-based EVAs. The oxygen transferred for the EVAs was via the Airlock Transfer Panel and the ISS Recharge Oxygen Orifice Bypass Assembly (ROOBA). The Vestibule was leak and pressure was reverified prior to undocking operations. An ISS repressurization was also performed prior to undocking using the Orbiter ARPCS. The repressurization raised the ISS pressure to approximately 14.82 psi using both nitrogen and oxygen to support the ISS atmospheric pressure mixture.

### **Supply and Waste Water System**

The Supply Water and Waste Management Systems performed nominally throughout the mission and all but one of the scheduled File IX in-flight checkout requirements were satisfied.

Supply water was managed through the use of the FES, water transfer to the ISS, and the overboard nozzle dump system. Four supply water nozzle dumps were performed at a nominal dump rate of 1.7 percent (2.8 lb/min). The line heater "B" maintained the supply water dump line temperature between 69.7 °F and 91 °F throughout the mission.

Four waste water (from waste tank) nozzle dumps at an average rate of 1.97 percent/min (3.25 lb/min) were performed. During this mission, two Contingency Water Containers (CWCs) containing Shuttle condensate and one Payload Water Reservoir (PWR) containing iodinated water were dumped through the waste water dump nozzle. The waste water dump line temperature was maintained between 56.6 °F and 75.9 °F throughout the mission.

At 261/05:56:00 GMT (08/14:41:05 MET) after a nominal simultaneous dump-line purge procedure, the Supply nozzle heater was turned off and Supply nozzle temperature dropped sharply 21 min into the cool down. The Nozzle bake-out procedure was performed again to clear any ice and temperature dropped down sharply during the trend down. This indicated that the dump valve was leaking. A second purge cycle was requested to clear the dump line and a temperature drop was noticed about 40 min after the bake-out. A third purge and fourth bake-out was performed, except the isolation valve was left closed for a safe configuration (STS-115-V-13). The vacuum vent line temperature was maintained between 58.6 °F and 74.8 °F.

Eleven CWCs were filled with supply water and transferred to the ISS, for a total of 1043.8 lbm. In addition, 3 PWRs of iodinated water for a total 66.1 lbm were filled and transferred to ISS. PWR 4 leaked after it was filled and was not transferred to ISS. The bag was not leaking rapidly; but it was wet on the side. The PWR leakage did not impact the cabin and the CWC was contained in a bag to secure from leaking into the cabin. The PWR was dumped overboard through the waste water dump line.

The one in-flight checkout item not fulfilled was the heater "A" control thermostat not controlling to its nominal controlling set point. Due to this event, heater B was reconfigured to control the supply dump line temperature and heater "B" performed nominally throughout the mission.

### **Smoke Detection and Fire Suppression System**

The Smoke Detection and Fire Suppression (SDFS) operated nominally with no in-flight problems or anomalies identified. The test of the Smoke Detection system was performed on FD2. All smoke detection A and B system sensor circuits passed after the retest on the smoke detection circuit B Part 1.

Use of the Fire Suppression system was not required.



## **Active Thermal Control System**

The Active Thermal Control System (ATCS) performed satisfactorily in support of the planned mission. Three in-flight anomalies were identified and these are discussed in later paragraphs and it should be noted that none of these anomalies impacted the completion of the planned mission in any manner.

The radiators were not deployed in this flight. It was noted during the post mission radiator structures inspection that the starboard aft radiator panel 4 sustained a large high-velocity debris hit with penetration completely through the panel (STS-115-V-27).

The Forward Mid-body FES Water Feedline sensor was dithering. Dithering is a phenomenon whereby the controlling thermostat goes into a rapid-cycling mode such that the heater is on and off long enough to allow the appearance of constant mid-band temperature. This mode of operation is not detrimental to the operating system, and should the thermostat's useful cycle life be expended and cause a failure, the system A heater can be reactivated. Dithering thermostats can be caused by corrosion of the switch contacts, fatigue of the bimetallic disc or debris between the contacts. Since an alternate sensor exists for this location, a decision has been made to not pursue removing and replacing this sensor.

At approximately 1 minute 29 sec after launch, the Flash Evaporator System (FES) outlet temperature began dropping from 83 °F to as low as 51 °F at which point the FES was activated by the primary A General Purpose Computer (GPC) command (STS-115-V-10). Concurrent with this event, the FES high-load inboard and outboard duct temperatures dropped from approximately 256 °F to 76 °F. This signature is indicative of pre-evaporative cooling. Approximately 2 min later, the FES shut down. After the FES shut down, the FES primary A GPC command was restarted by the crew. The restart was successful with the FES outlet temperatures reaching the control band of  $39 \pm 1$  °F. The FES duct temperatures also began to warm up to at least 150 °F within min. The FES operated satisfactorily for the remainder of the mission.

The cause of the shutdown is the significant amount of pre-evaporative cooling caused by a large amount of condensate in the FES high-load core. The large amount of condensate led to excessive carryover during ascent such that cooling became unstable when the FES was in the middle of startup. Excessive carryover is water that has not been flashed in the core. The high-load core provides at least 80-percent of the cooling capacity of the FES during full-up operations; therefore, an unstable high-load core easily affects how the FES brings the outlet temperatures into the control band. Condensate formation is expected to be high because weather conditions in the days prior to launch were ideal in forming high moisture conditions inside the FES cores. Most of the condensate collected in the high-load core during ground operation because the high-load core is downstream of the topper where the Freon is colder.

After the planned inhibit of the FES approximately 6 min before landing, the left-duct temperature sensor on the FES topping-duct system began to show erratic readings

that continued through landing (STS-115-V-19). The erratic temperature readings continued during the post-landing period. Drops in temperatures from approximately 140 °F down to 50 °F and 40 °F as well as off-scale low were observed within sec after which the temperatures returned to values that were observed prior to the anomaly. The readings eventually returned to pre-anomaly values after several min in the post-landing phase. These signatures indicate a malfunctioning temperature measurement. There was no impact to the vehicle/mission and no changes to crew procedure were required. Postflight testing has exonerated the sensor as a cause and wire-movement tests are scheduled to attempt to locate an intermittent connection.

### **Flight Software**

Performance of all flight software (Primary Avionics Software System (PASS) and Backup Flight System (BFS) was nominal throughout the STS-115 mission. No unexpected PASS or BFS General Purpose Computer (GPC) errors or Input/Output (I/O) errors were encountered.

Three GPC errors were annunciated by the PASS redundant set. The errors (square root of negative argument) are explained by PASS Program Note 046501. User parameter processing requirements for the computation of altitude rate (h) in MM 305 and MM 603 include a compensation for pitch rate effects. This compensation subtracts the "false" component of altitude rate sensed by the IMU's when the vehicle is experiencing pitch rates.

As the vehicle is stopping on the runway, the velocity is nearly zero. Vehicle rotations such as the 'rock-back' effect after braking or noise in the selected RGA pitch rate may produce erroneous altitude rates due to the actual numeric values used. If a small altitude rate residual value exists after this pitch rate compensation has been applied, a negative square root argument GPC error may be observed.

### **Data Processing System Hardware**

The Data Processing System (DPS) hardware performed nominally throughout the STS-115 mission. This hardware includes the General Purpose Computers (GPC), Multiplexer Interface Adapters (MIA), Data Bus Couplers (DBC), Data Bus Isolation Amplifiers (DBIA), Keyboard units (KBU), Multiplexer/Demultiplexers (MDM and EMDM), Engine Interface Units (EIU), and Master Events Controllers (MEC) / Backup Flight Controllers (BFC).

### **Multifunction Electronic Display System**

The Multifunction Display System (MEDS) performed satisfactorily during the STS-115 mission. Post-flight review of MEDS telemetry fault logs confirmed their nominal performance. No issues or in-flight anomalies were noted during the evaluation.

During the September 8 post-scrub egress operations, the Multifunction Display Unit (MDU) Aft Flight Deck (AFD) 1 power switch was inadvertently turned on. The condition had no adverse affect upon unit/system performance other than removing the system from correct launch configuration. The switch was turned off (correct position) prior to launch the next day, thus causing no constraint to launch.

The crew reported that Cathode Ray Tube (CRT) 4 was “blank” after Integrated Data Processor (IDP) 4 and CRT 4 were powered on FD3. The MDU was recovered after the fourth MDU power cycle. An incorrect power-on sequence contributed to the condition. The proper MDU power-on refresher procedure was incorporated into FD4 Execute Package. No repeat occurrences of this condition were reported during the duration of the mission. This condition was explained by MEDS Hardware User Note HW-0002, Rev.\_C:

The crew reported an “Off” flag was set on MDU Commander (CDR) 2 during the MEDS Checkout portion of the FCS Checkout. An IDP1 power cycle cleared the anomalous condition. No repeat occurrences of this condition were reported during the duration of the mission. This condition was explained by MEDS Software User Note 109791

## **Displays and Controls System**

The Displays and Controls System (D&C) performed nominally throughout the mission with no problems or in-flight anomalies identified.

## **Flight Control System**

Flight control hardware/effector systems performed nominally throughout ascent. At all times, the SRB TVC, MPS TVC, and aerosurface actuators were positioned exactly where the GPCs commanded them with normal driver currents (with the exception of a momentary intermittent Speedbrake channel 3 driver current signal), secondary differential pressures, and elevon primary differential pressures. The rate outputs of the four Orbiter Rate Gyro Assemblies (ORGAs) and four Station Rate Gyro Assemblies (SRGAs) tracked each another normally, and there were no Spin motor Rotation Detector (SMRD) dropouts. The outputs of the four Accelerometer Assemblies (AAs) also tracked each other normally. Reaction Jet Driver (RJD) operation was also normal with no thruster failures or other anomalies were noted. Data Display Unit (DDU) and controller operation was nominal as well: the Rotation Hand Controller (RHC) and Translation Hand Controller (THC) were both used and exhibited normal channel tracking.

Flight Controls performed nominally during all On-Orbit operations. Additional testing was requested to gain insight into the Aerosurface Speedbrake Assembly (ASA) channel 3 driver intermittent-current anomaly (STS-115-V-02). All data taken during sleep periods were analyzed in an attempt to isolate the ASA channel 3 driver current intermittent problem. The problem was not observed at any time between the second orbit and Entry Interface. During the FCS checkout, the secondary actuator check

positive stimulus performed channel 3 before channel 1, 2, and 4 as part of the troubleshooting plan. Speedbrake channel 3 was manually bypassed before the negative stimulus and remained bypassed for the remainder of the mission. No anomalies were observed during the Speedbrake checkout. Postflight testing isolated the cause of the ASA to a disconnected wire, which has been repaired and successfully tested.

Entry performance was nominal from deorbit through vehicle touchdown. The pre-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 pressures ( $\Delta P$ ) for all actuators were well within the equalization threshold and all actuator positions closely tracked GPC commands. Entry hydraulic system temperatures were comparable to previous flights with aerosurface actuator temperatures being within the normal limits. MPS TVC Actuator performance was normal with the secondary  $\Delta P$  within threshold values and TVC actuator positions and GPC commands following each other closely.

The Speedbrake channel 3 driver current signal became erratic during the landing flare, again during rollout, and once more at wheels stop. The signature of the erratic driver current was consistent with an intermittent wire, connector, or circuit located in the path from MDM FA3 to ASA 3.

ORGAs and AAs performed normally and RGA SMRD signals remained good throughout entry. DDU and Hand Controller operation of the RHC and THC was nominal and good channel tracking was verified. Landing Sensors and nose-wheel steering performed nominally.

### **Air Data System**

All four Air Data Transducer Assemblies (ADTAs) functioned nominally during pre-launch testing and throughout the flight. There is no insight into ADTA performance during the ascent phase until the post-insertion elevon park

Right and left air data probe (ADP) deployments were initiated at approximately Mach 4.99 using the deploy switch positions. The left and right ADP deployments were nominal. ADTA transducer entry performance was nominal from deorbit through wheel-stop. All 16 transducers tracked each other during the pre-probe deployment phase of entry, and no ADTA dilemmas or redundancy management failures occurred during deployment through wheel-stop.

ADTA entry data was retrieved and reviewed, and one anomaly was observed. The ADTA 4 total temperature measurement was observed to be off-nominal during the right ADP deployment. The measurement was observed to begin rising toward the nominal off-scale-high reading (650 °C) after the ADP was deployed, but fell to a much lower temperature value (150 °C) before slowly rising to the nominal off-scale-high reading

over 15 sec. From this point in the entry, the ADTA 4 reading tracked the ADTA 2 reading.

Post-flight ground troubleshooting using the ADP heaters to stimulate the temperature sensor was unable to recreate the condition. The temperature measurements are not used by the Orbiter flight control system and are instrumentation only. Further, the total temperature measurements are not used in the LCC, nor called out in the OMRSD. ADTA 4 is planned for removal following the STS-120 turnaround flow to incorporate new power input/output circuit card assemblies within the ADTA.

### **Inertial Measurement Unit and Star Tracker Systems**

The Inertial Measurement Unit and Star Tracker Systems performed satisfactorily throughout the STS-115 mission. No in-flight anomalies or problems were identified during the analysis of the data from both systems.

### **Global Positioning System Navigation**

The Global Positioning System (GPS) operation during STS-115 was nominal. The GPS consisted of the Miniaturized Airborne GPS Receiver (MAGR) that was located in Avionics Bay 3B, and two preamplifiers that were located on the Xo576 bulkhead. This is the "Single String GPS" configuration. The MAGR was loaded with firmware (Link - 007) that reflected corrections of several minor discrepancies that were found in the previous link. This link was flown for the first time on this mission.

The GPS was powered on prior to launch at liftoff minus 5 hr 15 min 49 sec. The GPS remained operating for the entire mission until 14 min 14 sec after Touchdown. There was one occurrence where the GPS Data Valid flag went off for two sec. This occurred as the GPS briefly lost track of two satellites, and switched to a new set. While undocked from the ISS, two occurrences of Figure of Merit (FOM) Chimneys, were defined when the GPS FOM was greater than five for more than 138 sec. These FOM chimneys lasted 166 sec and 181 sec. Both FOM chimney instances occurred when the pointing angle to the desired satellite was near the Earth's horizon and the satellite was located in the Orbiter wing plane and temporarily "hidden" from both the upper and lower antennas. Brief periods of invalid GPS data and FOM Chimneys are exacerbated by orbital conditions and are expected occasionally. Neither invalid data nor FOM Chimneys occurred during the critical phase of Entry where the GPS satellite geometry is less dynamic.

A major GPS milestone for this flight was the automatic incorporation of the GPS state vector into the Primary Avionics Software System (PASS) Navigation (NAV) existing state vector during the final phase of entry. In accordance with the pre-planned GPS Ramp-Up plan, the GPS state vector was incorporated into PASS NAV after performance confirmation with high speed C-band tracking. This occurred at 21 min 47 sec after Entry Interface (EI) at 137,000 ft altitude (or 9 min 52 sec before touchdown. The effect was that the PASS navigation state vector errors (compared to

the ground filter state vector) were reduced from approximately 1200 ft altitude to less than 100 ft. The PASS navigation state vector errors remained consistently less than 100 feet from GPS incorporation through rollout.

## **Communications and Tracking System and Navigation Aids**

The Communications and Tracking system and Navigation Aids performed nominally during the STS-115 mission, however, communication and tracking anomalies and problems were identified and are discussed in the following paragraphs. None of these problems had any impact on the successful completion of the STS-115 mission.

The Headset Interface Unit (HIU) for MS4 was not performing properly during and after the MS4 crewmember ingress the vehicle (STS-115-V-06). The failed HIU was exchanged for a HIU that was being used by Astronaut Support Person. There was no flight impact.

Upon exiting ISS blockage, the Ku-Band antenna was commanded on and would not slew. This was an explained condition resulting from the Motor Control Assembly (MCA) logic switches being off during the P3/P4 unberthing. This condition resulted in the Transmit/Scan Enable discrete not being provided to the Ku-Band electronics assembly and the Ku-Band antenna remaining in the idle mode.

The flight control team reported a loss of Sequential Still Video (SSV) lock on the PDI and no video was received on the ground (STS-115-V-14). The SSV unit provides downlink video from the Orbiter via the S-Band system through the Payload Data Interleaver (PDI). The crew reported that the data indication Light-Emitting Diodes (LEDs) on the SSV unit were not lit. The crew then performed a power cycle of the SSV, and the SSV locked to the PDI, but video was not received on the ground during the remainder of the mission.

During uplink of the crew wakeup music on Air-to-Ground 1 with the Big Loop configured to provide intercommunications between the ISS and the Orbiter, no corresponding audio was heard on Station-to-Ground 1 (STS-115-V-17). Prior to this, the Big Loop from the Orbiter to the ISS was operational. Troubleshooting did not recover the link to the ISS and it was not usable for the remainder of the docked operations. After undocking, the Orbiter audio performed nominally.

Throughout the mission, there were numerous S Band Phase-Modulation (PM) forward-link communications dropouts during ascent and on-orbit operations (STS-115-V-18). The initial investigation of that data showed that some dropouts occurred on all Orbiter S-Band antennas; however, the majority of dropouts occurred when the lower right antenna was selected. The dropouts were erratic in occurrence and were not apparent every time the lower-right (LR) antenna was selected. This problem was apparent on both String 1 and String 2 as well as on high and low frequency, and was intermittent and varying in severity.

Post-mission, six periods during the flight (each 2 to 5 min in duration) were identified where the Ku-Band actual angles seemed to behave abnormally (STS-115-V-26). The signature was similar to what is typically seen due to Orbiter or ISS blockage, but for these 6 events, no known blockage could be initially identified. 2 of the events were later attributed to ISS forward radiator blockage. The sequence of dropping lock and reacquiring repeated (up to 6 times per minute) until the system locked up solid and tracked. The 6 events accounted for about 20 minutes of the 260+ hours of Ku-Band on time. This condition did not appear to affect RADAR operations. .

## **Operational Instrumentation/Modular Auxiliary Data System**

The overall performance of the Operational Instrumentation (OI) and Modular Auxiliary Data System (MADS) was satisfactory. Three MADS anomalies were noted and these are discussed in the following paragraphs.

While Dumping MADS Pulse Code Modulation (PCM) ascent data, the data were good up to liftoff, at which time the recorded data became very erratic (STS-115-V-04). Data dropouts did not clear up until after MECO. The same data was dumped three times into the same buffer, which is a technique used to improve data dump quality in case of a weak communications link, but the data quality did not improve, which indicated the data were recorded in that condition. There was no impact to the mission. The MADS PCM data that were recorded on the MADS recorder were available postflight. The MADS recorder was successfully dumped after landing, and a review of the data verified good signal strength and data integrity.

During the MADS De-orbit Checkout prior to the OMS deorbit maneuver, the recorder mode indicated STOP and the percent-tape indication did not increment after activation (STS-115-V-22). The MADS recorder telemetry indicated the recorder responded to the power-on command and all recorder indications of normal operation were observed. Numerous commands were attempted to start recording, but the recorder did not respond. The recorder was later commanded to playback forward, the recorder was verified running at 15 in/sec. Data review indicated that the commands were been sent and the S-band transponder was operating during the time the commands were issued. During postflight turnaround activities, the recorder operated correctly. The recorder was dumped and all possible failure scenarios that would cause a possible sticky tape problem were exonerated. The MADS recorder was dumped successfully post landing and review of the data verified good signal and data integrity.

During entry, the MADS Frequency Division Multiplexer (FDM) 2 Multiplexer (MUX) D indicated BITE FAIL (STS-115-V-20). The FDM was power cycled several times, but the MUX D BITE continued to indicate FAIL. Approximately two min after landing, the MUX D BITE went good and stayed good until the MADS was powered down approximately 30 min later. No entry data were lost as a result of the observed failure. A review of the MADS FDM data will determine the extent of the problem and whether removal and replacement of the unit will be required.

Four instrumentation anomalies were identified from the OI data. These are shown in the following listing, and are discussed in the affected system in this report.

1. MPS engine 2 LO<sub>2</sub> Inlet Pressure Transducer read 17 psi low.
2. APU 3 EGT 2 was erratic beginning 3 min into ascent.
3. APU 2 EGT 1 was erratic during entry.
4. FES topping left duct sensor was erratic last 6 min before landing.

## **Mechanical Systems**

The Mechanical systems performed satisfactorily throughout the mission. No significant problems were identified.

Vent Door operations prior to liftoff were as expected. During Ascent, no Mechanical Systems were active. Following External Tank (ET) Separation,, the port and starboard ET doors closed without issue. And during Post-Insertion, the two Star Tracker Doors opened nominally.

In preparation for Entry, Star Tracker Door closing and Vent Door repositioning were as expected. Vent Door repositioning during and after Entry Interface (EI) and Air Data Probe deployment during approach were nominal. Post-landing, ET Door opening and Vent Door repositioning on the runway was nominal.

The Ku-Band antenna deployment and stow times were nominal.

The payload bay doors (PLBDs) commenced opening as planned at 252/16:41:26 GMT (00/01:26:31 MET). All AC currents were nominal and the motors opened the doors in dual motor time. During the starboard PLBD opening, the aft limit switch (B) indication continued to show closed after the door was open (STS-115-V-03). At varying times later in the flight, the limit switch off (not closed), then to on (closed) and back to off where it stayed until door closure for entry. There was no further impact to the flight.

During the port PLBD bulkhead latch opening, the forward limit switch (A) indication transitioned from closed to open prematurely (occurred after approximately half of the distance of travel) (STS-115-V-09). The crew received a PBD CONFIG message and the Auto Mode was terminated. The Manual Mode was then used to complete payload bay door opening, and was of no impact for the remainder of the flight.

The PLBDs commenced closing at 264/06:28:35 GMT (11/15:13:39 MET) in preparation for the first landing opportunity at KSC. The operation of the doors was nominal.

The port and starboard Manipulator Positioning Mechanism (MPM) were deployed on Flight Day 1 prior to RMS Uncradle and Checkout, and they were stowed on FD10 following the completion of the OBSS late inspection for MMOD damage. Due to debris spotted floating near the Orbiter during FCS Checkout, the port and starboard MPMs were re-deployed on FD 11 to support SRMS/OBSS inspections and re-stowed



following the surveys. All MPM deploys and stows were nominal and in dual-motor time.

All Manipulator Retention Latch (MRL) release and latch operations associated with the port and starboard MPM's were nominal run time (dual motor time for Port MRL's, and single motor time for starboard MRL's).

During latching of the OBSS into the MPMs on FD 2, the aft pedestal MRL Latch System 2 indication did not come on. System 1 latch time was nominal. The most probable cause is that Aft MRL Motor 2 was not energized and did not drive until its 'latch' limit switch actuated. There is a flight rule that pulls circuit breakers to inhibit the MPMs deploy/stow drive motors to prevent possible inadvertent motion of the OBSS or RMS MPMs. MRL Motor 2 is on one of those breakers. During post-flight ground processing operations, the Aft MRL motor 2 was energized and the Motor 2 limit switch transferred to 'latch' as expected. This supported the logic tendered during the mission; which predicted the motor 2 latch limit switch did not transfer because it was rigged slightly behind the motor 1 limit switch. Slight differential rigging is allowed per the MRL assembly specifications.

### **Landing and Deceleration System**

The main landing gear touchdown and drag chute deployment and rollout at KSC was normal. The nose landing gear tires were in good condition and performed nominally. The main landing gear tires were nominal, but did display some cord patches on areas of the tire's surface. However, this condition is expected.

Three ground straps pulled off the blankets in the drag chute compartment (STS-115-V-30). Two were found on the runway and one was found in the compartment itself during a post-flight inspection. This was of no impact to deceleration.

The following table presents the pertinent data on the landing of the STS-115 Orbiter.

#### **LANDING PARAMETERS**

Parameter	From threshold, ft	Speed, keas <sup>a</sup>	Sink rate, ft/sec	Pitch rate, deg/sec
Main landing gear touchdown	3170.0	188.8	1.29	N/A
Nose landing gear touchdown	5772.4	155.3	N/A	-5.53
Parameter	Data			
Brake Initiation speed	102.2 keas			
Brake-on time	31.93 sec			
Rollout distance from touchdown to stop	7578.4 ft (touchdown to wheel stop)			
Rollout time	51.46 sec			
Runway	33 (Concrete) KSC			
Orbiter weight at landing	200006.5 lb			

## LANDING PARAMETERS (Concluded)

Parameter	Maximum Brake Pressure, psia	Total Brake Energy, M ft/sec
Left inboard	924.3	14.80
Left outboard	818.9	12.06
Right inboard	747.5	17.36
Right outboard	769.2	18.73

<sup>a</sup>Knots equivalent air speed

### Entry Aeroheating/Thermal

The post-flight inspections indicate that the overall Orbiter TPS looked normal with no signs of excessive local heating. The preliminary estimated Orbiter Boundary Layer Transition (BLT) onset time is at approximately 1303 sec after entry interface or Mach 6.5 based on the location of X/L = 0.6. The vicinity of the small TPS damages at the windward and leeward and down stream of the gap filler protrusion at the elevon did not show any trace of significantly elevated local heating. The recorded temperatures are within the flight experience of OV-104. Temperature at P4 experienced the most temperature rise for the OV-104 flights; however, the maximum temperature was at 30 min after wheel stop.

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)	137.0	113.4
Lower fuselage forward left-hand (B2)	172.0	161.4
Lower fuselage forward mid left-hand (B3)	158.9	163.3
Lower fuselage mid center (B4)	140.2	139.0
Port side fuselage aft center (P5)	75.2	72.9
Starboard side FRCS Forward (S1)	142.5	95.7
Starboard side fuselage forward center (S2)	132.5	98.3
Starboard side fuselage forward mid center (S3)	109.5	72.6
Starboard side fuselage mid-aft center (S4)	62.0 <sup>a</sup>	55.9 <sup>a</sup>
Starboard side fuselage aft center (S5)	88.3	64.5
Left-hand OMS pod side forward (LP)	62.3 <sup>a</sup>	56.3 <sup>a</sup>
Right-hand OMS pod side forward (RP)	70.1 <sup>a</sup>	59.2 <sup>a</sup>

Thermal Sensor Location	Maximum Temperature, °F	Maximum Temperature Rise, °F
Lower body flap center	116.8	92.9
Right-hand OMS-pod side forward	67.5	41.1
Left-hand OMS-pod side forward	72.6	64.2
Right-hand PLBD forward	59.6	89.3
Left-hand PLBD forward	59.6	106.8
Right-hand PLBD aft	75.3	97.0
Left-hand PLBD aft	70.1	107.3
Right wing upper center	85.5	107.7
Lower fuselage mid aft center (B5)	158.9	150.2
Lower fuselage aft center (B6)	180.7	146.5
Left-wing center (LW)	103.7	128.4
Right wing center (RW)	124.7	126.4
Port side FRCS forward (P1)	119.3	100.9
Port side fuselage forward center (P2)	75.1	92.0
Port side fuselage forward mid center (P3)	70.3	84.7
Port side fuselage mid aft center (P4)	54.7a	79.1

### **Thermal Control System**

The Thermal Control System (TCS) controlled and maintained temperatures satisfactorily throughout the mission. One in-flight anomaly was noted in this system. Notable items are discussed in the following paragraphs. As a result of this mission, all general heater reconfigurations were performed after undocking to improve the chances of having both “A” and “B” heater cycles on most systems.

An electrical short-to-ground of one phase of a fuel cell 1 coolant pump motor occurred during the first launch attempt with the result that only two of the three field coil windings could be energized (STS-115-V-02). As a result, with one phase missing (i.e., 2-phase rather than 3-phase operation), the remaining two phases would use higher amperage and were expected to run warmer than normal. A simplified thermal model of the motor was built from pertinent drawings and design information about the motor including details of the windings, power generation and coolant configuration. The predicted differential temperature was 5.3 °F which compared well with an independent model. It was concluded that 2-phase motor operation was thermally acceptable. The coolant pump operated normally throughout the mission.

After launch, the supply water dump line temperature cycled to 103 °F on system A (STS-115-V-11). The OV-104 thermostat set-points for this heater are 72.5 to 84.9 °F, and the over-temperature thermostat set-points are 92.4 to 107.1 °F. The second heater cycle peaked at 80 °F. Subsequent heater cycles indicated the supply water dump line thermostat was dithering around 82 to 85 °F. The dithering on system “A”

has been observed on most flights of OV-104 but the range of the sensor response has been slowly increasing with on-orbit time. The system B heater cycled between 69 to 95 °F, indicating normal heater operation for the remainder of the flight. The system A control thermostat was replaced during turnaround operations.

The heater on RCS thruster R4R failed ON during entry about 25 min before touchdown (STS-115-V-24). There was no mission impact as the peak injector temperature was near 138 °F. The thruster will be replaced during the turnaround activities for this vehicle.

Three ground straps pulled off the blankets in the drag chute compartment (STS-115-V-30). Two were found on the runway and one was found in the compartment itself during a post-flight inspection. Investigation determined that the three blankets were improperly installed causing the ground straps to be exposed to the mortar in the chute compartment and pulled off during chute deployment.

### **Thermal Protection System**

The Thermal Protection System (TPS) performed satisfactorily. No significant areas of damage occurred.

### **Tile and Blanket Flight Assessment**

The Damage Assessment Team (DAT) examined ascent debris imagery, the FD 2 OBSS inspection imagery, and the Flight Day 3 RPM maneuver imagery. Isolated cases of minor TPS damage were identified and evaluated (IFA STS-115-V-08).

The analysis included: seven occurrences of tile damage in proximity to Windows 3 and 4 (140-01 through 140-07); small protruding blanket fabric (540-05) and seven areas of tile damage (540-01, 02, 03a, 03b, 06, 07, 08) on the right OMS pod; eight occurrences of tile damage on the left OMS pod (550-01 through 550-08); four areas of tile damage near the on the port ET door (870-01, 02, 03, and 330-01); an aft facing step on a tile near the starboard Air Data Probe; a protruding gap filler on the left inboard elevon; and a protruding shim stock on the port ET door.

At the FD 4 Mission Management Team (MMT), the TPS DAT summarized the possible areas of concern and recommended closure of all open TPS issues. No focused inspection was required for TPS, and the vehicle was cleared for entry.

An object was observed traveling parallel to the Orbiter late on FD 11. On the following day, additional vehicle underside inspections were performed using the RMS and OBSS. All of the survey imagery was downlinked and evaluated by the DAT, and no areas of concern were identified. The vehicle was cleared for entry.

## Reinforced Carbon Carbon Flight Assessment

All available ascent data were reviewed by the Leading Edge Subsystem (LESS) members of the DAT. No confirmed impact events were identified on the LESS in the Ascent Imagery, and radar tracking identified no impact events on the Orbiter as evidenced by no range/Doppler shifts that would indicate a debris trajectory change. Additionally, the Wing Leading Edge Instrumentation Data System (WLEIDS) identified a total of six events, the most significant being an event at 14.3 seconds. No WLEIDS event was definitively corroborated by ascent imagery or radar. All indications were used to prioritize the on-orbit inspections.

All FD 2 Laser Dynamic Range Imager (LDRI) survey imagery was evaluated and a total of 504 Regions of Interest (ROIs) were identified. A total of 119 ROIs were subsequently found in the baseline or determined to be image artifacts. An additional 325 ROIs were determined to be benign (not exceeding damage criteria and not exhibiting damage characteristics). Also, 60 ROIs required additional evaluation, and none exhibited damage characteristics. No focused inspections were requested by LESS, and from an Ascent damage perspective, the LESS was declared safe for entry

The planned inspections of the FD 10 nose cap, starboard wing, and port wing Reinforced Carbon Carbon (RCC) for MMOD damage, using the LDRI on the tip of the OBSS, were completed satisfactorily. No issues were identified.

### Post-landing Assessment

The Orbiter TPS performed satisfactorily throughout the mission. Overall, the Orbiter post-landing inspection showed the vehicle to be in excellent condition with some minor items that are discussed in later paragraphs of this section.

The Orbiter lower surface sustained a total of 118 hits, of which 6 had a major dimension of 1 in or larger. The upper surface/windows sustained 17 hits, of which only one had a major dimension greater than 1 in. Overall, the number of hits was much better than the previous two flights. Likewise, the overall condition of the lower surface was within the previous flight experience.

### SUMMARY OF IMPACT SITES FOR EACH ORBITER SURFACE

Orbiter Surface	Impacts > 1in.	Total impacts
Lower surface	6	118
Upper surface/Window area	1	17
Right side	0	14
Left side	1	3
Right OMS pod	2	27
Left OMS pod	3	22
<b>Totals</b>	<b>13</b>	<b>201</b>

The inspection verified that a gap-filler was protruding from the –Y inboard elevon. This condition was noted by the DAT in their evaluation of the in-flight photographs.

The RCC panel had a 1-ft long scratch on its surface. The source of this condition is not known at this time. A chip was observed on the nose cap lower expansion seal that measured 0.9 by 0.3 in (STS-115-V-21). Nose-to-chin interference is the leading cause for the defect.

Numerous small tile chips were noted in various areas of the vehicle, but these were not significant and had no impact on the vehicle or its operation during entry.

The left OMS pod blanket right at the tile interface had some surface material missing and the batting was exposed.

### **Windows**

The window performed as designed. Windows W1 through W6 were removed and taken to the NASA Shuttle Logistics Depot (NSLD) for detailed inspection and the remaining windows were inspected on the Orbiter. Window W5 was noted to have four streaks, with the largest being approximately 5 in long. The detailed inspection of all of the windows revealed a total of 224 impacts, many of which occurred on previous missions and were in the “bruise” category. Two windows (W1, W7) were scrapped as a result of the detailed inspection.

### **Waste Collection System**

The Waste Collection System operated satisfactorily and no in-flight anomalies were reported by the crew.

## **EXTRAVEHICULAR ACTIVITY**

The three Extravehicular Activities (EVA's) were successfully completed for a total of 20hr 19min of extravehicular operations for the two EVA teams.

### **FIRST EXTRAVEHICULAR ACTIVITY**

Space Shuttle Mission Specialists Joe Tanner (MS1) and Heidi Stefanyshyn-Piper (MS3) completed the first of three scheduled EVAs on FD 4. The total time of the first EVA was 6 hr 26min. The main objectives of the first EVA were to:

1. Connect the P1-to-P3 umbilicals – Lower and Upper Tray;
2. Prepare the two P4 Solar Array Wings (SAWs) for deployment;
3. Prepare the Solar Alpha Rotary Joint (SARJ) for activation/rotation. [Drive Lock Assembly (DLA) 1 and 2 were deployed, Alpha Joint Interface Structure (AJIS) struts were installed and the outboard spring clamps were released]; and
4. Remove the two Electronics Control Unit (ECU) covers and the two Sequential Shunt Unit (SSU) covers.

Because the crew completed the planned EVA 1 tasks ahead of the timeline, they were able to start on the EVA 2 get-ahead tasks. They also were able to:

1. Complete Cover 15 (Launch Lock 2) activity, Cover 21 (Launch Lock 7) activity and P3 Solar Alpha Rotary Joint (SARJ) brace beams from the second EVA timeline; and
2. Retrieve the vent tool from the Z1 tray, which was a get-ahead task for EVA 3.

The EVA began with the connection of the P1-to-P3 lower umbilical tray. Following this task, the crew started the tasks required to prepare the SAWs for deployment. One crewmember removed the SAW Blanket Box (SABB) launch restraints and the Beta Gimbal Assembly (BGA) launch restraints, which enabled the deployment of the BGA 4 Bar. Once the first BGA was deployed, the crewmember unstowed the SABB and released the mast-tip fittings to complete the preparation for deployment of that first SAW.

The second crewmember then completed the tasks required to prepare the second SAW wing for deployment. The crew started the tasks required to prepare the SARJ for rotation. The two SARJ DLAs were deployed and the AJIS struts were installed to rigidize the P4 truss. The crew also removed the ECU and SSU covers. The crew was running about an hour ahead of the timeline throughout most of the EVA. The preflight plan was to start on a subset of the tasks planned on the next EVA in the event the crew ran ahead of schedule. Because the crew was ahead, the tasks required to prepare the SARJ for rotation were continued. The crew completed removal of SARJ Launch Lock 2 and Launch Lock 7 to obtain some insight for the second EVA. The crew also installed the P3 SARJ brace beams and removed the 4A SSU Shroud, also a get-ahead

from the second EVA timeline. The crew retrieved the vent tool from Z1 tray, which was also a get-ahead task for the third EVA.

## **SECOND EXTRAVEHICULAR ACTIVITY**

Space Shuttle Mission Specialists Dan Burbank (MS2) and Steve MacLean (MS4) completed the second of three scheduled EVAs on FD 5. The total time of the second EVA was 7 hr and 11 min. The main objective of the second EVA was to complete the SARJ preparation tasks, which were the removal of the SARJ Launch Locks (14) and Launch Restraints (6).

The crew was able to complete the following tasks in addition to the planned second EVA tasks:

1. Reattach SARJ Thermal Blanket, which was a requested task from the Mission Control Center (MCC);
2. Remove and stow the P3 Keel Pin and Drag Link;
3. Clear the P3 Mobile Transporter (MT) path (removed Space Vision System (SVS) Target, EVA Temporary Rail Stop (ETRS) installed, P1 Mobile Transporter (MT) stop, P3 MT stop PIP pin);
4. P3 Cleanup Tasks;
5. Remove Remote Power Distribution Assembly (RPDA) Thermal Shrouds; and
6. Relocate Articulating Portable Foot Restraint (APFR).

During the second EVA, the two crewmembers successfully completed the tasks required to prepare the SARJ for rotation by removing the remaining 14 launch locks and 6 launch restraints, also ahead of the timeline. This allowed the crew to start on the third EVA tasks to clear the P3 MT path. The crew removed the Space Vision System (SVS) target and the RPDA shrouds, removed the P3 keel pin and drag link and stowed it inside the P3 truss and installed the ETRS and MT stops.

## **THIRD EXTRAVEHICULAR ACTIVITY**

The MS1 and MS3 crewmembers completed the final EVA of three on FD 8 in 6 hr and 42 min. The main objectives of the third EVA were:

1. Preparation for Photovoltaic Radiator (PVR) Deployment - Cinch (6) and Winch Release;
2. Remove and Replace the S- band 1 S-band Antenna Subassembly (SASA);
3. Remove and replace the S-band 1 Baseband Signal Processor (BSP) and Transponder;
4. Install the P6 Beta Gimbal Assembly (BGA) shoulder clip (8);
5. Engage the P6 4-bar hinge lock – this task was attempted but the lock could not be engaged;
6. Retrieve the Materials International Space Station Experiment (MISSE5); and
7. Install the Ku-band Antenna Group Interface Tube (AGIT) Heat shield.



The following EVA get-ahead tasks were also completed:

1. Perform Infrared (IR) camera Development Test Objective (DTO) 851 – Wing Leading Edge (WLE) imagery with daylight conditions;
2. Release P4 Integrated Equipment Assembly (IEA) Micrometeoroid Orbital Debris (MMOD) Shield Torque;
3. Relocate APFRs for the first EVA of the next Shuttle flight;
4. Fulfill the MCC requested BSP and Transponder Wireless Video System (WVS) Imagery; and
5. Fulfill the MCC requested WVS closeout Imagery of the S-Band and the Space-to-Ground-Antenna (SGANT) heat shield.

The crew translated to P6 and installed the 8 P6 BGA shoulder clips and attempted to engage the P6 hinge lock. The crew was unable to engage the P6 hinge lock. The second crewmember prepared the PVR for deployment by releasing the cinches and winches. Once those tasks were completed, the crew began the removal and replacement of the SASA, the first of 3 S-band Orbital Replacement Units (ORUs). The spare SASA was removed from the Z1 stowage location and transferred to the S1 SASA location. The degraded SASA was removed from the S1 location and temporarily stowed while the new SASA was installed. The degraded SASA was then stowed in the Z1 stowage location for return on a later Shuttle flight. One crewmember then exchanged the S1 S-band BSP and transponder while the second crewmember installed the Ku-band heat shield and retrieved the MISSE 5 payload from P6. The crew was also able to complete a number of get-ahead tasks including the DTO IR Camera daylight imagery, the P4 IEA MMOD shield release and relocation of an APFR for the next Shuttle flight's first EVA

## **REMOTE MANIPULATOR SYSTEM AND ORBITER BOOM SENSOR SYSTEM**

The Shuttle Remote Manipulator System (SRMS) and Orbiter Boom Sensor System (OBSS) performed nominally during the mission. No in-flight anomalies were identified in the analysis of the data.

STS-115 was the 72nd flight of the SRMS, the 26th flight of SRMS S/N 301, the 3rd flight of the OBSS, and the second flight of Inspection Boom Assembly (IBA) S/N 201.

On Flight Day (FD) 1, on-orbit initialization of the SRMS was performed at 252/17:51 GMT (00/02:36 MET). The port and starboard Manipulator Positioning Mechanisms (MPMs) were deployed, and the SRMS shoulder brace was released. SRMS Checkout was completed by 252/19:34 GMT (00/04:19 MET). SRMS performance during the checkout was nominal.

On FD 2, the SRMS unberthed the OBSS and performed the Laser Dynamic Range Imager (LDRI) port and starboard wing leading edge (WLE) Reinforced Carbon Carbon (RCC) and nose-cap surveys. These surveys were completed satisfactorily, and the SRMS then berthed the OBSS. During latching, the starboard Aft Manipulator System 2 Retention Latch (MRL) indication was not received by the crew or Mission Control. Since the System 1 latch time was nominal, and latching was confirmed by visual inspection, this was deemed to have no impact to operations. The SRMS completed the End Effector Crew Cabin Survey satisfactorily and the RMS was returned to the pre-cradle position.

On FD 3, Atlantis docked with the ISS with the SRMS in the pre-cradle position. Prior to beginning the P3/P4 truss operations, the crew performed a brief SRMS hand-controller check. With the SRMS in test mode (no RMS motion), the operator simulated Z unberth and Y bias maneuvers. The flight control team then determined the corresponding Point of Resolution (POR) rate for these deflections, and provided the information to the crew. The SRMS grappled the P3/P4 truss segment at 254/12:30 GMT (01/21:15 MET), and the crew paused to open the hatches between the Shuttle and ISS and receive a safety briefing. The SRMS continued with P3/P4 truss unberth at 254/13:38 GMT (01/22:23 MET), maneuvering it to the P3/P4 handoff position. The P3/P4 truss was grappled by the Space Station Remote Manipulator System (SSRMS), and the SRMS released the Truss. The SRMS was then moved to the Space Vision System (SVS) viewing position.

On FD 4, the SRMS provided viewing support during the SSRMS installation of the P3/P4 truss and camera views during the first Extravehicular Activity (EVA), while remaining at the SVS Viewing position. The SRMS was then returned to the pre-cradle position, where it remained until FD 10. There were no SRMS or OBSS activities on Flight Days 5 through 9.

On FD 10 following undocking, the SRMS unberthed the OBSS and completed the LDRI port, starboard, and nose-cap final inspection. When the SRMS berthed the OBSS, the starboard Aft MRL System 2 Latch indication was not received during OBSS latching as on FD 2. The SRMS was then cradled and latched, and the port and starboard MPMs stowed.

Due to debris spotted floating near the Orbiter, the Mission Management Team (MMT) decided that further inspections with the SRMS and OBSS would be performed to verify that the debris did not come from any critical Orbiter systems. On FD 11, the port and starboard MPMs were re-deployed, and the SRMS was powered up and moved to the pre-cradle position.

On FD 12, the SRMS End Effector camera was used to inspect sections of the Orbiter's starboard and port wings, nose cap and lower surface. This inspection began at 263/04:15 GMT (10/13:00 MET) and was completed 4 hr 12 min later. The SRMS then unberthed the OBSS and completed the starboard and port side scans. Based on the imagery collected, Atlantis was cleared to land. Following these scans, the SRMS berthed the OBSS, and was then cradled and powered down. The port and starboard MPMs were subsequently stowed.

# WING LEADING EDGE IMPACT DETECTION SYSTEM

## ASCENT MONITORING

The ascent analysis requests, downloads, downlinks, and analysis of the Wing Leading Edge Impact Detection System (WLE IDS) data began at 5 hr Mission Elapsed Time (MET) and continued until 22 hr MET. The first ascent in-flight report contained five probable impacts. The final ascent report was released at 22 hr MET and contained one additional probable impact just above the 1.0 Grms reporting threshold. Requests for detailed ascent data began before the complete set of ascent summary data were downlinked and processed. To complete the WLE IDS ascent analysis and the Micrometeoroid and Orbital Debris (MMOD) analysis required continuous support throughout the mission.

## MMOD MONITORING

The MMOD monitoring began at approximately 43 hr MET. Due to the thermal profile, MMOD monitoring on the starboard wing occurred on Flight Day (FD) 3 and 6, and then again after undocking on FD 9 through 12, for a total monitoring time of approximately 64.5 hr. MMOD monitoring on the port wing occurred on FD 4 through 9, then again after undocking until the wing became too cold for a total monitoring time of approximately 103.5 hr. Each WLE was monitored with groups of 3 units covering nine Reinforced Carbon-Carbon (RCC) panel interfaces. Due to sensor-unit battery-life limitations, which are highly dependent upon the thermal environment, continuous on-orbit monitoring of each RCC panel was not possible.

On FD 11, the WLE IDS detected 9 valid triggers associated with 8 triggering events. However, because of their repeated occurrence at the same interfaces, these were initially reported as MMOD impacts. However, continued evaluation identified these triggers as being caused by the Flight Control System (FCS) checkout. A detailed report outlining the correspondence with FCS checkout timing was submitted to the MMT, and the findings were accepted.

## IMPACT ANALYSIS

### Ascent Debris

All units triggered at Main Engine ignition and began recording data at launch within 0.1 sec of each other. The small errors between units allowed analysis to proceed without additional synchronization. The summary of all probable and questionable impacts above 1.0 Grms for this flight is shown in the following table.

## SUSPECTED ASCENT DEBRIS IMPACTS ABOVE 1.0 Grms

Time (s)		Location			Magnitude		Criteria				Impact <sup>†</sup>	
MET	DET	Wing	RCC	Unit-Channel	Maximum Grms	Maximum G	Transient	Local	Spectral	Shock	In-flight	Post-flight
14.2	23.4	Port	6-7	1085-J3	3.9	23.8	+	+	+	+	P	P
60.7	69.9	Port	14-15	1100-J1	1.3	4.5	+	+	+	+	U	P
82.2	91.4	Stbd	5-6	1071-J3	1.8	9.3	+	+	+	+	N	P
85.7	94.9	Stbd	5-6	1070-J3	1.1	3.5	+	+	+	+	U	P
89.4	98.6	Port	18-19	1103-J2	1.1	3.2	+	+	+	+	P	P
103.0	112.2	Stbd	6-7	1076-J3	1.6	7.9	+	+	+	+	P	P
114.8	124.0	Port	5-6	1075-J3	1.2	6.5	+	+	+	+	P	P
115.2	124.4	Port	5-6	1075-J3	1.3	5.8	+	+	+	+	P	P
277.1	286.3	Port	7-8	1087-J1	1.0	7.7	+	+	+	+	P	P

<sup>†</sup> P=probable, Q=questionable, N=no, U=unfound

A total of 6 probable debris impacts above 1.0 Grms (5 on the port and 1 on the starboard wing) were found and reported during the flight. Post-flight analysis concluded that all cases except one found during flight were analyzed correctly. The case at 82.2 sec MET was underrated as no impact due to incorrect evaluation of the shock criterion. Collective post-flight review determined that the corresponding transient was not anomalous and should therefore be considered as a valid shock response. Since all the other criteria were met, the case was upgraded to impact probable.

Post-flight analysis found another 2 suspected impacts above 1.0 Grms. These impacts were not found by reviewing the summary data during the flight because they were close to the aero-acoustic noise floor around the time of Max Q. Automatic scanning of the full set of post-flight raw data allowed these impacts to be detected.

Automatic scanning of post-flight data acquired from 10 to approximately 500 sec MET revealed a total of 157 probable ascent debris impacts on the wing leading edge (70 on the port and 87 on the starboard wing) ranging from 0.1 Grms to 3.9 Grms.

### MMOD Impacts

A total of 9 valid triggers attributed to 8 distinct events were recorded by the WLE IDS system during MMOD monitoring. These events were correlated with the hydraulic pressurization of elevon actuators during on-orbit FCS checkout. No suspected MMOD impact was found during the in-flight or post-flight analysis.

## ANOMALIES

Structural noise during ascent was found at panel interface 11/12 on both wings and panel interface 3/4 on the starboard wing. The source of the structural noise has not yet been determined. Selected timeframes of the noisy interfaces were ignored for ascent in-flight and post-flight analysis.

One data anomaly was found and reported during flight. The ascent data analysis case at 82.2 sec MET (shown in the previous table) was incorrectly evaluated as an anomalous transient, but was not reported as such.

Automatic scanning of post-flight data revealed 2 additional anomalous transients as shown in following table. These data anomalies did not significantly affect data analysis during the mission.

### ASCENT IMPACT DATA ANOMALIES

Time (s)		Location			Magnitude		Criteria				Anomaly <sup>†</sup>	
MET	DET	Wing	RCC	Unit-Channel	Maximum Grms	Maximum G	Transient	Local	Spectral	Shock	In-flight	Post-flight
114.9	124.1	Port	Chine	1086-J2	0.6	1.6	+	+	-	-	U	P
212.0	221.2	Stbd	16-17	1121-J2	1.0	2.4	+	+	-	-	P	P
508.7	517.9	Port	12-13	1093-J3	0.1	0.3	+	+	-	-	U	P

<sup>†</sup> P=probable, Q=questionable, N=no, U=unfound

### SUPPLEMENTAL DATA COLLECTED

Five sec of time-only data were collected from the port wing on FD 4 crew sleep period (256/01:38:00 GMT) to establish the quiescent background for these units prior to beginning MMOD monitoring. Port units 1086 and 1094 experienced local timeouts when commanded, and did not collect data as requested. Starboard wing data collection was planned for favorable thermal conditions at 108 hr MET, but during this timeframe, difficulties were experienced in commanding units to collect these data, and time-only data was not collected for the starboard wing.

## CONCLUSIONS

The WLE IDS system performed well for ascent impact monitoring, allowing a final ascent report to be published at 22 MET hr. Most of the reported impacts were close to the 1.0 Grms reporting threshold, with the exception of one response of 3.9 Grms at 14.2 sec MET. This event could not be corroborated by other assets. A decision was made not to perform a focused WLE inspection for this flight based on the findings from all systems including WLE IDS.

The MMOD monitoring capability was limited due to lack of continuous wing coverage associated with battery/thermal considerations, gaps in coverage due to lack of Ku- band antenna communications, the time required to request units be placed into MMOD monitoring mode, and excessive invalid triggering of the units. Substantial resources were required for this flight to downlink and evaluate recorded raw data windows to determine trigger validity. Valid triggers were detected on FD 11, but were determined to be caused by excitations from the FCS checkout. No other valid triggers were detected.

## **GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT**

The Government Furnished Equipment/Flight Crew Equipment (GFE/CFE) performed nominally throughout the mission. Some minor problems surfaced and these are discussed along with other GFE/FCE that operated properly in the following paragraphs.

During the second EVA on Flight Day (FD) 5, the EV2 Extravehicular Mobility Unit (EMU) Camera Assembly video and telemetry were present and then lost. The crew performed troubleshooting, and the loss of power to the camera assembly was determined to be a connector on the EMU was not connected. This connector supplies the power to the EMU power harness.

On FD 8, the Sequential Still Video (SSV) failed to provide video when power was applied to the unit (STS-115-V-14). Numerous attempts were made to power the unit on, but none were successful. As a result, no initial camera views to determine the correct sensor pointing during surveys were available for the remainder of the mission. Post-flight troubleshooting revealed a failure of a specific integrated circuit on the Motion-JPEG encoder board. The integrated circuit had a "burn mark", which indicated a likely internal short.

Two Aft Fuselage Sample Bottles, 1076 (LH1) and 1095 (RH2), did not hold the gas samples as reported in the KSC Gas Sample Analysis Report (STS-115-V-25). The bottles were returned to the vendor for Helium leak checks to determine the leak source, and no leaks were identified in the bottles.

At the post-flight crew debriefing, the crew reported that a flickering noise could be heard on Closed Circuit Television (CCTV) Monitor 1 when the contrast was turned all the way up (STS-115-V-28). There was no impact to functionality or video feed and turning down the contrast made the noise go away. The monitor was removed and sent to JSC for troubleshooting and analysis.

Two problems were identified with the Orbiter Umbilical 16mm ET Separation Camera System (STS-115-V-29). Camera Assembly (S/N 1003, 10mm lens) captured no imagery because the film did not advance. The anomaly was isolated to a film jam caused by improper loading of the film. Camera Assembly (S/N 1001, 5mm lens) imagery was found to be slightly out of focus when reviewed by the imagery evaluation personnel. The camera was shipped to the vendor for lens adjustment.

During post-flight checkout, a technician discovered a missing fastener and two adjacent fasteners that were finger-loose on the Launch/Entry Suit (LES) Breathing Regulator Mounting Block (STS-115-V-31). The helmet regulator provides 100-percent of the oxygen to the crewmember via the Launch And Entry Helmet.



## **DEVELOPMENT TEST OBJECTIVES**

**DTO 805 Crosswind Landing Performance** – This Development Test Objective (DTO) of opportunity was not performed during landing because sufficient crosswinds were not present at the landing site.

**DTO 851 EVA Infrared (IR) Camera** - The purpose of this DTO was to test the application of infrared thermography on the Reinforced Carbon Carbon (RCC) during on-orbit inspection, and to obtain on-orbit boundary conditions on the RCC. Previous flight tests (STS-121 and an ISS EVA on August 3, 2006) had successfully completed the first objective of the DTO, leaving only the collection of temperature measurements on the wing leading edge during the daylight portion of the orbit remaining for all DTO objectives to be met. Measurements of the on-orbit temperature of the wing leading edge are used to estimate the boundary conditions on the RCC, and these are important to a Non-Destructive Evaluation (NDE) inspection. These parameters are required to predict damage detection limits.

Data taken during STS-115 on September 15, 2006, was an attempt to obtain WLE temperature data during the initiation of solar heating of the RCC. This is the time when NDE simulations indicate there is the maximum contrast between flaw and unflawed RCC. Analysis of the data showed that while the times correspond to data taken during daylight, the Shuttle is oriented in such a way that sunlight is impinging on the lower surface of the RCC while the camera is viewing the top surface. A small band of higher temperature along the apex of the WLE can be observed. Solar energy that would have been incident on the upper surface of the RCC is blocked by the ISS. This creates a complex set of thermal boundary conditions that will be investigated further.

The EVA IR Camera System has completed three flight tests and has operated successfully each time it has been used in orbit. The camera has acquired over 450 Mbytes of on-orbit infrared imagery. All DTO mission objectives have been met, and both the camera and the inspection procedure have been effectively demonstrated.

A mature NDE technology for detecting subsurface damage in RCC on the ground has been successfully transitioned and demonstrated as an orbital inspection technique. It has been shown that subsurface delaminations as small as 1 in in diameter and 75-percent deep in the RCC panel can be detected with this camera system using passive solar heating. This does not represent the limit of detectability for the system, simply what has been detected thus far in the evaluation in the use of the camera.

## **POSTLAUNCH PAD INSPECTION**

The post-launch inspection of the Mobile Launch Platform (MLP) -2, Launch Complex 39B Flight Service Structure (FSS), and Launch Complex 39 B apron and perimeter was conducted on September 9, 2006, from Launch +2.5 hr to 6.0 hr. The inspection did not find any flight hardware.

The Orbiter lift-off lateral acceleration data was evaluated and the data indicate a maximum of 0.1 g. Hold-down stud hang-ups were noted with lateral accelerations above 0.19 g. Inspection of the SRB holddown posts was performed, and the south holddown studs and shoe sidewalls were visually assessed and verified as having no indication of hang-ups. The shim material was present on all south skirt shoes. The shim at post no. 5 had evidence of blast imperfections; however, this condition is nominal. The post no. 2 left sidewall was delaminated from the Inconel substrate. The conditions on both post no.5 and post no. 2 were acceptable per published documentation. Erosion was typical for both the north and south posts.

The Room Temperature Vulcanizing (RTV) material on the North Holddown-Post (HDP) blast cover exhibited nominal erosion from the Solid Rocket Booster (SRB) exhaust plume damage. However, the erosion on HDP no. 8 was more than on the other three HDPs based on the lack of red colorization from the RTV laminate system. Both SRB aft skirt GN<sub>2</sub> purge lines were intact and still standing straight up. The protective-tape layering was mostly eroded from both lines. The braiding for both lines appeared to be completely intact without any evidence of any fraying. Approximately 5 to 6 in of eroded NASA Standard Initiator (NSI) firing line was protruding from HDPs no.5 and no. 6. The left and right SRB T-0 Ground Umbilical Carrier Assemblies (GUCAs) also appeared to be in nominal condition.

The LO<sub>2</sub> and LH<sub>2</sub> Tail Service Masts (TSM) appeared undamaged and both bonnets appeared to have closed properly. The deck of the MLP was generally in excellent condition. Typical blast erosion was observed in and around the SRB flame holes. All suppression-line bracket shims were still in place.

The GH<sub>2</sub> vent line latched on the eighth tooth (of eight) on the latching mechanism. The vent line was located well left of the center position in the latching mechanism as seen from the MLP. The forks of the latching mechanism were found to be straddling the left tube support, but no witness marks were obvious on the left tube that would indicate hard contact. The External Tank (ET) GUCA 7-inch GH<sub>2</sub> 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; however, the GH<sub>2</sub> vent line blanket was mostly torn away by plume impingement.

The Orbiter Access Arm (OAA) appeared to be intact with no evidence of plume impingement. All slidewire baskets were secured with no evidence of damage.

The Gaseous Oxygen (GOX) vent arm, vent hood, ducts and structure appeared to be in nominal condition. The top of the GOX Vent Arm (GVA) hood plenum exhibited multiple areas of missing Thermal Protection System (TPS) material. During the third run of the L-1 day inspection, vultures were seen picking at the TPS. The GOX vent seals were not inspected due to access limitation.

Although many items were found, the Pad facility was in excellent condition from a debris/damage standpoint as compared to previous postlaunch inspections. The most notable debris items using the new debris collection criteria included numerous pieces of SRB throat plug material on the Pad apron, and multiple large pieces of concrete/fondue fire material in the bottom of the SRB flame trench and outlying areas.

**APPENDIX A**  
**STS-115 MISSION EVENTS**

<b>Event</b>	<b>Description</b>	<b>Actual, GMT</b>
APU activation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	252:15:10:04.647 252:15:10:05.761 252:15:10:06.976
*SRB HPU activation	Left HPU System A start command Left HPU System B start command Right HPU System A start command Right HPU System B start command	252:15:14:26.828 252:15:14:26.988 252:15:14:27.108 252:15:14:27.268
*MPS Main Engine (ME) start	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	252:15:14:48.448 252:15:14:48.564 252:15:15:48.698
*SRB ignition command (liftoff)	SRB Ignition command	252:15:14:55.008
Throttle at 104.5 percent	ME-1 Command accepted ME-2 Command accepted ME-3 Command accepted	252:15:14:58.815 252:15:14:58.820 252:15:14:58.844
Throttle to 72percent	ME-1 Command accepted ME-2 Command accepted ME-3 Command accepted	252:15:15:29.215 252:15:15:29.221 252:15:15:29.245
Maximum Dynamic Pressure	Derived ascent dynamic pressure	252:15:15:45
RCS window protect	Ignition command	252:15:17:18
*Both RSRMs chamber pressure < 50 psi	Left RSRM chamber pressure Right RSRM chamber pressure	252:15:16:52.408 252:15:16:52.928
*End RSRM action time	Left RSRM chamber pressure Right RSRM chamber pressure	252:15:16:57.608 252:15:16:58.008
*SRB physical separation	Left APU B turbine speed – LOS	252:15:16:57.608
OMS assist ignition	Left engine bi-prop valve position Right engine bi-prop valve position	252:15:17:07.8 252/15:17:07.9
OMS assist cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	252/15:20:00.3 252/15:20:00.4
Throttle down for 3G	ME-1 command accepted ME-2 command accepted ME-3 command accepted	252:15:22:18.492 252:15:22:18.503 252:15:22:18.510
3g acceleration	Total load factor (g)	252:15:23:00.7
Throttle down to 67 percent for cutoff	ME-1 command accepted ME-2 command accepted ME-3 command accepted	252:15:23:12.893 252:15:23:12.904 252:15:23:12.911
SSME shutdown	ME-1 command accepted ME-2 command accepted ME-3 command accepted	252:15:23:19.413 252:15:23:19.425 252:15:23:12.431
MECO	MECO command flag MECO confirmed flag	252:15:23:20 252:15:23:21
ET separation	ET separation command flag	252:15:23:42
APU deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	252:15:29:02.451 252:15:20:21.501 252:15:29:30.032

## **APPENDIX A (Continued)**

<b>Event</b>	<b>Description</b>	<b>Actual, GMT</b>
OMS-1 ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Not required
OMS-1 cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	Not required
OMS-2 ignition	Right engine bi-prop valve position Left engine bi-prop valve position	252:15:52:15.8 252:15:52:15.9
OMS-2 cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	252:15:54:41.3 252:15:54:41.4
PLBD open	Right PLBD open 1 Left PLBD open 1	252:16:41:26 252:16:51:47
OMS-3 ignition	Left engine bi-prop valve position Right engine bi-prop valve position	252:18:11:31.0 252:18:11:31.0
OMS-3 cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	252:18:12:23.0 252:18:12:23.2
OMS-4 ignition	Left engine bi-prop valve position Right engine bi-prop valve position	253:07:07:39.6 253:07:07:39.6
OMS-4 cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	253:07:08.12.8 253:07:08.12.8
OMS-5 ignition (Right engine only)	Right engine bi-prop valve position	254:06:36:29.4
OMS-5 cutoff (Right engine only)	Right engine bi-prop valve position	254:06:36.44.6
OMS-6 ignition (Left engine only )	Left engine bi-prop valve position	254:08:08:08.2
OMS-6 cutoff (Left engine only)	Left engine bi-prop valve position	254:08:08:19.4
Docking	Capture	254:10:48:27
Undocking	Undocking complete	260:12:49:50
APU ignition for Flight Control System FCS) checkout	APU-1GG chamber pressure	262:05:12:44.430
APU stop for FCS checkout	APU-1GG chamber pressure	262:05:17:15:730
PLBD close	Left PLBD close 1 Right PLBD close 1	264:06:29:32 264:06:33:02
APU activation	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	264:09:09:23.453 264:09:36:55.356 264:09:36:45.583
Deorbit maneuver	Left engine bi-prop valve position Right engine bi-prop valve position	264:09:14:23.3 264:09:14:23.3
Deorbit maneuver cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	264:09:17:04.9 264:09:17:04.9

## APPENDIX A (Concluded)

Event	Description	Actual, GMT
Entry interface	Orbiter alternate/reference ellipsoid	264:09:49:44
Blackout end	Data locked (high signal rate)	No blackout
TAEM	Major mode code (305)	264:10:14:52
Main landing gear (MLG) contact	MLG left tire press 2 MLG right tire press 1	264:10:21:23 264:10:21:23
MLG weight on wheels	MLG left weight on wheels MLG right weight on wheels	264:10:21:25 264:10:21:27
Drag chute deploy	Drag chute deploy No. 1 CP Volts	264:10:21:26.4
Nose landing gear (NLG) contact	NLG left tire press 2	264:10:21:32
NLG weight on wheels	NLG weight on wheels	264:10:21:32
Drag chute jettison	Drag chute jettison No. 2 CP Volts	264:10:21:53.0
Wheels stop	Velocity WRT runway (F/S)	264:10:22:15
APU deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	264:10:38:59.410 264:10:39:07.443 264:10:39:13.766

## **INTRODUCTION**

This appendix contains listings and discussions of each of the In-Flight Anomalies (IFAs) that were identified for the STS-115 mission.

1. Orbiter
2. Solid Rocket Booster (SRB) (No anomalies identified)
3. Reusable Solid Rocket Motor (RSRM)
4. External Tank (ET)
5. Space Shuttle Main Engine (SSME)
6. Systems Engineering and Integration (SE&I)
7. Flight Operations and Integration (FO&I)
8. Mission Operations Directorate (MOD)

No Solid Rocket Booster In-Flight Anomalies were identified for the STS-115 Mission.

## IN-FLIGHT ANOMALIES ORBITER

IFA Number	Title	Comments
STS-115-V-01	FC1 Coolant Pump AC1 Phase A Short	Following nominal fuel cell 1 pump activation, the Hydrogen (H <sub>2</sub> ) pump motor status experienced a step increase from 0.48 to 0.64 Vdc. High currents were seen on AC1 phase A bus prior to losing phase A current to the fuel cell 1 coolant pump. The pump continued to operate nominally on the 2 remaining phases. Flow-through and pulse purges were nominal. Because of a concern that the coolant pump may be operating on only two phases, the connection of fuel cell 1 to main bus A was delayed. The decision was made to fly fuel cell 1 as is (cooling pump operating on 2 phases). The fuel cell in-flight performance was nominal. The coolant pump operated on only 2 phases for the duration of the flight and no other anomalies were reported.
STS-115-V-02	ASA 3 Speed Brake Driver Channel 3 Erratic	During ascent, the Aerosurface Servo Amplifier (ASA) 3 speedbrake driver channel 3 indicated erratic behavior suggesting an open-circuit condition somewhere between Multiplexer/Demultiplexer (MDM) FA 3 and the Speedbrake Power Drive Unit (PDU) servovalve coil. The signature occurred again after the APU shutdown. The behavior of the secondary differential pressures confirmed a real condition. The erratic output did not persist for a long enough time to cause an automatic deselection of the channel by ASA Redundancy Management (RM). The Elevon Park procedure was performed with ASA 3 rather than ASA 4 to monitor the status of ASA 3. Results of KSC troubleshooting were that flexing of the MDM FA3 connector repeated the failure. Further troubleshooting found a bad crimp on pin 25 of the MDM connector. Unit was removed for repair, and the problem was resolved and closed.
STS-115-V-03	Starboard PLBD Aft (B) Closed Indication was ON and should have been OFF	During opening of the starboard Payload Bay Door (PLBD), the aft limit switch (B) continued to show closed after the door was open. This is similar to what was seen on STS-114. A workaround exists to remove power from the limit switch to regain dual-motor drive to close the door at the end-of-mission (EOM). Approximately two days later, the limit switch transferred and no longer indicated "closed". The system functioned nominally and within dual-motor drive time for door closure prior to entry. The starboard aft switch module was removed and replaced with a spare.



## IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-115-V-04	MADS PCM Data Dropouts	<p>While dumping Modular Auxiliary Data System (MADS) Pulse Code Modulation (PCM) ascent data, it was noted that the data were good up to lift-off, at which time the recorded data became very erratic. The data dropouts did not clear until after Main Engine Cutoff (MECO). The same data were dumped three times into the same buffer, which is a technique used to clean up dumps in case of a weak communication link, but the data did not clean up, which indicated the data was recorded in that condition. This problem did not impact the flight. The MADS PCM data are recorded on the MADS recorder which is available postflight. Postflight troubleshooting and data review revealed that no discrepancies existed in the signal from the MADS PCM to the MADS Recorder. The problem has been determined to be between the coupler and MMU1, in that the harness was terminated shorter than intended. The entire leg consisting of coupler, filter and wiring to MMU1 will be replaced. Preliminary data review from MADS testing indicates no hardware issues. This anomaly was declared an unexplained anomaly pending completion of harness failure analysis.</p>
STS-115-V-05	FRD Thruster Tyvek Cover Late Release	<p>During ascent, ground imagery indicated that the Tyvek rain cover on Reaction Control System (RCS) thruster F4D released late at 16.4 sec MET. No recontact with Orbiter was observed. The approximate vehicle velocity at that time was approximately 354 ft/sec (240 mph). The thruster cover release certification requirement is 170 mph. Ascent video review suggested premature failure of Room Temperature Vulcanizing (RTV) material dots on cover leading edge, allowing leading edge to roll over and block pocket inflation. Post Flight verification of the failure mode suggested 3 possible contributors for the F4D late release. Testing of all three combined produced the flight failure signature, thus the PRT believes the late release is a combination of all three factors:</p> <ol style="list-style-type: none"> <li>1) Inadequate RTV dot contact</li> <li>2) Tile protrusion interfering with parachute corners</li> <li>3) Imperfectly folded parachutes</li> </ol> <p>Corrective actions were implemented to address each of the three factors.</p>
STS-115-V-06	Headset Interface Unit Anomaly During Crew Ingress	<p>During the MS4 crewmember communications check, the crewmember reported hearing squelch when the Intercommunications (ICOM) button was pushed on the Headset Interface Unit (HIU) S/N 0026. The support personnel cycled the Orbiter Crew Communications Unit (CCU) power, but the squelch continued when the ICOM button was pushed. The suspect HIU (S/N 0026) was exchanged with spare HIU (S/N 0004). Spare HIU (S/N 0004) was a support person spare and was not the crew spare located in the saddle bag.</p>

## IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-115-V-07	WSB3 GN2 Regulator Relief Valve Pressure Decay	<p>During ascent, the Water Spray Boiler (WSB) gaseous nitrogen (GN<sub>2</sub>) Regulator/Relief Valve re-seat pressure marginally violated the File IX requirement that the GN<sub>2</sub> regulator outlet pressure should be no-less-than (NLT) 28.0 psia at relief valve re-seat. The WSB 3 regulator/relief valve re-seat pressure was tagged as 27.93 psia. During the flight, the GN<sub>2</sub> pressure decayed below the 25.8 psia regulated value, but remained well within specification limits. There was no impact to the vehicle or mission. The WSB 3 GN<sub>2</sub> pressure transducer was functioning nominally and the WSB GN<sub>2</sub> pressure decay was within the specification limit of no-more-than (NMT) 0.06 psi/hour.</p> <p>The high-pressure GN<sub>2</sub> tank (source) isolation valve was closed, isolating the GN<sub>2</sub> high-pressure source from the GN<sub>2</sub> Regulator/Relief Valve. Performance was nominal for entry. Postflight, regulator replacement was initially deferred for one flight, but replaced while at the pad prior to the following launch due to subsequent leakage.</p>
STS-115-V-08	TPS Tile and Blanket Anomalies and Missing Ceramic Inserts	<p>During the flight, the following TPS areas of interest were assessed. The damage assessment team determined that no focused inspection was required, and that the TPS tile &amp; blanket was cleared for entry.</p> <ul style="list-style-type: none"> <li>a) Left &amp; Right ET Door, Left Inboard Elevon Protruding Gap Fillers</li> <li>b) Left ET Door Protruding Shim Stock</li> <li>c) Right OMS Pod Blanket damage</li> <li>d) OMS Pod, Vertical Tail, ET Door, and Window tile damage.</li> </ul> <p>During standard post-flight vehicle inspection, the following was also identified:</p> <ul style="list-style-type: none"> <li>e) Two missing ceramic tile inserts from the upper stub near the body flap leading edge below engine bells. Entire inserts and FRSI were missing</li> <li>f) Acreage putty repairs identified as missing.</li> </ul> <p>The standard post-flight inspection was performed and repairs conducted with the following notes related to the topics above: a) No gap filler protrusions occurred where gap filler replacements were conducted. b) ET door locations were not inspected for shims prior to previous flight. Inspections were completed on the door locations previously missed. e) For the missing ceramic inserts, documentation and history of failures were reviewed and no discrepancies were identified. Rework of 3 loose inserts was completed. f) Putty Repair minimum gap inspections were performed in locations identified by DTA to have transport to windows and RCC component.</p>

## IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-115-V-09	Port PLBD Forward (A) Closed Indication Lost Prematurely	<p>The Payload Bay Door (PLBD) forward close microswitch indication was lost during the port bulkhead latch opening (occurred after approximately ½ of the door travel. The crew received a PBD CONFIG message and the automatic mode for door opening was terminated. The manual mode was used to complete the door opening. This failure was no impact to the mission as the PLBD opened to the correct position and both the manual and automatic modes for door closure were available. The doors closed nominally in preparation for entry.</p> <p>Post-flight checks of the PLDB port forward A switch module rigging showed the rigging to be within specification. Rational is being developed to fly an additional flight as-is and assess performance.</p>
STS-115-V-10	Flash Evaporator System (FES) Shutdown During Ascent	<p>At approximately 252/15:16:27 GMT (00/00:01:32 MET), the FES outlet temperature began dropping from 83 °F to as low as 51 °F at which point the FES was activated by the primary A General Purpose Computer (GPC) command. Concurrent with this event, the FES high-load duct inboard and duct outboard temperatures dropped from approximately 256 °F to 76 °F. This signature is indicative of pre-evaporative cooling. Two minutes after the initial temperature drop was noted, the FES shutdown. After shutdown, the crew restarted the FES with the FES primary A command. The restart was successful with the FES outlet temperatures reaching the control band of 39 ±1 °F. The FES duct temperatures also began to warm up to at least 150 °F within 7 minutes.</p> <p>The cause of the shutdown was the significant amount of pre-evaporative cooling caused by a large amount of condensate in the FES high-load core. The large amount of condensate led to excessive carryover during ascent during ascent such that cooling became unstable when the FES was in the middle of startup. Excessive carryover is water that has not been flashed in the core. The high load core provides at least 80 percent of the cooling capacity of the FES during full-up operations; therefore an unstably high high-load core easily affect how the FES brings the outlet temperatures into the control band. Condensate formation was expected to be high because weather conditions in the days prior to launch were ideal for forming high moisture condition inside the FES cores. Most of the condensate collected in the high-load core because the high-load core is upstream of the topper so Freon is colder in the high-load core.</p>

## IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-115-V-11	Water Supply Dump Line Heater A abnormal Temperature Cycling	<p>After the simultaneous supply water and waste water dump, the supply water dump line heater A began cycling in the over-temperature range. At heater activation, the first complete heater cycle was similar to the last flight of this vehicle (STS-112), except that the peak was 11 °F higher and it exceeded nominal limits. The heater then dithered until the simultaneous dump. When the simultaneous dump was completed, the heater stopped dithering, but began cycling in a range that appeared that the heater was turning on at the lower set-point of the Control Thermostat (CT) and off at the upper set-point of the over-temperature thermostat that was between 75 °F and 106 °F.</p> <p>Post-flight troubleshooting verified the off nominal performance of the A control thermostat which was removed and replaced.</p>
STS-115-V-12	Hydraulic System 3 Thrust Vector Control Pitch Actuator Indication	<p>The hydraulic system 3 TVC pitch actuator switching valve did not indicate proper switching position. The switching valve indication remained in the primary position when standby hydraulic system 2 was pressurized for both pre-launch circulation pump and main pump activation. The secondary differential pressure on the TVC 3 pitch actuator showed the proper response to hydraulic system 2 activation followed by the indication of switching back to primary system 3. The Pre-Launch Slew test performance was nominal. All indications were that TVC 3 Pitch actuator switching valve was working properly.</p> <p>Post-flight troubleshooting discovered that four contacts were incorrectly pinned into connector 50P575 of wire harness V070-775271. Connector terminations were returned to print and tested successfully.</p>
STS-115-V-13	Water Supply Dump Valve Leak	<p>After a nominal simultaneous waste water and supply water dump and performance of the dump-line purge procedure, the supply nozzle heater was turned off and the supply nozzle temperature dropped sharply 21 minutes into the cool down. The Nozzle bake-out procedure was performed again to clear any ice, and the temperature dropped down sharply during the trend down. This indicated that the dump valve was leaking. A second purge cycle was requested to clear the dump line and temperature drop was noticed about 40 minutes after the bake-out. Another simultaneous-dump was performed on FD 12 (mission extension day), and was the dump was nominal.</p> <p>Post-flight leak check performed on the supply water dump valve showed no leakage. Investigation revealed that the dump valve replaced in 1992 was not per print, but it had flown approximately 14 flights in this configuration without a similar problem. Further review of the dump data indicated that ice caused the valve to burp. Post supply dump purging normally clears any ice in the dump line. The dump isolation valve can be closed should the same problem re-occur after dump. Dump capability will not be lost. Further troubleshooting will be deferred for one flight.</p>

## IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-115-V-14	SSV (Sequential Still Video) Failure	The Sequential Still Video (SSV) unit is used to downlink video from the Orbiter to MCC via the S-Band system through the Payload Data Interleaver (PDI). Initially, a loss of SSV lock on the PDI was reported, and no video was received on the ground. The crew reported that the data indication was that the Light Emitting Diodes (LEDs) on the SSV unit were not lit. The crew then performed a power cycle of the SSV, and the SSV locked to the PDI, but video was not received on the ground. Additional troubleshooting attempts were unsuccessful. Post-flight troubleshooting revealed a failure of a specific integrated circuit on the Motion-JPEG encoder board. The integrated circuit had a "burn mark", which indicated a likely internal short. The circuit card was removed and sent to the Receiving Inspection and Test Facility (RITF) for testing to find the cause of the "burn mark". This failure appears to be a one-time anomaly.
STS-115-V-15	Auxiliary Power Unit (APU) 2 X-Axis Accelerometer Data Erratic	Brief periods of intermittent dropout of the APU-2 X-axis accelerometer to zero g's peak-to-peak were seen beginning at liftoff + 4 seconds (252/15:14:56 GMT) to approximately liftoff + 46 seconds (252/15:15:38 GMT), then returning to nominal performance for the remainder of the ascent APU operations. The APU 2 X-Axis accelerometer was again found to drop out intermittently for short periods of time during entry and was consistent with the behavior observed during ascent. This had no effect on APU performance, safety, nor to APU selection or operation for the mission. No crew actions were required. APUs have x-axis and z-axis accelerometer measurements that are used as a long-term health indicator. Per the Shuttle Operational Data Book (SODB), an APU should not be operated for extended periods of time above 100 g's peak-to-peak in either axis. Both of APU 410's were reading nominally (less than 15 g's peak-to-peak), with no change from its seven previous flights. The accelerometer was replaced post-flight.
STS-115-V-16	APU 2 Exhaust Gas Temperature (EGT) 1 Erratic during Entry	During entry the APU 2 Turbine Exhaust Gas Temperature 1 was found to be erratic. This sensor is a high-temp high-vibration application. There have been many EGT failures in the past and they are well understood. The sensor was removed and replaced.
STS-115-V-17	Docked Air-to-Ground Loop Failure	During uplink of the Flight Day 4 crew wakeup music on Air-To-Ground (A/G) 1, which was configured to the Big Loop (Orbiter to ISS), no corresponding audio was heard on ISS-Ground (S/G) 1. Prior to this, the Big Loop from Orbiter to ISS was operational. Ground and onboard troubleshooting were not successful in restoring the voice communication. After undocking, the Orbiter audio performed nominally. Post-flight audio checks to/from ODS X4 connector (ISS interface) verified good Orbiter circuit-integrity with no repeat of the anomaly.

## IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-115-V-18	S-Band Lower Right Antenna Comm Problems	Throughout the mission, there were numerous S Band PM forward-link communications dropouts. The initial investigation of that data showed that some dropouts occurred on all Orbiter antennas; however, the majority occurred when the lower right (LR) S-Band Quad Antenna was selected. These dropouts were not apparent every time the LR antenna was selected; there were some clean passes while using the LR antenna. This problem was apparent on both String 1 and String 2 as well as on high and low frequency. Overall, the problem was intermittent and varied in severity. Post-flight tests and checkout were performed on the S-Band Quad antenna paths and these showed higher-than-nominal temperatures in the Lower Right coaxial cable path connector. The cable was replaced and temperatures reduced to the nominal range. Further inspection of the removed cable revealed the Teflon insulation at the base of the center pin on the P2 end was missing or damaged. Troubleshooting also found a noisy S-Band pre-amplifier that was contributing to the data dropouts so the pre-amplifier was also replaced.
STS-115-V-19	FES Topping Left Duct Sensor Erratic/Off-Scale Low	After the planned inhibit of the Flash Evaporator System (FES), and approximately 6 minutes before landing, the left-duct temperature sensor on the FES Topping duct system began to show erratic readings that continued through landing. The erratic temperature readings started around 264/10:16 GMT and continued throughout the post-landing period. Drops in temperatures from approximately 140 °F down to 50 and 40 ° F as well as off-scale low were observed within seconds and then returned to values that were observed prior to the anomaly. The readings eventually settled back to pre-anomaly values after several minutes in the post-landing phase. There was no impact to the vehicle/mission. Post-flight troubleshooting revealed a splice in sensor assembly wiring was causing erratic operation. The splice was repaired and the sensor was checked out during flow operations.
STS-115-V-20	Modular Auxiliary Data System (MADS) Built-In Test Equipment (BITE) Indication on Frequency Division Multiplexer (FDM) 2 Multiplexer D	When the MADS was powered up prior to the deorbit burn, the FDM 2 Multiplexer (MUX) D indicated BITE FAIL. Power to the FDM was cycled several times, but the BITE continued to indicate FAIL. After landing, the BITE indication returned to normal. The BITE FAIL indication is triggered by the amplitude of the MUX 4 mixer amplifier output falling 3 dB below its nominal value. Depending on the actual signal amplitude, this condition may make data from the MADS FDM measurements, which comprise this composite signal, unrecoverable from the MADS tape recorder during postflight data reduction. The only FDM 2, MUX D measurement active on STS-115 was a SSME 3 vibration measurement. A review of the MADS FDM data dumped post-flight determined that the data was noisy. The FDM 2 was removed and replaced.

## IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-115-V-21	Nose Cap Expansion Seal RCC Damage	Following the successful landing of OV-104, a chip was revealed on the nose cap lower expansion seal that measured 0.9 by 0.3 in. The defect was not visible during the pre-flight or the on-orbit inspections. Nose-to-chin interference is the leading cause for the defect. The preflight gap in this area was 0.004 in, which is less than the gap criteria of 0.016 and 0.086 in. Although this was accepted from a mechanical loading standpoint, the analysis did not take into account the RCC-to-RCC edge loading that appears to have contributed to this condition. The Nose Cap was repaired successfully, and Chin panel to Nose Cap gaps have been measured and adjustments made to preclude tight gap tolerances. Follow-on activity includes monitoring of this condition at KSC using Infrared (IR) Thermography and Engineering Evaluation.
STS-115-V-22	MADS Failure to Pull Tape	During the MADS De-orbit Checkout at TIG-1 hour, the recorder mode indicated STOP and percent-tape indication did not increment after activation. The MADS recorder telemetry indicated the recorder responded to the "power on" command and a "RCDR BITE Good" and tape-motion events were observed. Post flight, the recorder operated correctly during testing. A ground commanding procedural error was discovered as the cause of the failure.
STS-115-V-23	Main Engine 2 LO <sub>2</sub> Inlet Pressure Transducer Reading Low	The subject transducer read 17 psi lower than the Low Pressure Oxidizer Turbopump (LPOTP) discharge pressure throughout tanking. The low reading exceeds the 3-percent accuracy of 9 psi. Post-flight troubleshooting confirmed that the problem was within the transducer, which was removed and replaced.
STS-115-V-24	Reaction Control System (RCS) Thruster R4R Heater Failed On	During entry, primary RCS thruster R4R injector temperatures indicated that the thruster heater was on through post landing. The signature indicated that the heater remained on until the end of recorded data. Post-flight, the R4R Thruster plus two companion thrusters were removed. The three thrusters were sent to White Sands Test Facility (WSTF) where the thruster R4R will be repaired and the other two companion thruster valves will be flushed and re-verified. The thrusters will be reinstalled after completion of WSTF activities.
STS-115-V-25	Aft Sample Bottles L1 and R2 Leaking	Two bottles, 1076 (LH1) and 1095 (RH2), did not hold the gas samples as reported in the KSC Gas Sample Analysis Report. The bottles were returned to the vendor for Helium leak checks to determine the leak source. No leaks were identified in the bottles. The bottles were also leak tested at JSC following the vendor checks and no leaks were identified. During the last 45 flights, only one bottle failure has been recorded. Based on this analysis, post-flight handling or processing of the bottles was the most likely cause of the lost samples.

## IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-115-V-26	Ku-Band Angle Tracking Problem	Six periods during the flight (each 2 to 5 minutes in duration) were identified where the Ku-Band actual angles seemed to behave abnormally. The signature was similar to what is typically seen due to Orbiter or ISS blockage, but for these 6 events, no known blockage could be initially identified. 2 of the events were later attributed to ISS forward radiator blockage. The sequence of dropping lock and reacquiring repeated (up to 6 times per minute) until the system locked up solid and tracked. The 6 events accounted for about 20 minutes of the 260+ hours of Ku-Band on time. This condition did not appear to affect RADAR operations. Post-flight troubleshooting was unable to repeat the anomaly. The plan is to fly "as is" and monitor Ku-Band operations next mission. A UA was raised with the most probable cause as environmental impact, such as interference or blockage from another source.
STS-115-V-27	Starboard Radiator Micrometeoroid Orbital Debris (MMOD) Strike	During post-flight inspection, KSC personnel identified a large MMOD-related damage on the starboard payload bay radiator number 4. The debris punched all the way through the radiator and the face-sheet hole was 0.108 in. diameter. The core inside the panel was completely destroyed for at least a 1 in. diameter below the face sheet damage. This was the most significant MMOD damage recorded on the Orbiter radiators and second for the Orbiter overall to the payload bay door impact encountered on STS-72. The radiator was successfully repaired.
STS-115-V-28	Closed Circuit Television (CCTV) Monitor 1 Flickering	At the crew debriefing, it was reported that a flickering noise could be heard when the contrast was turned all the way up. There was no impact to functionality or video feed and turning down the contrast made the noise go away. The monitor was removed and sent to JSC for troubleshooting and analysis. A spare unit replaced the faulty unit.
STS-115-V-29	Orbiter Umbilical 16mm ET Separation Camera Lack of Imagery and Focus Problem	Two problems were identified with the 16mm ET Separation Camera System. Camera Assembly (S/N 1003, 10mm lens) captured no imagery because the film did not advance. The anomaly was isolated to a film jam caused by improper loading of the film. The film loading procedure was modified to eliminate repeat of the error. Camera Assembly (S/N 1001, 5mm lens) imagery was found to be slightly out of focus when reviewed by the imagery evaluation personnel. The camera has been shipped to a vendor for lens adjustment.
STS-115-V-30	Thermal Control System (TCS) Ground Straps from the Drag Chute found Near the Chute	Two TCS Ground Straps were found on the runway and a third was found in the drag chute compartment itself during post-flight inspection. The three ground straps were pulled off the blankets in the drag chute compartment due to improper blanket installation which caused the ground straps to be exposed to the mortar in the chute compartment and to pull off during chute deployment. The blankets were reinstalled and fastened correctly. Additionally, there was an unrelated modification which moved one of the ground straps further back in the compartment away from the end of the mortar.



## IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-115-V-31	Launch Entry Suit (LES) Missing Breathing Regulator Mounting Block Fastener	During post-flight checkout, a technician discovered a missing fastener and two adjacent fasteners that were finger-loose. The helmet regulator provides 100-percent of the oxygen to the crewperson via the Launch And Entry Helmet. A final root cause has not been determined; the investigation concluded this was an unexplainable anomaly. Additional inspection points were added as good engineering practice.
STS-115-V-32	MADS Left OMS Pod LRSI Surface Temp OSH	Just prior to launch, at T-4 seconds, the MADS Left OMS Low-Temperature Reusable Insulation (LRSI) measurement started ramping up from a near nominal ambient temperature of 87.8 °F to an Off-Scale High (OSH) value during ascent. The sensor remained OSH for the duration of the mission. The measurement, which is used for thermal trend analysis, remained OSH post-flight. Further troubleshooting will be deferred for one flight.

## **IN-FLIGHT ANOMALIES SOLID ROCKET BOOSTER**

No SRB in-flight anomalies were identified during the review of the data and its evaluation.

## IN-FLIGHT ANOMALIES REUSABLE SOLID ROCKET MOTOR

IFA Number	Title	Comments
STS-115-M-001	Gas Penetration in Joint 5 Room Temperature Vulcanizing (RTV) Material	Gas penetration was observed through the RTV in a non-contact region of the Left-Hand (LH) nozzle joint 5 at 317 degrees. No heat effects to the RTV or phenolic surfaces were observed, and no soot was observed to the primary O-ring. These conditions were re-evaluated and are well within family. Cause is understood and analytical expectations are unchanged. There are no challenges to established flight-safety rationale.
STS-115-M-002	Gas Paths in Left Hand Joint 2 RTV	Two distinct gas paths through the LH joint 2 RTV were observed at 140 and 258 deg. Non-distinct gas penetrations through the RTV were observed intermittently for the full circumference on both the LH and Right-Hand (RH). Soot was observed to LH primary O-ring from 126-138, 165, 204-228, and 324-336 degrees, and soot was observed to RH primary O-ring from 320-0-5 degrees. No soot was observed past the primary O-ring on either motor as well as joint metal surfaces, O-rings, and port plugs, which were in good condition with no anomalies observed. These conditions were re-evaluated and are well within family. Cause is understood and analytical expectations are unchanged. There are no challenges to established flight safety rationale.

## IN-FLIGHT ANOMALIES EXTERNAL TANK

IFA Number	Title	Comments
STS-115-T-01	Liquid Hydrogen (LH <sub>2</sub> ) Engine Cutoff (ECO) Sensor Circuit	While filling the External Tank (ET) during the morning of September 8, 2006, Liquid Hydrogen (LH <sub>2</sub> ) Engine Cutoff (ECO) sensor no. 3 indicated dry when it should have been wet. The anomaly was isolated to a defect in the electrical circuit that cannot interact with the three other sensor circuits. The design was modified to replace the 1993 vintage sensors with 2003 production sensors for follow-on ETs.
STS-115-T-02	Accelerometer T08D9070A (327A502) was non-operational past approximately 48 sec after Main Engine Ignition (54 seconds MEI)	Data was received for ~48 sec. then no data was received for LO <sub>2</sub> Cable Tray Radial Measurement T0809070A. The available data does not indicate the cause of this measurement failure and probable cause will be investigated. Loss of these data are not considered a safety of flight concern, as additional instrumentation in the cable tray performed throughout the flight regime as expected and structural integrity of the cable tray was not compromised.
STS-115-T-03	LH <sub>2</sub> Acreage, Xt1306 (PDL Repair, )	Approximate Dimension using known hardware geometry is 3.4”L by 2.4”W by .95”. Density - 3.44 lb/ft <sup>3</sup> / NCFI 2.43 lb/ft <sup>3</sup> , Mass - ~0.005 lbm, MET ~170 seconds. NSTS 60559 Requirement ET-LH2T-002-02-A was violated (≤135 seconds: 0.004 lbm, > 135 seconds: 0.015 lbm). Probable Cause is Void Cryogenic-Pumping. Void at the substrate would likely result in the loss of the entire repair, as evidenced by separation imagery.
STS-115-T-04	LO <sub>2</sub> Feedline Yoke Support Bracket, Xt1377	Approximate dimension using known hardware geometry is 3.50” by 2.2” by 2.8” (Major dimension). Density – 1.92 lb/ft <sup>3</sup> , Mass – 0.024 lbm, MET 27 sec. NSTS 60559 Requirement ET-COMP5-139-00-A was violated ≤135 seconds: 0.013 lbm, > 135 seconds: 0.013 lbm) Probable cause is the cracking of the TPS due to mechanical interference with “gap ice” coupled with aero shear.

## IN-FLIGHT ANOMALIES SPACE SHUTTLE MAIN ENGINE

IFA Number	Title	Comments
STS-121-E-01	High Pressure Fuel Pump Channel B Speed Sensor Hashy	At Space Shuttle Main Engine (SSME) start plus 255 sec, the High Pressure Fuel Turbopump (HPFTP) Channel B Speed Sensor became hashy. This same anomaly occurred on STS-111, and as a result, discriminator logic was implemented for all future flights. Redundant sensor channel and pump/engine performance data confirm nominal engine and pump performance. The HPFTP shaft speed is monitored from SSME start plus 1.40 sec to Engine start plus 1.44 sec for ignition confirm redline. New AHMS synchronous vibration logic has speed sensor redundancy built into redline. Loss of channel A defaults to channel B and if both are disqualified, a loss of redline protection occurs.
STS-115-E-02	SSME Fuel Flow meter Kf Shift	A 30-degree (approximately 0.75 percent) shift in the High Pressure Oxidizer turbopump (HPOTP) turbine discharge temperature was noted prior to Maximum Dynamic Pressure (Max Q) throttle down. This reduction resulted in lower-than-expected fuel consumption. The engine flow meter returned to as-expected Kf performance when the SSME entered the 72 percent power level bucket at 41 seconds. The ICD limit is $\pm 1$ percent error; however, the practice is to remove the duct and fuel flow meter from the flight program with $\leq 0.5$ percent shift during mainstage operations.

## IN-FLIGHT ANOMALIES SYSTEM ENGINEERING AND INTEGRATION

IFA Number	Title	Comments
STS-115-I-002	SSME 1 Fuel Flow Measurement Shift	Several measurements indicated a fuel flowmeter shift occurred at approximately 40 sec after SSME start. A determination will be made on whether the existing controls for the engine flowmeter shifts are proper and adequate, given this type of performance shift in a flowmeter. Reference STS-115-E-02.
STS-115-I-003	SRB EDAS Channel 4 Data Dropped at 50 seconds MET.	The LO <sub>2</sub> Cable Tray Radial accelerometer, located on the fixed cable tray end, channel 4 recorded approximately 50 seconds of valid ET LO <sub>2</sub> PAL ramp accelerometer data. Valid data should have been recorded through SRB separation. SRB has cleared the hardware through post-flight inspection and testing. Reference STS-115-T-02.
STS-115-I-004	LH <sub>2</sub> Low Liquid Level Sensor no. 3 Failed Wet	The LH <sub>2</sub> Engine Cutoff Sensor (ECO) no. 3 failed the Pre-Replenish sensor checkout during the September 8, 2006 LH <sub>2</sub> tanking. The launch attempt was scrubbed due to violating the MPS-22 Launch Commit Criteria (LCC). The ECO sensor checkout results indicated that the LH <sub>2</sub> ECO sensor no. 3 failed wet when both the wet and dry simulation checkout commands were applied. The STS-114 and -121 IFA's were closed and documented in the STS-115 ILFA, with referenced KSC paper traceability. Reference STS-115-T-01.
STS-115-I-005	Forward Reaction Control System (FRCS) Thruster F4D Late Tyvek Release	During ascent, ground imagery indicated thruster F4D's Tyvek rain cover released at 16.4 seconds MET. The approximate vehicle velocity was 354 ft/sec (240 mph). The thruster covers release certification requirement is 170 mph. Reference STS-115-V-05.
STS-115-I-006	TPS Tile Anomalies	The shim stock was protruding significantly from the left (port) ET door. The 3-D convergent photogrammetry gives the maximum height above the tiles as 1.6 ± 0.15 inches. The total length when seen from above was 5.2 ± 0.15 inches. Reference STS-115-V-08.
STS-115-I-007	SSME GN <sub>2</sub> Purge Control Valve in Main Launch Platform (MLP) was slow to cycle	During SSME purge initiation per S1003 procedures, it was noted that the SSME GN <sub>2</sub> control valve on the MLP took 26 seconds to open and it should have opened in approximately 6 seconds. Resistance tests were completed on the relay modules. Circuits had appropriate infinite resistance. Therefore, this condition is not a generic hardware problem. Conductive residue was found inside the failed relay.
STS-115-I-009	Lift-Off Debris	Debris found during the post-launch Pad walk-down inspections or seen with imagery from numerous camera sources. Mitigation plans are in-work.
STS-115-I-010	Firex Line Leakage in MLP compartment 44A.	A small leak was found from the 1/8 in diameter hole in 6-in Orbiter Firex line. A hole in the pipe had plug installed to stop leak to support wash-downs. The pipe section was inspected for any signs of a systemic corrosion problem. Past pin hole leaks have had a non-destructive evaluation (NDE) and only isolated corrosion was found. Leak was found to be due to pipe corrosion.

## IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-115-I-011	Missing TPS Tiles	TPS was missing from a corner of bracket at the outboard (+Y) side of LO <sub>2</sub> Feedline. Possible correlation to 27, 64, or 71 sec debris spray event in NASA Reporting Imagery Database (NRID). The ET Project, using the LM CATIA model, assessed this loss to be 0.024 lb mass @ 27.3 seconds. Reference STS-115-T-04.
STS-115-I-012	Suspect Impacts on Single Aft Booster Separation Motor (BSM) Cover TPS	The Post-retrieval analysis was unable to determine the debris source or time of impact. Significant heat effects support potential ascent time frame. Impact was within the damage tolerance limits. However, the impact was above Cycle 1 DTA limit for ice of 643 in-lb. Close as UA for STS-116.

## IN-FLIGHT ANOMALIES

### FLIGHT OPERATIONS & INTEGRATION

IFA Number	Title	Comments
STS-115-N-01	Increased Orbiter Carbon Dioxide (CO <sub>2</sub> ) Levels	Although Shuttle IRCO <sub>2</sub> sensor and ISS CO <sub>2</sub> sensors tracked well with each other the entire flight and CO <sub>2</sub> levels remained below the 7.6 mmHg, at the post-flight debrief the crew commented about CO <sub>2</sub> levels during docked sleep periods. The ECLSS Joint Technical Working Group concluded that the crew symptoms from high CO <sub>2</sub> levels most likely resulted from localized CO <sub>2</sub> build up due to a variety of configuration changes made on orbit as well as crew choice to sleep in ventilation “dead spaces”. A recommendation was made to raise the crew awareness of the need to avoid blockage of air flow passages, choosing sleep locations with adequate air flow, as well as increased coordination between the Surgeon and EECOM, and MER ATCS on crew status and Lithium hydroxide (LiOH) management.
STS-115-N-02	Docked Air-To-Ground Loop Failure	Reference STS-115-V-17.
STS-115-N-03	Inadvertent Return of Battery Powered Speaker Microphone Unit (BPSMU) Cable	During post dock on-orbit preparations, the STS-115 flight crew and the ISS crew discovered two BPSMU cables and one adapter missing from the ISS staged compliment. This prevented Orbiter Crew from hearing Orbiter Caution and Warning audio while in the ISS. MOD/DX33 provided a real-time alternate plan with the final version using the Hand-Held Microphone and the BPSMU unit on the Flight Deck. The Flight Crew Equipment office reviewed the Crew Compartment Configuration Drawing (CCCD) process and instituted an additional process to verify all returned flight hardware and identify an inconsistencies, including extra surplus items following a flight.



## IN-FLIGHT ANOMALIES

### MISSION OPERATIONS

IFA Number	Title	Comments
STS-115-D-001	Abort Region Determinator (ARD) Loss at 14 sec MET	The ARD Flight Dynamics Officer (FDO) abort assessment tool was lost for use at 14 sec MET when it was moded to compute a Return To Launch Site (RTL) abort due to an erroneous telemetry frame received at the Mission Control Center (MCC). The ARD cannot be reset once it has been initialized. Consequently, abort regions for the remainder of ascent were computed using backup procedures that use no communications pre-launch abort velocities and real-time tracking data. The ARD Monitor Display was susceptible to a single erroneous telemetry input. The exact cause of the telemetry frame error has not been determined with the most probable cause was a ratty data transmission due to Orbiter S-Band antenna switch at approximately 14 sec MET. This condition is known to occur during antenna switches. There has been no previous occurrence of an erroneous telemetry frame or frames affecting the ARD. For STS-116, a three-frame counter was planned for implementation on the four telemetry parameters used to initiate aborts.
STS-115-D-002	MCC Onboard Fault Summary Tool Loss of Function	On FD 9, the MCC Onboard Fault Summary (OFS) Primary Avionics Software System (PASS) tool failed, and the failure was not detected for a period of 20 minutes. The OFS processes downlinked fault codes into fault messages for use in the MCC, and serves as an aid in monitoring vehicle status. The OFS tool failure in this specific instance was caused by out-of-limit data which the computation received during a period of ratty communications. Automated console tools attempted two restarts, but these were unsuccessful since the period of ratty communications was longer than the time allowed for restarts. In addition, no status of the specific condition was provided by the console tool. The OFS will be modified to increase the number of restarts to 10 and tool failure indications are under evaluation. A workaround will be provided for STS-116, if the planned change is not available.
STS-115-D-003	Incorrect Orbiter Boom Sensor System/Intensified Television Camera (OBSS/ITVC) Pan Value Limit	The STS-115 OBSS/ITVC flight documentation and procedures were based on incorrect OBSS/ITVC pan angle limits. During the FD12 late vehicle inspection, the crew called down that the ITVC could not be panned to +195 deg as called out in the procedure. The ITVC could not be panned past + 178 deg. Prior to STS-114, a cable issue on the OBSS pan-tilt unit was identified. The cable routing/length was modified and the hardware hard stops were set to more restrictive. The hard stop limit change was communicated to MOD personnel working STS-114 via email. However, this change was not fully communicated to personnel working subsequent mission planning as well as simulator personnel. The OBSS documentation will be updated for STS-116 and subsequent to reflect the limits after the limits have been verified using the flight hardware.

## IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-115-D-004	Elevon Positioning for Inspection Procedure Error in Flight Data File (FDF)	In the Elevon Positioning for Inspection Procedure in the Flight Data File, the step number references for Data Processing System (DPS) G2 to G8 and G8 to G2 transition procedures were incorrect by one step number. The procedure was not actually used on STS-115; however, the errors were discovered during an on-console review of the procedure in preparation for possible use for the FD12 late vehicle inspection.
STS-115-D-005	Incorrect Payload Data Interface Panel (PDIP) Power Switch Nomenclature Post-Insertion FDF	The PDIP-2 Power Switch nomenclature in the flown STS-115 Post-Insertion FDF did not match the OV-104/STS-115 panel nomenclature. The switch nomenclature was updated at the Flight Operations Review (FOR) with formal paperwork. Also, the STS-115 FDF nomenclature matched the nomenclature on the overlay in the Shuttle Mission Simulator (SMS). At some undetermined date, the switch nomenclature was changed on the OV-104 panel and MOD did not receive formal notification. For STS-116 and subsequent flights, MOD will verify all vehicle/flight unique FDF panel nomenclature using photographs of the actual vehicle panels.

## **APPENDIX C**

### **DOCUMENT SOURCES**

#### **MER DAILY REPORTS**

The following STS-115 MER Daily Reports by David S. Moyer, Lead MER Manager:

First Daily Report (Ascent Plus 2-Hour Report), dated September 10, 2006

Second Daily Report, dated September 10, 2006

Third Daily Report, dated September 11, 2006

Fourth Daily Report, dated September 12, 2006

Fifth Daily Report, dated September 13, 2006

Sixth Daily Report, dated September 14, 2006

Seventh Daily Report, dated September 15, 2006

Eighth Daily Report, dated September 16, 2006

Ninth Daily Report, dated September 17, 2006

Tenth Eleventh Daily Report, dated September 18, 2006

Eleventh Daily Report, dated September 19, 2006

Twelfth Daily Report, dated September 20, 2006

Landing Plus 2 Hour Report, dated September 22, 2006

#### **ET/SRB/RSRM/SSME REPORTS**

STS-115 SRB, RSRM and ET Console Flash Report, David W. Moor, USA-Huntsville, received September 10, 2006.

STS-115 Preliminary Event Times, David W. Moor, USA-Huntsville, received September 10, 2006.

STS-115 RSRM Executive Summary, Larry Manuel, ATK-Huntsville, received October 6, 2006.

#### **ORBITER REPORTS**

STS-115 Orbiter IFA's, Malise Fletcher, NASA-JSC (MV6) received October 20, 2006

STS-115 Landing and Deceleration System, Chip C. Heinol, Boeing-Houston, received October 17, 2006.

STS-115 Auxiliary Power Unit System, Christopher N. Adi, Boeing-Houston, received October 13, 2006

STS-115 Electrical Power and Distribution and Control, P. Peterson, Boeing-Houston,, received October 9, 2006

STS-115 MPS Mission Report, Mohammed M. Jebiril, Boeing-Houston, received October 13, 2006.

STS-115 MEDS Report, Christopher Gentz, Boeing-Houston, received October 11, 2006

STS-115 OI/MADS Mission Reports, Dwight A. Favors, Boeing-Houston, received October 11, 2006.

STS-115 MADS Recorder Data, Reynaldo Rivas, Boeing-Houston, received October 11, 2006

STS-115 Data Processing System, James Cooley. Boeing-Houston, received October 10, 2006

STS-115 D & C Post Mission Summary, Quoc F. Ngo, Boeing-Houston, received October 13, 2006.

STS-115 ATCS Post-Flight Mission Report, Christopher Hoffman, Boeing-Houston, received October 13, 2006  
STS-115 Life Support Systems Report (ARPCS and Airlock Systems; Supply Water and Waste Water Management, and Fire and Smoke Detection System), Isaac Andu, Boeing-Houston, received October 16, 2006  
STS-115 Flight Control Systems, Donald L. McCorvey, Boeing-Houston, received October 13, 2006  
STS-115 Orbiter Docking System, Chip C. Heinol, Boeing-Houston, received October 17, 2006.  
STS-115 Hydraulics-WSB System, Daniel Zalit, Boeing-Houston, received October 13, 2006.  
STS-115 Land and Descent System, Chip. C. Heinol, Boeing-Houston, received October 20, 2006  
STS-115 OMS Report, Donald E. Varanauski, Boeing-Houston, received October 13, 2006  
STS-115 RCS Mission Report, Mickie Equia, Boeing-Houston, received October 13, 2006  
STS-115 Aeroheating Report, Darwin G. Moon and Dennis C. Chao, Boeing-Houston, received September 29, 2006  
STS-115 Orbiter IFA Inputs, Michael D Wright, JSC-MV6, received October 20 and November 15, 2006  
STS-115 Fuel Cells and PRSD Mission Report, Johnny D. Wong, Boeing-Houston, received October 13, 2006.  
STS-115 Flight Software Report, Stephen D, Jayne, Boeing-Houston, received November 1, 2006  
STS-115 ADTA Report, Howard A. Damoff, Boeing—Houston, received October 12, 2006.  
STS-115 Communications and Tracking Report, Martha M. May, Boeing-Houston, received October 12, 2006  
STS-115 Power Reactant Storage and Distribution Report, Johnny D. Wong, Boeing-Houston, received October 13, 2006  
STS-115 Global Positioning System Report, Ray W. Nuss, NASA-JSC, received October 10, 2006  
STS-115 WLE IDS Post Flight Report, Jennifer C. Babst, Boeing-Houston, received January 2, 2006.  
STS-115 Thermal Control System Mission Summary, Kent K. Rowley, Boeing-Houston, received August 10, 2006.  
STS-115 Structures and Mechanical Report, Jeffrey A. Goodmark & Link J. Salvador, Boeing-Houston, received date unknown.  
STS-115 Sample Bottle Data, Keith E. Van Tassel, NASA-JSC, received date unknown.

## **OTHER REPORTS**

STS-115 Postlaunch Pad Inspection, Jeffrey S. Thon, NASA-KSC, received October 26, 2006  
STS-115 Landing and Debris Map, Thomas F. Ford, NASA-KSC, received December 4, 2006  
STS-115 Preliminary Debris Assessment, Thomas F. Ford, NASA-KSC, received December 4, 2006  
STS-115 Remote Manipulator and Orbiter Boom Sensor System, Leissa Smith, MDAC Corporation-Houston, received October 16, 2006  
STS-115 CSR Final Report, Michael Darnell, JSC-MO3, received November 30, 2006  
STS-115 EVA Report, Maria Tullar, NASA-JSC, received November 2, 2006.  
STS-115 Payload and Experiments Report, Michael Darnell, NASA-JSC, received November 30, 2006  
STS-115 Final Mission Events List, Vernon C. Hill, ESCG-Houston, received August 21, 2006.

## **APPENDIX D**

### **ACRONYMS AND ABBREVIATIONS**

<b><u>Acronym</u></b>	<b><u>Explanation</u></b>
AC	alternating current
ADTA	Air Data Transducer Assembly
ADP	Air Data Probe
AFD	Aft Flight Deck
AFRSI	Advanced Flexible Reusable Surface Insulation
A/G	Air-To-Ground
AGC	Automatic Gain Control
AGIT	Antenna Group Interface Tube
AGT	adaptive guidance throttling
AMOS	Air Force Maui Optical and Supercomputing Site
APFR	Articulating Portable Foot Return
APU	Auxiliary power unit
ARPCS	Atmospheric Revitalization Pressure Control System
ARS	Atmospheric Revitalization System
ASA	Aerosurface Actuator
ASP	Astronaut Support Person
ATCS	Active Thermal Control System
BFC`	Backup Flight Controller
BFS	Backup Flight system
BGA	Beta Gimbal Assembly
BGTS	Beta Gimbal Transition Structures
BLT	Boundary Layer Transition
BITE	built-in test equipment
BSM	Booster Separation Motor
BSP	Baseband Signal Processor
CCU	Crew Communications Unit
CDR	Commander
CETA	Crew Equipment Transition Aid
CID	Circuit Interrupt Device
CRT	Cathode Ray Tube
CST	comprehensive self-test
CT	Control Thermostat
CWC	contingency water container
CWS	Centenary Wire System
DBIA	Data Bus Isolation Amplifier
DBS	Data Bus Couplets
D&C	Displays and Controls
DCP	Docking Control Panel
DDU	display driver unit
DLA	Drive Lock Assemblies
DOD	Department of Defense
DPS	Data Processing System
$\Delta p/\Delta T$	Differential Pressure/Differential Temperature
DTA	Debris Transport Analysis
DTN	Data Trend Notification

DTO	Development Test Objective
$\Delta V$	Differential Velocity
ECLSS	Environmental Control and Life Support System
ECO	engine cutoff
ECU	Electronics Control Unit
EGT	Exhaust Gas Temperature
EI	Entry Interface
EIU	Engine Interface Unit
EMU	extravehicular mobility unit
EOM	End of Mission
EPDC	Electrical Power Distribution and Control
ERCA	EMU RF Camera Assembly
ET	External Tank
ETA	ET Attachment
ETD	ET Door
ETRS	EVA Temporary Rail Stop
EVA	extravehicular activity
FA	Flight Aft
FBMBT	flexible bearing mean bulk temperature
FC	Fuel Cell
FCMS	Fuel Cell Monitoring System
FCS	Flight Control System
FDA	Fault Detection and Annunciation
FD	Flight Day
FDM	Frequency Division Multiplexer
FOM	Figure of Merit
FES	Flash Evaporator System
FOD	Foreign Object Debris
FRCS	Forward Reaction Control System
FRSI	Flexible Reusable Surface Insulation
GAP	Group Activation Pack
GEI	ground environmental instrumentation
GG	Gas Generator
GMT	Greenwich mean time
GOX	Gaseous Oxygen
GPC	General Purpose Computer
GPS	Global Positioning System
GUCA	ground umbilical carrier assemblies
HIU	Headset Interface Unit
HPFTP	high-pressure fuel turbopump
HPGT	High Pressure Gas Tank
HPOTP	high-pressure oxidizer turbopump
HYD	Hydraulics
IBA	Inspection Boom Assembly
ICD	Interface Control Document
ICOM	Intercommunications
IDC	Integrated Digital Camera
IEA	Integrated Equipment Assembly
IFA	In-flight anomaly
IR	Infrared
ISIS	Integrated Sensor Inspection System

ISS	International Space Station
ITS	Integrated Truss Segment
JSC	Lyndon B. Johnson Space Center
KBU	Keyboard Unit
KSC	John F. Kennedy Space Center
lbm	pounds mass
LCC	Launch Commit Criteria
LCS	Laser Camera System
LDRI	Laser Dynamic Range Imager
LESS	Leading Edge Structural System
LED	Light Emitting Diode
LES	Launch/Entry Suit
LH	left hand
LiOH	Lithium Hydroxide
LPOTP	Low Pressure Oxidizer Turbopump
LR	Lower right
LRSI	Low Temperature Reusable Surface Insulation
MADS	Modular Auxiliary Data System
MAUI	Maui Analysis of Upper Atmosphere Injections
MAGR	Miniature Airborne-To-Ground Receiver
MCA	Motor Control Assembly
MCC	Mission Control Center
MDM	Multiplexer/Demultiplexer
MDU	multifunction display unit
MEC	Master Events Controller
MECO	main engine cutoff
MEDS	Multifunction Electronic Display System
MER	Mission Evaluation Room
MET	mission elapsed time
MIA	Multiplexer Interface Adapter
MIP	Mission Integration Plan
MISSE	Material International Space Station Experiment
Mlbf	Million pounds force
MLP	Main Launch Platform
MMOD	MicroMeteoroid Orbital Debris
MMT	Mission Management Team
MPM	manipulator positioning mechanism
MPS	Main Propulsion System
MRL	manipulator release latch
MRTAS	Manual Rocketdyne Truss Attachment System
MS	Mission Specialist
MSS	Mobile Servicing System
MT	Mobile Transporter
MUX	Multiplexer
N/A	not applicable
NASA	National Aeronautics and Space Administration
NAVAID	Navigation Aid
NLT	No less than
nmi	Nautical mile
NMT	No more than
NPV	Non-Propulsive Vent

OAA	Orbiter Access Arm
OBSS	Orbiter Boom Sensor System
ODS	Orbiter Docking System
OI	operational instrumentation
OMRSD	Operational Maintenance Requirements and Specifications Document
OMS	Orbital Maneuvering System
ORGA	Orbiter rate gyro assembly
OSH	Off-Scale High
OV	Orbiter Vehicle
PAL	Protuberance Air Load (Ramp)
PASS	Primary Avionics Software System
PCM	Pulse Code Modulation
PCS	Pressure Control System
PDI	Payload Data Interleaver
PEC	Passive Experiment Container
PGME	Propylene Glycol Monomethyl Ether
PGSC	payload general support computer
PLBD	payload bay door
PM	Phase Modulation
PMBT	propellant mean bulk temperature
PMZ	Promethazine
POR	Point of Resolution
ppCO <sub>2</sub>	Partial Pressure Carbon Dioxide
ppm	parts per million
PRSD	Power Reactant Storage and Distribution System
PRT	Problem Resolution Team
psia	Pound per square inch
Psig	Pound per square inch gravity
PV&D	Purge, Vent, and Drain
PVR	Photovoltaic Radiator
PVM	Photovoltaic Module
PWR	payload water reservoir
RAMBO	Ram Burn Observation
RCC	reinforced carbon-carbon
RCS	Reaction Control System
RF	Radio Frequency
RH	right hand
RHC	rotational hand controller
RITF	Receiving Inspection and Test Facility
RJD	reaction jet driver
RM	Redundancy Management
RMS	Remote Manipulator System
ROOBA	Recharge Oxygen Orifice Bypass Assembly
RPC	Remote Power Controller
RPDA	Remote Power Distribution Assembly
RPM	R-bar pitch maneuver
RSB PDU	Rudder/Speed Brake Power Drive Unit
RSC	RMS Sideview Camera
RSRM	Reusable Solid Rocket Motor
RTV	Room Temperature Vulcanizing (Material)



S&A	safe and arm
SASA	S-Band Antenna Support Assembly
S/N	serial number
SARJ	Solar Alpha Rotary Joint
SAW	Solar Array Wing
SAWBB	Solar Array Wing Blanket Box
SDBI	Short Duration BioAstronautics Investigation
SDFS	Smoke Detection and Fire Suppression
SDTO	Secondary Development Test Objective
S/G	Space to Ground (Comminuncations)
SIM	Sensor Interface Module
SLWT	Super LightWeight (ET)
SMRD	spin motor rotation detector
SODB	Shuttle Operational Data Book
SP	sensor package
SRB	Solid Rocket Booster
SRGA	station rate gyro assembly
SRMS	Shuttle Remote Manipulator System
SRSS	Shuttle Range Safety System
SSME	Space Shuttle Main Engine
SSP	Space Shuttle Program
SSRMS	Space Station Remote Manipulator System
SSU	Sequential Shunt Unit
SSV	Sequential Still Video
STS	Space Transportation System
SVS	Space Vision System
TAEM	Terminal Area Energy Management
TDRSS	Tracking and Data Retrieval Satellite System
TCS	Thermal Control System
THC	transitional hand controller
TI	Target Intercept
TPS	Thermal Protection System
Tropi	European Modular Cultivation System
TSA	Tool Stowage Assembly
TSM	Tail Service Mast
TVC	thrust vector controller
UA	Unexplained Anomaly
UCCAS	Unpressurized Cargo Carrier Attachment System
USOS	United States On-Orbit Segment
VAB	Vehicle Assembly Building
WLE	wing leading edge
WLEIDS	Wing Leading Edge Impact Detection System
WSB	water spray boiler
WSTF	White Sands Test Facility

Abbreviated Form	Explanation
A	Ampere
CO <sub>2</sub>	Carbon Dioxide
dB	Decibel
deg/sec	degree per second
°C	degree Centigrade
°F	degree Fahrenheit
ΔV	differential velocity
Ft	feet
g	gravity
GH <sub>2</sub>	gaseous hydrogen
GN <sub>2</sub>	gaseous nitrogen
GO <sub>2</sub>	gaseous oxygen
H <sub>2</sub>	hydrogen
He	Helium
hr	hour
I <sub>sp</sub>	specific impulse
kA	Kilo amperes
kWh	kilowatt hour
Lb	pound
LiOH	lithium hydroxide
LH <sub>2</sub>	liquid hydrogen
LO <sub>2</sub>	liquid oxygen
min	minute
mmHg	Millimeters Mercury
Mph	miles per hour
Pc	chamber pressure
sec	second
T	time
Vdc	Volt direct current