

STS-111 SPACE SHUTTLE MISSION REPORT

July 2002



**National Aeronautics and
Space Administration**

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

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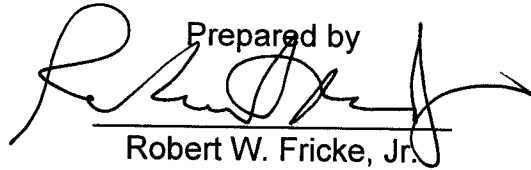
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SPACE SHUTTLE

MISSION REPORT

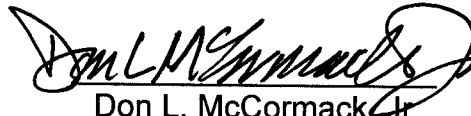
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INTRODUCTION

The Space Transportation System (STS) -111 Space Shuttle Program Mission Report presents a discussion of the Orbiter activities of the mission, as well as presenting a summary of the External Tank (ET), Solid Rocket Booster (SRB), Reusable Solid Rocket Motor (RSRM), and Space Shuttle main engine (SSME) performance during this one-hundred and tenth mission of the Space Shuttle Program. The STS-111 flight was the fourteenth flight to the International Space Station (ISS). STS-111 was the eighty-fifth mission since the return to flight, and the eighteenth flight of the OV-105 (Endeavour) vehicle.

The flight vehicle consisted of the Orbiter vehicle (OV) -105 Orbiter; an ET, which was the fourteenth Super Lightweight Tank (SLWT), and it was designated ET-113; three Block II SSMEs that were designated as S/Ns 2050, 2044 and 2054 in positions 1, 2 and 3 respectively, and two SRBs that were designated BI113. The two RSRMs were designated RSRM-84 with one installed in each SRB. The individual RSRM serial numbers were 360W084A for the left SRB and 360W084B for the right SRB.

The primary objective of the STS-111 mission was the delivery and integration of the Utilization Flight (UF) -2 launch package (LP) to the orbiting ISS Stage 8A; and included ISS crew rotation of three crewmembers. The LP consisted of a passive Multi-Purpose Logistics Module (MPLM), a Mobile Remote Servicer (MRS) Base System (MBS), Space Shuttle Remote Manipulator System (SSRMS) wrist roll joint (WRJ), and two Assembly Power Converter Units (APCUs) with interconnecting cabling and mounting brackets, as well as payload and stowage items located in the Orbiter middeck.

The MPLM transported eight resupply stowage racks (RSRs), five resupply stowage platforms (RSP)s), and two international standard payload racks (ISPR). The MPLM is used to transfer logistics and utilization items to and from the ISS.

A power data grapple fixture (PDGF) was integrated on the port side of bay 13 on an increased capacity adaptive payload carrier (ICAPC). The PDGF was installed on the P6 Truss during an extravehicular activity (EVA). Six Service Module Debris Panels (SMDP) were integrated into bay 13 (starboard side) on a Get Away Special (GAS) beam. The SMDP was temporarily stowed on the Pressurized Mating Adapter (PMA) -1 during the extravehicular activities (EVAs).

The Ram Burn Observation (RAMBO) payload was flown as a secondary middeck payload and a payload of opportunity. The RAMBO payload required one dedicated dual-engine orbital maneuvering subsystem (OMS) firing and a pre-burn state vector for burn-monitoring predictions.

The STS-111 flight was planned as an 12 day, plus 2-contingency-day flight, of which eight days were to be docked to the ISS. The two contingency days were available for landing weather avoidance or other Orbiter contingency operations. The sequence of mission events is shown in Table I, and the Orbiter In-Flight Anomaly List is shown in Table II.

All times during the flight are given in Greenwich mean time (G.m.t.) and mission elapsed time (MET). Appendix A lists the sources of data, both formal and informal, that were used in the preparation of this report. Appendix B provides the definition of acronyms and abbreviations used throughout this report.

The 10 crewmembers that were on the STS-111 mission consisted of the four Shuttle crewmembers, and six ISS-rotation crewmembers (three Expedition 5 crewmembers (ascent) and three Expedition 4 crewmembers (descent)). The four-person crew of the STS-111 Shuttle flight consisted of Kenneth D. Cockrell, Civilian, Commander; Paul S. Lockhart, Lt. Col., USAF, Pilot; Philippe Perrin, Colonel, French AF, Mission Specialist 1; and Franklin R. Chang-Diaz, Civilian, Mission Specialist 2. The Expedition 4 crew, returning from over 180 days on the ISS, consisted of Yuri I. Onufrienko, Cosmonaut, Colonel, Russian Air Force (Retired), Commander; Daniel W. Bursch, Captain, U. S. Navy, Flight Engineer; and Carl E. Walz, Colonel, U. S. Air Force, Flight Engineer. The Expedition 5 crew, who were taking up residence in the ISS, consisted of Peggy A. Whitson, Ph.D., Civilian, Flight Engineer; Valery G. Korzun, Cosmonaut, Colonel, Russian Air Force, Commander; and Sergei Y. Treschev, Cosmonaut, Civilian, Flight Engineer.

STS-111 was the seventh space flight for Mission Specialist 2, the fifth space flight for the Shuttle Commander, and the first space flight for the Pilot and Mission Specialist 1. Both Expedition 4 Flight Engineers (Bursch and Walz) completed their fifth Space Shuttle flight and their first long-duration space flight, and Expedition 4 Commander completed his second Space Shuttle flight and his second long-duration space flight. The Expedition 5 Commander (Korzun) began his first Space shuttle flight and began his second long-duration flight after having completed one long-duration (197 days) space flight on the Russian Mir 22 mission; both flight engineer Treschev (Mission Specialist 5) and Expedition 5 Flight Engineer Whitson began their first space flight in a Space Shuttle and began their first long-duration space flight.

MISSION SUMMARY

The launch of STS-111 was planned for May 30, 2002; however, because of adverse weather in the launch area, the countdown was stopped while in the T-9 minute hold. The launch was rescheduled to Friday, May 31, 2002, but adverse weather was again predicted, and the Mission Management Team (MMT) met and rescheduled the launch for Monday, June 3, 2002, with a proviso that the launch could slip one more day because of weather projections for Monday at Kennedy Space Center (KSC). At a subsequent MMT meeting it was decided that a leaking gaseous nitrogen (GN₂) regulator in the orbital maneuvering subsystem (OMS) required removal and replacement (Flight Problem STS-111-V-01). The effort to complete this replacement resulted in the launch being rescheduled for Wednesday, June 5, 2002.

The STS-111 mission was launched at 156:21:22:49.008 G.m.t. on June 5, 2002, on the fourteenth mission to the International Space Station (ISS). All Orbiter subsystems performed satisfactorily during ascent.

An OMS assist maneuver was performed following Solid Rocket Booster (SRB) separation. The maneuver was initiated at 156:21:25:03.1 G.m.t. (00:00:02:114.1MET) and was 48.4 seconds in duration.

The OMS 2 maneuver was performed at 156:22:01:33.9 G.m.t. (00:00:38:44.9 MET) and was 62.8 seconds in duration. The differential velocity (ΔV) was 95.2 ft/sec, and the orbit was 85.0 by 126.7 nautical miles (nmi) following the maneuver. The OMS performed satisfactorily throughout the maneuver.

The payload bay doors (PLBDs) were opened as planned at 156:22:59:13 G.m.t. (00:01:01:36:23 MET). All voltages were nominal and the motors opened the doors in nominal dual-motor time.

Early in the mission, the crew voice as received on the ground was weak. As a result of the low output, the crew switched to another hand-held microphone (HHM) and the change produced satisfactory audio levels on the ground. The problem did not impact the mission. The HHM will be returned to the Johnson Space Center (JSC) for troubleshooting.

During the initial setup of photographic/television equipment, the crew reported a problem with a camcorder-to-advanced video interface unit (AVIU) cable. The crew replaced the serial number 1045 cable with the serial number 1035 cable. The video image was restored to the downlink and to the cabin monitors. The AVIU cable will be returned to JSC for troubleshooting.

The remote manipulator system (RMS) was powered up at 157:14:47 G.m.t. (00:17:24 MET), and the RMS checkout was performed. The checkout was completed at 157:16:31 G.m.t. (00:19:08 MET), and no anomalies were detected. The single/direct-drive switch override was performed during the RMS power-up to minimize the use of this switch. The functions of the single/direct-drive switch were transferred to the proceed/stop switch. The override was performed because of concerns over the cycle life of the single/direct-drive switch. Following the checkout, the RMS was used to perform an abbreviated survey of the payload bay.

The Orbiter docking system (ODS) was powered as planned and the ring extension was completed nominally. The ODS was ready for rendezvous and docking operations. The trajectory control sensor (TCS) operated nominally during the rendezvous tools checkout and was ready to support rendezvous and docking operations.

At 158:10:49 G.m.t. (01:13:26 MET), the flash evaporator system (FES) failed to come out of standby when operating in the topping mode on the primary B controller (Flight Problem STS-111-V-02). At 158:12:07 G.m.t. (01:14:45 MET), a restart of the FES was attempted on the primary B controller and it was not successful. Ten minutes later, the FES was restarted nominally on the primary A controller. Subsequent to this restart, the FES nominally came out of standby on three occasions.

Since icing of the FES core was considered to be a possible explanation of the problem encountered on the primary B controller, the FES core-flush procedure was performed. Throughout the entire procedure, the FES duct temperatures showed no indication of ice passage or excess carryover, indicating that no ice was in the core. The last few steps of the flush procedures substituted the startup of the topper on the primary B controller using the high-set point on the radiators. FES topper start-up was attempted on the primary B controller, but resulted in failure when no reaction in the FES outlet temperatures was noted. Two minutes later, a second attempt to restart the topper on the primary B controller also failed with no change in FES outlet temperatures. Two minutes later, the primary B controller was deactivated and the FES topper was activated on the primary A controller. The restart was successful and primary A topper ran for 8 minutes before being deactivated for the docked phase of the mission.

There was no additional troubleshooting or checkouts performed using the primary B controller for the remainder of the mission. The attitude timeline was adequate for minimizing FES operations and there were no constraints on using the FES as required for water dumps. In the unlikely event that the primary A controller failed, thermal analyses determined that no Orbiter hardware temperature limits would be violated using the existing procedures. The only violations were the cabin temperature (which would peak at 91 °F at landing) and the dewpoint (which would peak at 68 °F). Typically, the cabin temperature is managed to remain below 75 °F to ensure crew comfort and performance. Additional analysis cases identified other actions could be taken to reduce the cabin temperature.

One day after undocking the FES was activated on the primary A controller. The FES performed nominally on the primary A controller for the remainder of the mission. Post-flight troubleshooting of the primary B controller will be performed.

During the rendezvous, the Ku-band radar system acquired the ISS at 158:13:13 G.m.t. (01:15:50 MET) at a range of 141,000 ft (approximately 23.5 nmi). At 158:15:34 G.m.t. (01:18:11 MET), at a range of 510 ft., the Ku-band system was placed in the communications mode. The performance of the Ku-band system was nominal.

The TCS was activated and initialized at a range of approximately 25,000 ft., and began acquiring the ISS at approximately 159:02:58 G.m.t. (02:05:35 MET) at a range of about 10,000 ft. The TCS began tracking the ISS at a range of 4,520 ft., and the tracking continued until post-capture at a range of approximately 4.2 ft. The performance of the TCS was nominal.

The following table shows the maneuvers that were performed to complete the rendezvous with the ISS.

RENDEZVOUS MANEUVERS

Maneuver	Time G.m.t./MET	ΔV ft/sec	Firing time sec	Orbit nmi.
NC1 (OMS-3) (Dual OMS)	157:00:57:20 00:03:34:31	169.9	110.2	126.1 by 180.4
NC2 (OMS-4) (Left OMS)	157:14:29:48 00:17:06:59	6.1	8	126.6 by 183.5
NC3 (OMS-5) (Dual OMS)	157:23:31:18 01:02:08:29	47.6	30.6	126.4 by 211.0
NC4 (OMS-6) (Dual OMS)	158:12:23:58 01:15:01:09	128.2	81.3	198.2 x 211.6
NCC (Multi-axis RCS)	158:12:59:07 01:15:36:18	1.3	-	198.2 x 211.4
Ti (OMS-7) (Left OMS)	158:13:13:56:49 01:15:51:07	9.6	11.6	202.4 x 212.1
MC1	Cancelled			
Out of Plane Null (Multi-axis RCS)	158:14:25:14 01:17:02:25	-	-	-
MC-2 (RCS)	158:14:49:08 01:17:26:19	0.7	3.0	202.6 x 212.0
MC-3 (RCS)	158:15:06:09 01:17:43:20	0.4	2.0	202.6 x 211.9
MC-4 (RCS)	158:15:16:16 01:17:53:27	1.2	6.0	203.3 x 211.9

The ODS captured the ISS at 158:16:24 G.m.t. (01:19:01 MET). The ring was out of alignment for 3 seconds and the high-energy dampers (HEDs) activated 5 seconds after capture and remained on until deactivated by the crew 1 minutes and 31 seconds later. With the ring in alignment, a 10-second ring retraction was performed. During the retraction, ODS petal 1 and petal 3 lagged behind petal 2. This potentially indicates stuck HEDs on petal 1 and 3. Ring alignment was lost 3 times during the following 5 minutes 49 seconds because of the oscillation of the docking ring. After remaining in alignment for 3 minutes and 48 seconds, a 7-second ring extension was performed. The ring remained in alignment during this ring extension and during the approximately 2.5-minute wait prior to starting ring retraction for hooks closure. Ring retraction started with less than a 0.8-percent difference between petal 1, 2 and 3 linear-advance telemetry measurements. During the approximately 2-minute and 30-second ring retraction, a slow divergence of the linear advance measurements occurred. Approximately 2 minutes and 12 seconds into the retraction, ring alignment was lost. After ring-motor stop, the ring reached an equilibrium state with petal 1 and petal 3 having a 4-percent linear advance difference. After more than a 6-minute wait, the forced alignment procedure was implemented requiring ring extension to forward position. As the ring extended, the divergence between the petals disappeared. The ring reached the forward position and remained at that position for greater than 10 minutes to allow dampening of the relative motion between the ISS and Shuttle. Ring retraction for hooks closure was again performed with nominal results. No divergence of the linear advance measurements was observed. Hooks and capture latch operations were nominal. Docking was successfully completed and the ODS was powered off.

Analytical modeling of the ODS performance is continuing and it now appears that the cause of the performance seen was a stuck HED. Stuck HEDs are a known and understood phenomenon that has been seen several times in the past. The performance on this flight is similar to what was seen on the STS-108 mission. Evaluation of this condition is continuing.

The RMS was powered up and uncradled at approximately 159:12:14 G.m.t. (02:14:51 MET). Following an inspection of the Node 1 active common berthing mechanism (ACBM), the RMS maneuvered to the Multi Purpose Logistics Module (MPLM) pre-capture position. The MPLM was captured and unberthed from the Orbiter payload bay and maneuvered to a low hover position. Installation of the MPLM to Node 1 was successfully completed at 159:14:28 G.m.t. (02:17:05 MET). Fifteen minutes later the RMS ungrappled the MPLM and the RMS was commanded in the single-joint mode to the power and data grapple fixture (PDGF) installation-viewing overnight park position.

The crew reported that pressing the transmit/intercommunication (XMIT/ICOM) key on the battery power speaker microphone unit (BPSMU) caused the video on the camcorder to flicker. The crew disconnected the audio cable from the camcorder and that corrected the problem. With this configuration, the crew was not able to record voice on the camcorder. When the crew required audio, alternate configurations were used to recover the function. The suspect hardware will be returned to JSC for troubleshooting.

The first extravehicular activity (EVA) was successfully completed with a total EVA time of 7 hours and 14 minutes. The EVA was conducted from the ISS airlock and officially started when the extravehicular mobility units (EMUs) were placed on internal battery power at 160:15:26 G.m.t. (03:18:03 MET). The primary objectives of the EVA were the installation of a PDGF on the P6 truss, the transfer of Service Module debris panels (SMDPs) onto the ISS, and the preparation of the mobile base system (MBS) for removal from the Orbiter payload bay. The EVA concluded when repressurization of the airlock was initiated at 160:22:40 G.m.t. (04:01:17 MET).

During the first EVA, no biomedical data were received from the extravehicular 1 (EV1) crewmember's operational bioinstrumentation system (OBS). Good biomedical data were received during EMU checkout but the data were lost at the initiation of the EVA. This failure had no impact on the EVA as the Surgeon relied on metabolic rate and voice call-downs to monitor the health status of the EV1 crewmember. During the second EVA preparations, an early OBS checkout showed no biomedical data were being received from the EV1 crewmember's EMU. The EVA cable was determined to be faulty (from the signal conditioner to the EMU electrical harness). The cable was replaced with serial number 1039. The suspect hardware will be returned to JSC for troubleshooting.

During the EVA, the RMS was used to provide camera views of the PDGF installation on P6 truss. At 160:18:35 G.m.t. (03:21:12 MET), the RMS was maneuvered to the mobile transporter capture latch (MTCL) viewing position to view mating of the MBS to the mobile transporter (MT).

The first reboost session was started at 161:20:53:24 G.m.t. (04:23:30:35 MET) when RCS primary thruster L1A was fired. The session lasted one hour, and used both the primary and vernier thrusters. The primary thruster pulse widths were 160 msec. The firing period was 11.8 seconds from the start of one pulse firing until the next firing. Breaks for attitude maintenance limited the number of pulses to 128 for the primary thrusters. There were approximately four breaks for attitude maintenance, which was performed with the vernier thrusters. The aft down-firing vernier thrusters had an

average duty cycle of 8.08-seconds on and 15.2 seconds off. RCS performance was nominal throughout the operation. The reboost resulted in an overall average altitude increase of 0.8 nmi for a final orbit of 212 by 205 nmi and a ΔV of 3.0 ft/sec.

At 158:13:28 G.m.t. (01:16:05 MET), the auxiliary power unit (APU) 1 fuel pump/line/gas generator valve module (GGVM) system A heater thermostat, which had been cycling in an 18 °F dead-band, shifted to a 6 °F dead-band, as indicated by the bypass-line temperature. This thermostat is located on a fuel line that is attached to the APU. Previous experience has shown that a thermostat located at this position on the APU will eventually fail once it begins to show signs of set-point shifting or erratic behavior. Generally, a set-point change is the first step followed by more erratic operation of the thermostat prior to failure. The thermostat will be removed and replaced during postflight turnaround operations at KSC.

The second EVA was successfully completed with a total EVA time of 5 hours. The EVA was conducted from the ISS airlock and officially started when the EMUs were placed on internal battery power at 162:15:19 G.m.t. (05:17:58 MET). The primary objective of the EVA was the installation of the MBS to the MT. The EVA concluded when repressurization of the airlock was initiated at 162:20:19 G.m.t. (05:22:58 MET).

The second reboost session was started at 163:13:08:02 G.m.t. (06:15:45:13 MET) when primary thruster L1A was fired. The session lasted one hour, and used both primary and vernier thrusters. The primary thruster pulse widths were 160 msec. The firing period was 11.8 seconds from the start of one pulse firing until the next firing. Breaks for attitude maintenance limited the number of pulses to 123 for the primary thrusters. There were approximately five breaks for attitude maintenance, which was performed with the verniers. The aft down-firing vernier thrusters had an average duty cycle of 8.08-seconds on and 15.2 seconds off. RCS performance was nominal throughout the operation. The reboost resulted in an overall average altitude increase of 0.81 nmi for a final orbit of 212.8 by 206.2 nmi and a ΔV of 3.0 ft/sec.

The third EVA was successfully completed with a total EVA time of 7 hours and 16 minutes. The EVA was conducted from the ISS airlock and officially started when the EMUs were placed on internal battery power at 164:15:16 G.m.t. (07:17:53 MET). The primary objective of the EVA was the removal of the defective Space Station remote manipulator system (SSRMS) wrist roll joint (WRJ) and installation of the replacement WRJ. The Shuttle RMS was used to maneuver the crew between the SSRMS and the payload bay during the removal and replacement activities. The EVA concluded when repressurization of the airlock was initiated at 164:22:32 G.m.t. (08:01:09:11MET).

During the prebreathe period prior to the third EVA, a loud constant noise was heard on the air-to-ground and space-to-ground radio links. Troubleshooting included beginning radio frequency (RF) communications early as well as switching the Space-to-Space Orbiter Radio (SSOR) strings. Neither of these steps resolved the problem. It was subsequently determined that one of the extravehicular crewmember's (EV1) microphone booms had been inadvertently moved out of position. Airflow was apparently constantly tripping the voice-operated (VOX) circuitry and this was causing the noise. The EV1 crewmember repositioned his microphone boom and the noise was eliminated. The EVA began on time and communications were satisfactory throughout the EVA.

The third ISS reboost maneuver was initiated at 165:11:51:26 G.m.t. (08:14:28:37 MET) when RCS vernier thrusters F5L, F5R, L5D and R5D were fired. The reboost maneuver lasted one hour. There was no predefined duty cycle as the thrusters were turned on

and off as necessary to maintain attitude within the 5-degree deadband. The reboost was performed in left OMS interconnect. The reboost maneuver resulted in an overall average altitude increase of 3.6 nmi for a final orbit of 214.4 by 211.1 nmi and a ΔV of 12.5 ft/sec.

Undocking from the ISS was completed with no anomalies. The ODS was powered up at 166:14:02 G.m.t. (09:16:39 MET), and undocking was completed at 166:14:31 G.m.t. (09:17:08 MET). The hook-9 individual position indication toggled very briefly at the start of hook opening, however, this signature has been seen on previous missions and is not an issue. Following undocking, the ODS was powered down at 166:14:39 G.m.t. (09:17:16 MET).

Following the successful undocking of the Orbiter from the ISS, the initial Orbiter separation maneuver from the ISS began with a +Z-axis pulse of primary RCS thrusters at 166:14:32:04 G.m.t. (09:17:09:15 MET). The ISS flyaround operations were nominal. Final separation from the ISS was accomplished with an 11.8-second +X-axis pulse of primary RCS thrusters L1A and R1A at 166:16:14:27 G.m.t. (09:18:51:38 MET). The ΔV delivered was 3.0 ft/sec and the resulting orbit was 212 by 211 nmi.

The TCS began tracking at 5.5 ft. from the ISS and continued to track to a range of 606 ft. The performance of the TCS was nominal.

The Ku-band system was placed in the radar mode at 166:16:05 G.m.t. (09:18:42 MET) and acquired the ISS at a range of 400 ft. The radar maintained lock-on to the ISS during the latter part of the ISS flyaround and during the separation maneuver. At a range of 1580 feet, the system was placed in the communications mode at 166:16:20 G.m.t. (09:18:57 MET).

The OMS 8 orbit-adjust maneuver was performed at 166:17:57:48 G.m.t. (09:20:34:59 MET) and was 27.3 seconds in duration. The ΔV was 45.6 ft/sec, and the orbit was 186.1 by 211.9 nmi following the maneuver. The OMS performed satisfactorily throughout the maneuver.

The flight control subsystem (FCS) checkout was performed satisfactorily using APU 1 to support the checkout with a start time of 167:11:46:19 G.m.t. (10:14:23:30 MET). The run time was 4 minutes and 6 seconds, and 14 pounds of fuel were used during the APU 1 operation. The total run time was too short to require spray cooling from the water spray boiler (WSB). FCS, APU, and hydraulics performance was nominal.

Following FCS checkout, the RCS hot-fire was performed nominally. The hot-fire began at 167:12:47:48 G.m.t. (09:16:24:04 MET) and ended at 167:13:18:11 G.m.t. (10:15:24:59 MET). A review of thruster chamber-pressure data confirmed that all of the thruster firings were satisfactory. Each thruster was fired at least once for at least a 240-millisecond duration.

The OMS 9 RAM Burn Observation (RAMBO) maneuver was performed at 167:15:30:00 G.m.t. (10:18:07:11 MET) and was approximately 10 seconds in duration. The ΔV was 16.9 ft/sec, and the orbit was 187.0 by 211.6 nmi following the maneuver. The OMS performed satisfactorily throughout the maneuver.

Spikes in the reflected power of the lower-left quad antenna were observed during several periods of the mission. The signature of these spikes was cyclic and the duration of the periods was on the order of 5 to 45 minutes. During each of the periods where

spikes occurred, the system was operating on S-band string 2. These spike were observed while docked and not docked with the ISS.

The PLBDs were closed and latched for the first KSC landing opportunity on the nominal end-of-mission landing day at 168:13:20:49 G.m.t. (11:15:58:00 MET). All payload bay door close and latch operations occurred in dual motor time.

Both landing opportunities for the planned landing day were waved-off because the forecasted and observed weather conditions were unacceptable. As a result, the PLBDs were reopened at 168:15:59:04 G.m.t. (11:17:36:15 MET).

At 168:15:47 G.m.t. (11:18:24 MET), the starboard forward-bulkhead latch-release A indication failed to turn on when the latches reached the released position. Approximately 40 minutes later, the switch began to toggle on and off, and did so 14 times over the next 1 minute and 33 seconds. The switch remained on after the last toggle. This failure had no impact on subsequent PLBD closure or re-opening operations.

At 168:15:58 G.m.t. (11:18:35 MET), when the port PLBD was driven open, all three port aft ready-to-latch (R-T-L) indications remained on (Flight Problem STS-111-V-03). The limit switches are contained in a switch module and actuated by a single paddle that contacts the door. The closed-2 limit switch, which is contained in the same switch module and actuated by the same paddle, operated properly. During door opening, the closed limit switch is deactivated before the three R-T-L switches. It is likely that the paddle was stuck between the closed and R-T-L positions. The starboard and port doors were successfully opened. The three R-T-L indications subsequently turned off over a period of several hours. This failure had no impact on subsequent PLBD closure or re-opening operations.

For the landing attempts on the first extension day, the PLBDs were closed and latched for the first KSC landing opportunity at 169:12:10:13 G.m.t. (12:14:47:24 MET). All payload bay door close and latch operations occurred in dual motor time.

Both landing opportunities for the first extension day were waved off because the forecasted and observed weather conditions were unacceptable. As a result, the PLBDs were reopened at 169:14:55:41 G.m.t. (12:17:32:52 MET).

The PLBD opening following the wave-off of the first extension day landing opportunities was performed in the manual mode due to the limit switch anomalies encountered during the nominal end-of-mission landing-day door opening. After the port door was opened, the three portside aft ready-to-latch (R-T-L) indications once again remained on when they should have transferred off. However, the starboard forward-bulkhead latch-release A indication anomaly that occurred on the nominal end-of-mission landing day did not repeat.

For the landing attempts on the second extension day, the PLBDs were closed and latched for the first KSC landing opportunity at 170:11:06:51 G.m.t. (13:13:44:02 MET). All payload bay door close and latch operations occurred in dual motor time.

Both KSC landing opportunities of the second extension day were waved off because the forecasted and observed weather conditions were not acceptable for landing. The planned mission duration was 12 days plus two contingency days for weather avoidance. A third contingency day was realized during the mission based on actual consumables available. To avoid delaying the landing to the last possible day, the landing was

scheduled for the first landing opportunity for Edwards Air Force Base (EAFB) on the second extension day. The deorbit maneuver for the first EAFB landing opportunity on the second extension day, a dual engine straight-feed firing, was performed on orbit 217 at 170:16:50:26.152 G.m.t. (13:19:27:37.144 MET). The maneuver was 176.3 seconds in duration with a ΔV of 307.7 ft/sec.

Entry interface occurred at 170:17:26:32 G.m.t. (13:20:03:43 MET) and entry was completed satisfactorily. Main landing gear touchdown occurred on EAFB concrete runway 22 at 170:17:57:41 G.m.t. (13:20:34:57 MET) on June 19, 2002. The drag chute was deployed at 170:17:57:45 G.m.t. The nose gear touchdown occurred at approximately 170:17:57:52 G.m.t. The drag chute was jettisoned at 170:17:58:23 G.m.t. Wheels stop occurred at 170:17:58:46 G.m.t. The rollout was normal in all respects. The flight duration was 13 days 20 hours 34 minutes 57 seconds. The APUs were shut down approximately 21 minutes and 31 seconds after landing.

During this mission, the Endeavour vehicle traveled approximately 5.8 million miles and the landing was the 49th at EAFB.

PAYLOADS AND EXPERIMENTS

SUMMARY

The STS-111 International Space Station (ISS) mission objectives were all successfully accomplished. These objectives were the delivery and integration the Utilization Flight (UF) -2 launch package (LP) to the orbiting ISS Stage 8A; and included ISS crew rotation of three crewmembers. The LP consisted of a passive Multi-Purpose Logistics Module (MPLM), a Mobile Remote Servicer (MRS) Base System (MBS), Space Station Remote Manipulator System (SSRMS) wrist roll joint (WRJ), power and data grapple fixture (PDGF), the Service Module Debris Panels (SMDPs) and two Assembly Power Converter Units (APCUs) with interconnecting cabling and mounting brackets, and payload and stowage items located in the Orbiter middeck. The replacement of the wrist roll joint on the SSRMS was the first launch-on-need (LON) of an ISS orbital replacement unit (ORU).

The Orbiter reboost of the ISS was performed during three one-hour reboost periods and the overall altitude increase was 5.2 nautical miles. The ISS orbit after the third reboost maneuver was 214.4 by 211.1 nautical miles (nmi).

TRANSFER ACTIVITIES

Three extravehicular activities (EVAs) were successfully performed to mount and integrate 3,606 lb of new external ISS hardware. In addition to the external hardware installed, 8,983 lb of payloads and logistics items were transferred from the MPLM and Orbiter middeck. The payload items transferred from the MPLM included two international standard payload racks (ISPRs), one expedite the processing of experiments to the Space Station (EXPRESS) rack and one microgravity science glovebox (MSG) rack. This MPLM, on it fifth flight, carried the more cargo to and from orbit than any previous MPLM mission and performed flawlessly.

The Orbiter also provided 19 lb of nitrogen, 4 payload water reservoirs (86 lb) and 8 contingency water containers (CWCs) of water (799 lb). Also, 34 lb of oxygen was also provided for the 3 EVAs that were performed from the ISS

The ISS Program (ISSP) utilization payloads, Zeolite Crystal Growth-Sample Stowage (ZCG-SS), Protein Crystal Growth-Single Thermal Enclosure System (PCG-STES), Arctic Freezer, Biotechnology Cell Science Stowage-Commercial Stelsys (BCSS-CS) 1 and Commercial Refrigeration Incubator Module-Commercial Stelsys (CRIM-CS) were transferred to the ISS from the Orbiter middeck. The Commercial Protein Crystal Growth-High Density Protein (CPCG-H), Biomass Production System (BPS), Commercial Generic Bioprocessing Apparatus (CGBA), Kennedy Space Center (KSC) gaseous nitrogen (GN₂) Freezer and Protein Crystal Growth-Enhanced Gaseous Nitrogen (PCG-EGN) utilization payloads were returned from the ISS to the Orbiter middeck.

TASKS COMPLETED

The following provides a list of all major activities accomplished during the mission.

1. Rotated Expedition 4 crew with Expedition 5 crew, and transferred all mandatory crew rotation equipment. Completed the tasks of installing the Individual Equipment Liner Kit (IELK) in the Soyuz and Sokol suit checkout as well as all safety briefings;
2. Transferred mandatory quantities of 8 CWCs of water and 4 PWRs of water;
3. Berthed the MPLM to Node 1;
4. Transferred Orbiter middeck items of the ISS;
5. Removed MBS from payload bay and provided keep-alive power;
6. Returned the MPLM to the payload bay using the Shuttle Remote Manipulator System (SRMS);
7. Performed crew handover tasks that required over 9 hours for Flight Engineer 2 to almost 16 hours for the Commander;
8. Performed the replacement of the wrist roll joint on the Space Station RMS (SSRMS);
9. Removed six SMDPs from the sidewall carriers in the Orbiter payload bay; with the SSRMS and transferred the SMDPs to the pressurized mating adapter (PMA) 1 for temporary stowage;
10. Removed the PDGF from the sidewall carrier using the SSRMS and installed the PGDF on the port 6 truss;
11. Transferred and returned MPLM stowed items, and transferred EXPRESS rack 3 and MSG rack to the U. S. Laboratory;
12. Completed the MBS outfitting;
13. Performed the internal thermal control system (ITCS) coolant sampling;
14. Performed the activation and checkout of the MBS, and installed the MBS to the Mobile Transporter (MT);
15. Transferred and activated the Advanced Astroculture (ADVASC) experiment hardware;
16. Performed the Russian high definition television (HDTV) experiment;
17. Performed the required setup and transferred nitrogen from the Orbiter to the ISS;
18. Performed three session of reboosts (3 hours) of the ISS, and raised the ISS altitude 5.2 nmi;
19. Performed Expedition 5 crew and returning Expedition 4 crew daily operations in support of the Human Research Facility (HRF) renal science data collections;
20. Performed EVA radiation monitoring (EVARM) experiment during all three EVAs.
21. Performed mandatory maintenance and daily activities for the following middeck and U. S. Laboratory payloads: BPS, CGBA, CPCG-H, PCG-STES, CRIM-CS and Dynamically Controlled Protein Crystal Growth (DCPCG);
22. Performed BPS mandatory science in support of payload return; and
23. Performed imagery survey of the ISS exterior during Orbiter flyaround after undocking.

There were no real-time task additions or transfers; however, a visual and photographic inspection of the failed ISS control moment gyroscope-1 (CMG 1) on the Z1 truss segment was performed. The only task that was not completed was the transfer of oxygen from the Orbiter to the ISS and this task was not required.

ISS ANOMALIES

The CMG-1 failed during installation of the MPLM. The failure was most likely caused by spin-bearing seizure. The three remaining CMGs are in control of the ISS and operating properly. There was no impact to mission operations as a result of this failure.

The SSRMS MBS power string failed to activate on the MBS. The most likely cause of the failure was an operations control software (OCS) timing problem. A software patch is currently being developed by the Canadian Space Agency and it is expected that this patch will resolve the problem. Delivery of the software patch is scheduled for July 5, 2002. The fix is required to be incorporated in the MBS prior to the STS-112/9A mission.

The airlock power supply assembly (PSA) gave an over-voltage indication during the preparations for the second EVA. Since the extravehicular mobility unit (EMU) battery had a sufficient charge, the EVA proceeded without incident. An investigation determined that the anomalous condition posed no risk to the crew or EVA hardware, and the PSA was used without incident during the third EVA. A team is investigating this anomaly and will provide a resolution in the future.

RAM BURN OBSERVATION

The RAM burn observations (RAMBO) were made on four orbital maneuvering subsystem (OMS) firings (OMS-2, NC-1, NC-3 and a dedicated RAMBO firing). Other firings (NC-2 and orbit adjust) were not in the view of the satellite so no observation attempts were made. Of the four possible firings, the OMS-2 and the NC-3 observations were successful. For the NC-1 and dedicated maneuvers, it was not possible to determine from the real-time data stream whether the observation was successful. Post-mission analysis of the data is required before final conclusions can be reached.

VEHICLE PERFORMANCE

LAUNCH DELAY

The launch of STS-111 was planned for May 30, 2002; however, because of adverse weather in the launch area, the countdown was stopped while in the T-9 minute hold. The launch was rescheduled to Friday, May 31, 2002, but adverse weather was again predicted, and the Mission Management Team (MMT) met and rescheduled the launch for Monday, June 3, 2002, with a proviso that the launch could slip one more day because of weather predictions for Monday at KSC. At a subsequent MMT meeting it was decided that a leaking gaseous nitrogen (GN₂) regulator in the orbital maneuvering subsystem (OMS) required removal and replacement. The effort to complete this replacement resulted in the launch being rescheduled for Wednesday, June 5, 2002.

SOLID ROCKET BOOSTERS

Analysis of the Solid Rocket Booster (SRB) systems data indicated nominal performance of all SRB subsystems. The prelaunch countdown was normal and no SRB Launch Commit Criteria (LCC) or Operations and Maintenance Requirements And Specifications Document (OMRSD) violations occurred. Likewise, no in-flight anomalies were identified in the evaluation of the data.

All 48 of the sea-water-activated release (SWAR) links (8 SWAR links for each parachute) fired and released properly.

Both SRBs were recovered and returned to KSC for inspection, disassembly and refurbishment. The inspection revealed that both SRBs were in excellent condition. No anomalous SRB conditions were noted during the postflight operations.

REUSABLE SOLID ROCKET MOTORS

Data analysis of the flight performance of both reusable solid rocket motors (RSRMs) showed all parameters to be within the contract end item (CEI) specification limits, and the performance was typical of that observed on previous flights. The prelaunch countdown was normal and no RSRM LCC or OMRSD violations occurred.

All RSRM temperatures were maintained within acceptable limits throughout the countdown. No in-flight anomalies were identified from the analysis of the data. The maximum in-flight trace shape variation of pressure versus time during the 62- to 80-second time frame was calculated to be 1.021 percent at 67.5 seconds and 0.321 percent at 73.0 seconds for the left and right motor, respectively. These values were well within the 3.2-percent allowable limits.

Power application and operation of all field-joint heaters was accomplished routinely. Field-joint heaters operated for 12 hours 36 minutes during the final launch countdown and 31 hours 50 minutes during the three launch countdowns. Power was applied to the heating elements an average of 23 percent of the time during the LCC time frame to maintain the field-joint temperatures in their normal operating range.

Power application and operation of all igniter-joint heaters was accomplished routinely. The igniter-joint heaters operated for 12 hours 27 minutes during the final launch

countdown and 31 hours 41 minutes during the three launch countdowns. Power was applied to the heating elements 32 percent of the time during the LCC time frame to maintain the igniter-joint temperatures in their normal operating range.

The heated, ground-supplied, aft skirt purges maintained the case/nozzle joint and flex bearing temperatures within the required LCC ranges. The purge was activated ten times for a total of 25 hours 14 minutes during the time of recorded data for the three countdowns. Four aft-skirt purge-activations were performed during the final countdown and these lasted for a total of 10 hours and 57 minutes. It was necessary to activate the aft-skirt purge to maintain the nozzle-case joint temperatures above the minimum LCC temperature but the purge was not required to thermally condition the flex bearing above the minimum required temperature of 60 °F. During the LCC time frame, the nozzle/case joint temperatures were nominal and ranged from 82 °F to 90 °F on both motors. The final flex bearing mean bulk temperature (FBMBT) was determined to be 86 °F.

Reconstructed motor performance parameters adjusted to a 60 °F propellant mean bulk temperature (PMBT) are shown in the following table. The predicted PMBT at launch was calculated to be 79 °F. The predicted and actual propulsion systems performance is shown in the RSRM Propulsion Performance table on the following page. The predicted burn rates were 0.3692 and 0.3677 in/sec for the left and right motors, respectively.

MOTOR PERFORMANCE PARAMETERS

Parameter	CEI Specification Limit (60 °F)	Left Motor Delivered	Right Motor Delivered
Web time, seconds	105.4 – 116.7	110.8	110.8
Action time, seconds	115.2 – 131.2	123.1	124.0
Head end pressure, psia	847.9 – 965.7	908.5	906.3
Maximum sea level thrust, MLbf	2.88 – 3.26	3.08	3.06
Web time average pressure, psia	629.9 – 700.5	665.5	663.0
Web time average vacuum thrust, MLbf	2.46 – 2.74	2.61	2.60
Web time total impulse, MLbf sec	285.8 – 291.6	288.8	287.5
Action time impulse, MLbf seconds	293.7 – 299.7	296.2	296.3
ISP average delivered, Lbf sec/Lbm	266.5 – 270.3	268.2	268.3
Loaded propellant weight, Lbm	>1103750	1104901	1104920

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

EXTERNAL TANK

All External Tank (ET) objectives and requirements were met during the propellant loading and flight operations. No significant oxygen or hydrogen leakage concentrations were detected in the intertank. All ET electrical equipment and instrumentation operated satisfactorily. Purge and heater operations were also nominal. No ET LCC or OMRSD violations occurred.

During prelaunch operations, the ice/frost red team reported a small crack in the second valley, -Z side of the -Y thrust panel and a small crack on the forward side of the -Y vertical strut. Both cracks were typical and acceptable. There were no changes in the cracks from the first tanking.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 74 °F		Right motor, 74 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10 ⁶ lbf-sec	64.91	65.98	64.91	65.55
I-60, 10 ⁶ lbf-sec	174.19	176.14	174.03	175.08
I-AT, 10 ⁶ lbf-sec	297.04	296.57	297.08	296.63
Vacuum Isp, lbf-sec/lbm	268.6	268.4	268.6	268.5
Burn rate, in/sec @ 60 °F At 625 psia	0.3664	0.3692	0.3664	0.3677
Event times, seconds ^a				
Ignition interval	0.232	N/A	0.232	N/A
Web time ^b	109.4	108.6	109.4	108.6
50 psia cue time	119.5	118.5	119.5	119.2
Action time ^b	121.7	120.7	121.7	121.6
Separation command	123.9	-	123.9	-
PMBT, °F	79	79	79	79
Maximum ignition rise rate, psia/10 ms	90.8	N/A	90.8	N/A
Decay time, seconds (59.4 psia to 85 K)	3.1	3.0	3.1	3.3
Tailoff Imbalance Impulse Differential	Predicted N/A		Actual 518.8	

Impulse Imbalance = Integral of the absolute value of the left motor thrust minus right motor thrust from web time to action time.

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

^b Referenced to liftoff time (ignition interval).

The pressurization systems functioned properly throughout engine start and flight. The minimum LO₂ ullage pressure experienced during the ullage pressure slump was 14.0 psid.

ET separation was confirmed. The postflight analysis of the impact point showed the ET impact to be 78.9 nautical miles uprange from the preflight predicted impact point.

SPACE SHUTTLE MAIN ENGINES

Prelaunch operations of the Space Shuttle main engines (SSMEs) were smooth with no LCC or OMSRD violations noted. The ignition confirm limits and mainstage redline margins were satisfactory. All Interface Control Document (ICD) start and shutdown transient requirements were met. Engine performance during start, mainstage, and shutdown was nominal and as predicted. Engine cutoff times were within the nominal limits for SSME 1, 2 and 3, respectively. Controller and software performance was satisfactory with no anomalies. No in-flight anomalies were identified from the review of the data.

The flight-derived specific impulse (I_{sp}) was 1.1 second higher than predicted. The Block II engines have typically delivered approximately 0.8-second higher flight I_{sp} than predicted from ground testing.

Main engine cutoff (MECO) occurred 506.5 seconds after SRB ignition. The commanded maximum dynamic pressure (max Q_d) throttle-down was a two-step throttle-down to 72 percent.

On STS-104, the first flight of a Block II engine, a pressure relief from the 12-inch feedline into the 17-inch manifold caused a manifold over-pressure condition. A change was made for STS-108 that resulted in the pressure in the 12-inch line being reduced 26 psi from STS-104. As a result, there was no pressure relief into the 17-inch manifold.

SHUTTLE RANGE SAFETY SYSTEM

The Shuttle Range Safety System (SRSS) closed-loop testing was completed as scheduled during the launch countdown. All SRSS safe and arm (S&A) devices were armed and system inhibits were turned off at appropriate times. The system operated as expected throughout the countdown and flight. As planned, the SRB S&A devices were safed and SRB system power was turned off prior to SRB separation.

ORBITER SUBSYSTEMS PERFORMANCE

Main Propulsion Subsystem

The main propulsion subsystem (MPS) performed satisfactorily. There were no LCC violations during the two loadings, and there were no in-flight anomalies identified from the analysis of the data. One item of interest occurred during the first loading and one OMRSD violation was noted during liquid oxygen (LO₂) loading during the second loading and the condition is discussed in a later paragraph.

Tabulation data for the prelaunch, MECO, post-MECO and entry and landing events revealed no anomalous valve movements. All timings were within the required specification and within the current database. The aft hazardous gas concentrations during both loading sequences were nominal. The peak hydrogen concentration during the second loading was 170 ppm, which compares favorably with previous data from this vehicle.

About 1 hour 40 minutes into the LO₂ fast-fill operations for the first loading, the hazardous gas detection system (HGDS) indicated increased oxygen levels in the aft compartment. The oxygen levels increased from approximately 13 ppm to a peak of approximately 140 ppm and did not drop below 100 ppm. During the oxygen detanking operations, the ullage pressure was raised by 8 psi and the oxygen concentration dropped to approximately 0 ppm. The oxygen concentrations during the second loading were 165-ppm peak and steady state.

The liquid hydrogen (LH₂) loading operations were normal throughout the entire process. Based on an analysis of loading system data, the LH₂ load at the end of replenish was nominal, which was well within loading accuracy requirements.

The liquid oxygen (LO₂) loading operations were completed satisfactorily, except a stop-flow occurred in the loading during slow-fill operations when the ground support equipment (GSE) measurement indicated an Orbiter inlet temperature violation that exceeded the OMRSD limit. Slow-fill resumed in 24 minutes and no further problems were noted. Based on an assessment of the load at the end of replenish showed the load to be well within the required MPS loading accuracy.

The overall gaseous hydrogen (GH₂) system performance during the ascent phase was nominal. All three flow-control valves (FCVs) performed nominally. The gaseous oxygen (GO₂) fixed orifice pressurization system performed as predicted. Reconstructed data from engine and MPS parameters closely matched the actual ET ullage pressure measurements. Helium system performance for the SSMEs and pneumatic Helium systems was also nominal. Entry Helium usage was xx x lbm, which is well within the allowable requirements.

Reaction Control Subsystem

The reaction control subsystem (RCS) performed satisfactorily throughout the mission. A total of ten significant maneuvers were completed satisfactorily. These included three 60-minute reboost periods that raised the altitude of the International Space Station (ISS) approximately 5.2 nautical miles. No in-flight anomalies were identified during the mission.

A total of 4758.6 lbm propellants (2959.6 lbm - oxidizer, 1799.0 lbm - fuel) were used from the RCS during the mission. A total of 1706.2 lbm of orbital maneuvering subsystem (OMS) propellants were also used by the RCS during the mission. The primary RCS thrusters had 5581 firings and a total firing time of approximately 1010.65 seconds. The vernier RCS thrusters had 10576 firings and a total firing time of 34,758.08 seconds.

The RCS window protect maneuver was initiated at 156:21:24:52 G.m.t. (00:00:02:03 MET) and was terminated 2.08 seconds later. This maneuver provided a method of protecting the windows of the Orbiter from booster separation motor exhaust products.

The following table shows the RCS maneuvers that were performed prior to docking with the ISS.

RCS MANEUVERS

Maneuver	Time, G.m.t./MET	ΔV , ft/sec	Firing time, sec	Orbit, nmi.
RCS Window Protect	156:21:24:52.0 00:00:02:03.0	N/A	2.08	N/A
ET Photographic Maneuver	156:21:31:43 00:00:08:54	N/A	16.16	N/A
NCC (Multi-axis RCS)	158:12:59:07 01:15:36:18	1.3	-	198.2 x 211.4
MC1	Cancelled			
Out of Plane Null (Multi-axis RCS)	158:14:25:14 01:17:02:25	N/A	N/A	N/A
MC-2 (RCS)	158:14:49:08 01:17:26:19	0.7	3.0	202.6 x 212.0
MC-3 (RCS)	158:15:06:09 01:17:43:20	0.4	2.0	202.6 x 211.9
MC-4 (RCS)	158:15:16:16 01:17:53:27	1.2	6.0	203.3 x 211.9

The first reboost session was started at 161:20:53:24 G.m.t. (04:23:30:35 MET) when RCS primary thruster L1A was fired. The session lasted one hour, and used both the primary and vernier thrusters. The primary thruster pulse widths were 160 msec. The firing period was 11.8 seconds from the start of one pulse firing until the next firing. Breaks for attitude maintenance limited the number of pulses to 128 for the primary thrusters. There were approximately four breaks for attitude maintenance, which was performed with the vernier thrusters. The aft down-firing vernier thrusters had an average duty cycle of 8.08-seconds on and 15.2-seconds off. RCS performance was nominal throughout the operation. The reboost resulted in an overall average altitude increase of 0.8 nmi for an orbit of 212 by 205 nmi and a ΔV of 3.0 ft/sec.

The second reboost session was started at 163:13:08:02 G.m.t. (06:15:45:13 MET) when RCS primary thruster L1A was fired. The session lasted one hour, and used both primary and vernier thrusters. The primary thruster pulse widths were 160 msec. The firing period was 11.8 seconds from the start of one pulse firing until the next firing. Breaks for attitude maintenance limited the number of pulses to 123 for the primary thrusters. There were approximately five breaks for attitude maintenance, which was performed with the verniers. The aft down-firing vernier thrusters had an average duty cycle of 8.08-seconds on and 15.2-seconds off. The reboost resulted in an overall average altitude increase of 0.81 nmi for an orbit of 212.8 by 206.2 nmi and a ΔV of 3.0 ft/sec.

The third ISS reboost maneuver was initiated at 165:11:51:26 G.m.t. (08:14:28:37 MET) when RCS vernier thrusters F5L, F5R, L5D and R5D were fired. The reboost maneuver lasted one hour. There was no predefined duty cycle as the thrusters were turned on and off as necessary to maintain attitude within the 5-degree deadband. The reboost was performed in left-OMS interconnect. The reboost maneuver resulted in an overall average altitude increase of 3.6 nmi for a final orbit of 214.4 by 211.1 nmi and a ΔV of 12.5 ft/sec.

The following table shows how the attitude control of the combined ISS and Orbiter were shared during the docked operations.

ATTITUDE CONTROL OF THE ISS/ORBITER DURING DOCKED OPERATIONS

Control Responsibility	Start, G.m.t.	End, G.m.t	Elapsed Time, DD:HH:MM	Comments
ISS	158:17:26:51	161:20:00:54	03:02:34:03	Initial handoff to ISS
Orbiter	161:20:00:54	161:22:35:59	00:02:35:05	Reboost 1 and water dumps
ISS	161:22:35:59	162:11:25:19	00:12:49:20	
Orbiter	162:11:25:19	162:14:36:18	00:03:10:59	Water dumps
ISS	162:14:36:18	163:12:19:39	00:21:43:21	
Orbiter	163:12:19:39	163:16:33:12	00:04:13:33	Reboost 2 and water dumps
ISS	163:16:33:12	164:10:57:54	00:18:24:42	
Orbiter	164:10:57:54	164:13:40:00	00:02:42:06	Supply water dump
ISS	164:13:40:00	165:11:51:26	00:22:11:26	
Orbiter	165:11:51:26	165:16:30:55	00:04:29:29	Reboost 3 and water dumps
ISS	165:16:20:55	166:13:22:06	00:21:01:11	
Orbiter	166:13:22:06	166:14:31:49	00:01:09:43	Undocking preparations

The attitude control during docked operations for the ISS was 7 days 2 hours 44 minutes and 03 seconds, and the Orbiter controlled the attitude for 18 hours 20 minutes 55 seconds.

Following the successful undocking of the Orbiter from the ISS, the initial Orbiter separation maneuver from the ISS began with a +Z-axis pulse of primary RCS thrusters at 166:14:32:04 G.m.t. (09:17:09:15 MET). The ISS flyaround operations were nominal. Final separation from the ISS was accomplished with an 11.8-second +X-axis pulse of primary RCS thrusters L1A and R1A at 166:16:14:27 G.m.t. (09:18:51:38 MET). The ΔV delivered was 3.0 ft/sec and the resulting orbit was 212 by 211 nmi.

Following FCS checkout, the RCS hot-fire was performed nominally. The hot-fire began at 167:12:47:48 G.m.t. (09:16:24:04 MET) and ended at 167:13:18:11 G.m.t. (10:15:24:59 MET). A review of thruster chamber-pressure data confirmed that all of the thruster firings were satisfactory. Each thruster was fired at least once for at least a 240-millisecond duration.

Orbital Maneuvering Subsystem

During the initial launch countdown, data showed a leaking gaseous nitrogen (GN₂) regulator in the orbital maneuvering subsystem (OMS) that required removal and replacement (Flight Problem STS-111-V-01). Following activation of the OMS engine arm/pressurization (A/P) switches, the left engine GN₂ regulator appeared to lock up at the nominal pressure of 349 psia; however, 20 seconds later a leak began at a rate of 680 cc/min as evidenced by the abnormal GN₂ pressure increase (32 psi/min). The crew closed the GN₂ isolation valve to prevent depletion of the GN₂ supply tank. At that time, the accumulator pressure had reached 494 psia. The nominal GN₂ lockup pressure is 340 to 350 psia and the relief valve on this regulator cracks at about 495 psia. Subsequent actions involved momentarily opening the purge valves to vent the GN₂ accumulator to less than 50 psia and repressurizing the accumulator by cycling the left orbital maneuvering engine (OME) A/P valve. Leakage through the regulator stopped and the accumulator pressure stabilized at 349 psia. To confirm functionality, the accumulator was vented and the A/P valve was cycled a second time with similar results. The most probable cause of this incident was considered to be transient contamination on the regulator poppet or seat. Subsequent to this event, the launch attempt was scrubbed because of the bad weather conditions. As a result of these circumstances, decisions were made to top-off the GN₂ tank and perform another functional test of the regulator. The regulator again leaked, failing to lock-up. The regulator was removed and replaced. The effort to complete the replacement of the GN₂ regulator resulted in the launch being rescheduled for Wednesday, June 5, 2002. Subsequent flight operations of the regulator were nominal and no further postflight action on the vehicle was required.

The OMS performed satisfactorily throughout the mission. There were no LCC or OMRSD violations during the countdown. No in-flight anomalies were identified during the data review.

A total of 24,903 lbm (15,529 lbm - oxidizer and 9374 lbm - fuel) of OMS propellants were consumed during the mission. A total of 1706.2 lbm of OMS propellants were provided during interconnect operations to the RCS. As a means of saving propellant, the NC1, NC2 and NPC maneuvers were deleted and the ΔV that was to be imparted to the vehicle was combined into the NH maneuver. The table on the following page list the maneuvers that were performed during the mission.

OMS MANEUVERS

Maneuver	Time G.m.t./MET	ΔV ft/sec	Firing time sec	Orbit nmi.
OMS assist (Dual OMS)	156:21:25:03.1 00:00:02:15	N/A	48.3	N/A
OMS-2 (Dual OMS)	156:22:01:33.9 00:00:38:44.9	95.2	62.8	85.0 by 126.7
NC1 (OMS-3) (Dual OMS)	157:00:57:20 00:03:34:31	169.9	110.2	126.1 by 180.4
NC2 (OMS-4) (Left OMS)	157:14:29:48 00:17:06:59	6.1	8	126.6 by 183.5
NC3 (OMS-5) (Dual OMS)	157:23:31:18 01:02:08:29	47.6	30.6	126.4 by 211.0
NC4 (OMS-6) (Dual OMS)	158:12:23:58 01:15:01:09	128.2	81.3	198.2 x 211.6
Ti (OMS-7) (Left OMS)	158:13:13:56:49 01:15:51:07	9.6	11.6	202.4 x 212.1
Orbit Adjust (OMS-8) (Dual OMS)	166:17:57:48 09:20:34:589	45.6	27.3	186.1 by 211.9
RAM Burn (RAMBO) (Dual OMS)	167:15:30:00 10:18:07:11	16.9	10.0	187.0 by 211.6

The OMS 9 RAM Burn Observation (RAMBO) maneuver was performed at 167:15:30:00 G.m.t. (10:18:07:11 MET) and was approximately 10 seconds in duration. The ΔV was 16.9 ft/sec, and the orbit was 187.0 by 211.6 nmi following the maneuver. The OMS performed satisfactorily throughout the maneuver.

Power Reactant Storage and Distribution

The power reactant storage and distribution (PRSD) subsystem performance was nominal throughout the STS-111 mission. No LCC or OMRSD violations occurred during the countdown and mission, and no in-flight anomalies were noted during the analysis of the data. All File IX requirements were satisfied during the mission.

The PRSD subsystem supplied the fuel cells with 3094 lbm of oxygen and 390 lbm of hydrogen for the production of 4525 kWh of electrical energy. In addition, the environmental control and life support system (ECLSS) was supplied 194 lbm of oxygen for life support. The average power level for the mission was 13.6 kW. A 42-hour mission extension was possible at the average power level with the reactants remaining at landing, and at an extension day power level of 13.4 kW, a 43-hour mission extension was possible.

PRSD tanks 4 and 5 were depleted to residual quantities during the mission. The Orbiter landed with 669 lbm of oxygen and 73 pounds of hydrogen remaining.

Fuel Cell Powerplant Subsystem

The overall performance of the fuel cell powerplant (FCP) subsystem was nominal during the mission. There were no OMRSD or LCC violations, nor were any in-flight anomalies found during the analysis of the data. The average power level and load was 13.6 kW

and 442 amperes. The fuel cells produced 3484 lbm of potable water and 4525 kWh of electrical energy while using 3094 lbm of oxygen and 390 lbm of hydrogen.

Two fuel cell start-up cycles were experienced because of the launch scrub that resulted from unacceptable weather conditions. The fuel cells operated between 33 and 36 hours before being shutdown as a result of the canceled launch attempt. The second start-up cycle for the fuel cells provided power for the mission, operating between 361 and 362 hours.

Six purges of the fuel cells were performed, all of which achieved nominal results. The fuel cell reactant purge system operated nominally in both the automatic and manual modes.

The actual fuel cell voltages at the end of the mission were 0.20 Vdc above the predicted for fuel cell 1, 0.15 Vdc above predicted for fuel cell 2, and as predicted for fuel cell 3. The voltage margin above the minimum performance curve at 200 amperes at the end of the mission was 0.9 Vdc for fuel cell 1, 1.1 volts for fuel cell 2, and 1.2 volts for fuel cell 3.

The overall thermal performance of the fuel cell water relief, water line, and reactant purge heater systems was normal. System A was used during the countdown, ascent and through approximately 6½ days of the mission for the water relief and water line systems. The B system was selected at that time and it operated nominally in both the automatic and manual modes for the remainder of the mission.

The fuel cell monitoring system (FCMS) was used to monitor individual cell voltages during prelaunch, on-orbit and postlanding operations. Full-rate data were recorded for 12 minutes beginning at 157:15:13 G.m.t. (00:17:56 MET) and all of the cell voltages were nominal.

Auxiliary Power Unit Subsystem

The auxiliary power unit (APU) subsystem performance was nominal throughout the mission. One-flight anomaly was identified during the evaluation of the data. All in-flight checkout requirements were completed satisfactorily.

The following table presents the APU run times and fuel consumption for the mission.

APU RUN TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (S/N 405)		APU 2 (S/N 303)		APU 3 (S/N 409)	
	Time, Min:sec	Fuel consumption, lb	Time, Min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	20:25	50	20:36	55	20:48	49
FCS checkout	4:06	14				
Entry ^a	65:12	116	94:23	205	65:28	119
Total	89:43	180	114:59	260	86:16	168

^a APUs were shut down 21 minutes 13 seconds after landing.

^b APU 1 was used for the FCS checkout.

At 158:13:28 G.m.t. (01:16:05 MET), the APU 1 fuel pump/line/gas generator valve module (GGVM) system A heater thermostat, which had been cycling in an 14 °F dead-band, shifted to a 6 °F dead-band, as indicated by the bypass-line temperature. This thermostat is located on a fuel line that is attached to the APU. Previous experience has shown that a thermostat located at this position on the APU will eventually fail once it begins to show signs of set point shifting or erratic behavior. Generally, a set-point change is the first step followed by more erratic operation of the thermostat prior to failure. The thermostat will be removed and replaced during postflight turnaround operations at Kennedy Space Center.

The flight control subsystem (FCS) checkout was performed satisfactorily using APU 1 to support the checkout with a start time of 167:11:46:19 G.m.t. (10:14:23:30 MET). The run time was 4 minutes and 6 seconds, and 14 pounds of fuel were used during the APU 1 operation. The total run time was too short to require spray cooling from the water spray boiler (WSB). APU and hydraulics performance was nominal.

During the first launch attempt, the APU 2 service line temperature was reading approximately 15 °F lower than an adjacent measurement (should be approximately the same temperature). The heater was operating on the B system and was functioning nominally but at the lower 45 °F minimum cycle temperature. The heater was reconfigured to the A system, thus raising the low cycle point to 46 °F, which it maintained throughout the launch attempt. A change was uplinked for the mission that lowered the minimum temperature to 42 °F, thus avoiding nuisance alarms during the mission. The temperature operated above the 42 °F limit throughout the mission.

Hydraulics/Water Spray Boiler Subsystem

The hydraulics/WSB subsystem performed satisfactorily throughout the mission. The water additive, Propylene Glycol Monomethyl Ether (PGME), provided satisfactory cooling of all three WSBs. No overcooling or undercooling conditions were noted in the data. Spray cooling was initiated on all three WSBs at lubrication oil return temperatures at less than 255 °F.

There were no unexpected decreases in reservoir quantity, indicating that the systems had no detectable leakage. Priority valve cracking at APU activation were all well below the 1-second specification. Priority valve reseal pressures following APU shutdown for systems 1, 2 and 3 were all above 2800 psia, thus satisfying the specification limit of no less than 2675 psia.

STS-111 was the second flight of the OI-29 software, which incorporates the lower circulation pump thermal limits on all three hydraulic systems. The use of the new lower limits reduces circulation pump operation to save cryogenics consumables during the docked phase of the mission. There were a total of six circulation pump operations during the mission.

A hydraulics loads test was performed post-landing and all operations were nominal.

Electrical Power Distribution and Control Subsystem

The electrical power distribution and control (EPDC) subsystem performed nominally throughout the mission. All File IX in-flight checkout requirements were completed satisfactorily. Likewise, no in-flight anomalies were identified in the evaluation of the data.

During prelaunch operations, a facility power problem caused the Orbiter Main A bus to be dropped. When main A was regained 2 hours later, the aft main A current transducer was indicating +175 amperes, which is the zero output value of the transducer. This condition indicates that the transducer has failed. There was no mission impact because of this failure.

Orbiter Docking System

The Orbiter docking system (ODS) operated nominally with the one exception noted in a following paragraph.

The ODS captured the ISS at 158:16:24 G.m.t. (01:19:01 MET). The ring was out of alignment for 3 seconds and the high-energy dampers (HEDs) were activated 5 seconds after capture and remained on until deactivated by the crew 1 minutes and 31 seconds later. With the ring in alignment, a 10-second ring retraction was performed. During the retraction, ODS petal 1 and petal 3 lagged behind petal 2. This potentially indicates stuck HEDs on petal 1 and 3. Ring alignment was lost 3 times during the following 5 minutes 49 seconds because of the oscillation of the docking ring. After remaining in alignment for 3 minutes and 48 seconds, a 7-second ring extension was performed. The ring remained in alignment during this ring extension and during the approximately 2.5-minute wait prior to starting ring retraction for hooks closure. Ring retraction started with less than a 0.8-percent difference between petal 1, 2 and 3 linear-advance telemetry measurements. During the approximately 2-minute and 30-second ring retraction, a slow divergence of the linear advance measurements occurred. Approximately 2 minutes and 12 seconds into the retraction, ring alignment was lost. After ring-motor stop, the ring reached an equilibrium state with petal 1 and petal 3 having a 4-percent linear advance difference. After more than a 6-minute wait, the forced alignment procedure was implemented requiring ring extension to forward position. As the ring extended, the divergence between the petals disappeared. The ring reached the forward position and remained at that position for greater than 10 minutes to allow dampening of the relative motion between the ISS and Shuttle. Ring retraction for hooks closure was again performed with nominal results. No divergence of the linear advance measurements was observed. Hooks and capture latch operations were nominal. Docking was successfully completed and the ODS was powered off.

Analytical modeling of the ODS performance is continuing and it now appears that the cause of the performance seen is a stuck HED. Stuck HEDs are a known and understood phenomenon that has been seen several times in the past. The performance on this flight is similar to what was seen on the STS-108 mission. Analysis is continuing to ensure that this performance will not become a problem in the future as the mass of the ISS increases.

Undocking from the ISS was completed with no anomalies. The ODS was powered up at 166:14:02 G.m.t. (09:16:39 MET), and undocking was completed at 166:14:31 G.m.t. (09:17:08 MET). The hook-9 individual position indication toggled very briefly at the start of hook opening, however, this signature has been seen on previous missions and is not an issue. Following undocking, the ODS was powered down at 166:14:39 G.m.t. (09:17:16 MET).

Atmospheric Revitalization Pressure Control Subsystem

The atmospheric revitalization pressure control subsystem (ARPCS) performed normally throughout the duration of the flight. To minimize the use of consumables and maintain adequate tank pressure for gas transfer to the ISS, the 14.7-psia cabin regulators were deenergized after orbital insertion.

All three extravehicular activities (EVAs) on this mission were performed from the ISS Airlock. Because of the large amount of oxygen exhausted into the cabin atmosphere during the ISS prebreathe procedure, cabin pressure during the docked period was maintained by the introduction of the oxygen from the ISS prebreathe and the ISS pressure control system.

During the docked period, approximately 19 lb of nitrogen was transferred to the ISS tanks using the transfer lines. Prior to undocking, a repressurization of the ISS and Orbiter to a pressure of 14.7 psia was accomplished with Orbiter oxygen at 164:23:31 G.m.t. (08:02:08 MET).

Atmospheric Revitalization Subsystem

The atmospheric revitalization subsystem (ARS) performed nominally through the duration of the flight with the following highlights provided for the mission.

During the prelaunch activities of the first scheduled launch attempt on May 30, the inertial measurement unit (IMU) fan differential pressure (ΔP) dropped below the Flight Rule limit for an operational fan. The Flight Rule considers an IMU fan lost if the fan ΔP drops below the measurement accuracy limit, which has a lower limit is 3.94 inches of water; however, the LCC lower limit for the IMU fan is 3.7 inches of water. The IMU fan ΔP was near 3.92 inches of water. During this time, the indicated cabin temperature was rising steadily and all three IMUs were powered on for launch. A review of the fan ΔP when powering the IMUs shows that the fan ΔP shifted downward from an average level of 4.2 inches of water to an average fan ΔP of 4.06 inches of water. The resulting heat load introduced into the IMU air loop because of operations for launch make the air less dense and result in the fan ΔP decreasing. The IMU fan ΔP drop below the lower limit was explained as associated with the rising cabin temperature.

When the launch countdown resumed a few days later, the IMU ΔP dropped to the lower limit of 3.94 inches of water but did not go below the limit. This condition was caused by the cabin temperature being slightly cooler reaching 76.5 °F prior to launch versus the cabin temperature reaching 78.09 °F during the launch scrub.

The 76.6 °F cabin air temperature at launch was 3.6 degrees warmer than the predicted preflight temperature of 73 °F, which was determined through the STS-111 ECLSS/Payload Thermal Compatibility Verification Analysis. The 76.6 °F exceeded the Flight Rule limit of 75 °F air temperature for the launch phase. Cabin temperature climbed to 82 °F at 3 hours and 12 minutes after launch and the cabin peak temperature was 84.2 °F, which occurred on flight day 10.

The partial pressure of carbon dioxide (ppCO₂) peaked at an indicated sensor value of 6.03 mmHg at 166:23:29 G.m.t. (10:02:06 MET). The peak occurred after undocking from the ISS. During joint operations with the Orbiter and ISS hatch interface open, the ppCO₂ peaked to 4.59 mmHg. This peak occurred during the pre-sleep activity of flight day 10. During the docked phase of the mission, only the Vozdukh (Russian CO₂

scrubbing device) was operational. The carbon dioxide removal assembly (CDRA) was non-operational during this flight because of power constraints and the ppCO₂ reading from the U. S. Laboratory was not available for STS-111. The preflight ppCO₂ analysis took into account that CDRA would be operational during the flight so the preflight analysis could not be utilized to predict and track Orbiter flight levels of CO₂.

From the lithium hydroxide (LiOH) canister card change-out schedule, a total of 44 LiOH canisters were expended during the flight. In addition, 8 LiOH canisters were transferred from the Orbiter to the ISS, thus increasing the station LiOH canister stockpile to 26.

The floodlight coldplate temperature location on the 576 bulkhead indicated the temperature remained above 64 °F during the mission.

During the on-orbit phase of the mission, the cabin temperature averaged 76 degrees. The Orbiter cabin temperature during the docked portion of the mission had temperature swings from a low of 75.5 °F to a high of 77 °F. The ppCO₂ peaked at an indicated reading of 4.6 mmHg during the docked phase of the mission and 6.02 mmHg during the non-docked phase of the mission.

Cabin humidity averaged 32.5 percent for the flight, with a peak to 57.6 percent during the second deorbit-preparation period of flight day 13.

During the landing phase of the flight, the heat exchanger outlet temperature peaked to 60.19 °F at 8 minutes and 12 seconds after wheel stop, with the cabin air temperature peaking to 74.1 °F at 32 minutes after wheel stop, and prior to crew egress. The temperature at landing was 72.34 °F, below the 75 °F cabin air-temperature limit. The cabin humidity peaked near 46.7 percent at approximately 10 minutes and 43 seconds after wheel stop.

Active Thermal Control Subsystem

Active thermal control subsystem (ATCS) performance was nominal during the ascent phase. Pre-evaporative cooling was observed when the evaporator outlet temperature peaked at 86.4 °F after which it then dropped to 62.3 °F before warming to 71.7 °F. The amount of cooling is within the historical limits. After the evaporator outlet temperature reached 71.7 °F, the flash evaporator system (FES) primary A controller was activated by the general-purpose computer (GPC) to begin cooling. During post-insertion operations after the FES had been reconfigured from the primary A to the primary B controller and the high load inhibited, the FES topping heat load exceeded the maximum Shuttle Operational Data Book (SODB) heat-load specification of 31,000 Btu/hr. The heat load peaked at 31,400 Btu/hr at 157:00:27 G.m.t. (00:03:04 MET). No anomalous signatures were observed in the FES outlet and duct temperatures. The FES performed nominally through the period of the high heat load.

At 158:10:49 G.m.t. (01:13:26 MET), the FES topper was operating on the primary B controller, and the FES failed to come out of the standby mode (Flight Problem STS-111-V-02). At approximately 158:12:08 G.m.t. (01:14:45 MET), a restart of the FES on the primary B controller was attempted, but the FES again failed to respond. About 10 minutes later, a successful attempt was made to restart the FES topper using the primary A controller. The FES had been running successfully, shifting in and out of standby a number of times, before it failed to come out of standby.

Since icing of the FES core was considered to be a possible explanation of the problem encountered with the primary B controller, a core flush procedure was recommended. At approximately 158:21:27 G.m.t. (02:00:04 MET), the FES topping core flush procedure was initiated and was completed at 26 minutes later. No ice signatures were observed from the topping duct temperatures. The evaporator outlet temperatures during the flush were nominal. After the flush, two restart attempts using the primary B controller were made, both of which were unsuccessful. The first attempt showed no evaporator outlet reaction. The second attempt showed a slight evaporator outlet change, but there was some small amount of feedline B water movement. The flush showed that the system B isolation and pulser valves on the FES were mechanically sound and that there was no obstruction in the feedline B system.

At 158:22:05 G.m.t. (02:00:42 MET), the FES topper was restarted successfully using the primary A controller. The FES was disabled 8 minutes later so that it would be inactive, as planned, for the entire docked period.

There was no additional troubleshooting or checkouts performed using the primary B controller for the remainder of the mission. The attitude timeline was adequate for minimizing FES operations and there were no constraints on using the FES as required for water dumps. In the unlikely event that the primary A controller failed, thermal analyses determined that no Orbiter hardware temperature limits would be violated using the current procedures. The only violations were the cabin temperature (which would peak at 91 °F at landing) and the dewpoint (which would peak at 68 °F). Typically, the cabin temperature is managed to remain below 75 °F to ensure crew comfort and performance. Additional analysis cases identified other actions could be taken to reduce the cabin temperature.

After undocking with the ISS, the primary A controller operated the FES satisfactorily for the rest of the flight. Testing of the primary B controller system was performed during the postflight turnaround activities. The problem was isolated to a failure of the primary B coil in the topper isolation valve.

The radiator bypass FES checkouts were performed for all deorbit attempts. The checkouts showed no anomalous signatures.

For postlanding operations, the ammonia boiler subsystem (ABS) was started on A-secondary at 170:18:06 G.m.t. The system A ran for approximately 37 minutes. The ABS was then switched to B-primary and deactivated less than 2 minutes later. This short-term operation was not long enough in time for the evaporator outlet to reach the controller temperature band. The GSE cooling was activated at 170:18:45 G.m.t.

Supply and Waste Water Subsystem

The supply water and waste management subsystems performed nominally throughout the mission and all of the scheduled in-flight checkout requirements were satisfied.

Supply water was managed through the use of the FES, water transfer to the International Space Station and the overboard nozzle dump system. Six supply water nozzle dumps were performed at a nominal dump rate of 2.4 percent/minute (3.96 lb/min). The line heater maintained the supply water dump line temperature between 75.8 °F and 96.9 °F throughout the mission.

Four wastewater (from waste tank) nozzle dumps at an average rate of 1.93 percent/minute (3.2 lb/min) were performed. One ISS-U. S. Laboratory condensate contingency water container (CWC) containing approximately 4.4 lb of condensate and 4.4 lb of gas from the bag, and three payload water reservoirs (PWRs) containing iodinated water were nominally dumped through the wastewater dump nozzle. Dumping of PWRs was performed as a simultaneous dump with supply water. The Shuttle Urine Pre-treat Assembly (SUPA) was manifested for STS-111, and condensate collection in a CWC was implemented to minimize waste dumps while docked to ISS. The SUPA was redesigned after STS-97 and the time of use was pre-sleep instead of post-sleep. The SUPA performed satisfactorily.

As a result of condensate separation/collection, two CWCs of Shuttle condensate were filled and dumped overboard through the wastewater dump nozzle. The waste dump isolation valve was closed prior to connecting the CWC/PWR into the waste cross-tie quick disconnect (QD) to prevent back flow from the waste tank. Cabin pressure was at 14.5 psia during the CWC and PWR condensate dumps. The wastewater dump line temperature was maintained between 57.3 °F and 79.6 °F throughout the mission.

Eight CWCs were filled with supply water and transferred to the ISS, for a total of 798.9 lb. Three of the CWCs transferred were potable and five were technical water. The calculated average fill rate for each CWC was 106 lb/hr. In addition, four PWRs of iodinated water (86.0 lb) were filled and transferred to ISS.

At 161:01:18:31 G.m.t. (04:03:55:42 MET), the supply water tank A quantity sensor exhibited a dropout at a tank quantity of 75.9 percent. The tank quantity dropped to 68 percent for one second and recovered. Tank A has a record of dropouts on previous flights, and the problem was caused by either contamination of the collector bar and/or a surface defect on the collector bar of the potentiometer, which causes an intermittent break in continuity. These dropouts are understood and replacement of the quantity sensor will occur during Orbiter major modification (OMM).

Vacuum vent line temperature was maintained between 57.7 °F and 80 °F.

Waste Collection Subsystem

The waste management subsystem performed satisfactorily throughout the mission.

Smoke Detection and Fire Suppression Subsystem

The Smoke Detection system showed no indications of smoke generation during the entire duration of the flight. Use of the Fire Suppression system was not required.

Flight Data Subsystem

The flight data subsystem performed nominally.

Flight Control Subsystem

The flight control subsystem (FCS) performance was nominal throughout the flight.

The operations (OPS) 8 data display unit (DDU) redundant power check was not performed correctly – power from both buses was removed at the same time. It was not considered necessary to repeat the test, and there was no flight impact. DDU redundant

power was verified in every flow on the pad, and this check was only recently added to OPS 8 checks.

The FCS checkout was performed satisfactorily using APU 1 to support the checkout with a start time of 167:11:46:19 G.m.t. (10:14:23:30 MET). The run time was 4 minutes and 6 seconds, and 14 pounds of fuel were used during the APU 1 operation. The total run time was too short to require spray cooling from the WSB. FCS performance was nominal.

The weight-on-wheels landing plots appear consistent with the "greased landing" phenomenon that is seen during exceptionally smooth landings. Following the initial touch of the main landing gear, the wheels were spun up and wheel contact reported by the redundant weight-on-wheels detectors; however, the Orbiter was still flying sufficiently to prevent compression of the oleo struts enough to activate the weight-on-wheels proximity detectors until five seconds had passed. The result was a false proximity switch fail indication on both the left and right sides. No flight impact occurs when this condition occurs.

Flight Software

The O1-29 software performed satisfactorily throughout the mission.

Displays and Controls Subsystem

The displays and controls subsystem performed nominally during the mission.

Communications and Tracking Subsystem

The communications and tracking subsystem performed satisfactorily throughout the mission. A minor problem was noted and is discussed in the last paragraph.

During the rendezvous, the Ku-band radar system acquired the ISS at 158:13:13 G.m.t. (01:15:50 MET) at a range of 141,000 ft (approximately 23.5 nmi). At 158:15:34 G.m.t. (01:18:11 MET), at a range of 510 ft., the Ku-band system was placed in the communications mode.

Following undocking from the ISS, the Ku-band system was placed in the radar mode at 166:16:05 G.m.t. (09:18:42 MET) and acquired the ISS at a range of 400 ft. The radar maintained lock-on to the ISS during the latter part of the ISS flyaround and during the separation maneuver. At a range of 1580 feet, the system was placed in the communications mode at 166:16:20 G.m.t. (09:18:57 MET). The performance of the Ku-band system was nominal.

Spikes in the reflected power of the lower-left quad antenna have been observed during several periods of the mission. The signature of these spikes has been cyclic and the duration of the periods has been on the order of 5 to 45 minutes. During each of the periods where spikes have occurred, the system was operating on S-band string 2. These spikes have been observed while docked and not docked with the ISS. There was no performance impact and no postflight troubleshooting is planned.

Operational Instrumentation/Modular Auxiliary Data System

The operational instrumentation/modular auxiliary data system performed satisfactorily throughout the mission. No problems or in-flight anomalies were noted in the data review.

Structures and Mechanical Subsystems

The structures and mechanical subsystems performed satisfactorily. No significant problems or in-flight anomalies were noted during the mission or the data review. The following table presents the pertinent data on the landing of the Orbiter.

LANDING PARAMETERS

Parameter	From Threshold, ft	Speed, Keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	1834.0	193.9	-0.75	N/A
Nose gear touchdown	5379.2	150.6	N/A	-3.63
Brake initiation speed		87.3 keas		
Brake-on time		35.97 seconds		
Rollout distance		11578.8 feet		
Rollout time		63.76 seconds		
Runway		22 (Concrete) EAFB		
Orbiter weight at landing		220,173.0 lb		
Brake sensor Location	Peak Pressure, Psia	Brake assembly	Gross energy, million ft-lb	
Left-hand inboard 1	769.6	Left-hand inboard	10.94	
Left-hand inboard 3	769.6			
Left-hand outboard 2	745.1	Left-hand outboard	10.42	
Left-hand outboard 4	745.1			
Right-hand inboard 1	921.6	Right-hand inboard	17.98	
Right-hand inboard 3	921.6			
Right-hand outboard 2	779.4	Right-hand outboard	15.45	
Right-hand outboard 4	779.4			

The payload bay doors were opened as planned at 156:22:59:13 G.m.t. (00:01:01:36:23 MET). All voltages were nominal and the motors opened the doors in nominal dual-motor time.

The main landing gear tires were reported to be in typical condition following a landing on the concrete runway. The main landing gear inboard tires both had damage on the second tread from the inboard side.

The ET/Orbiter (EO) separation devices EO-1, EO-2 and EO-3 were reported to have functioned normally. No ordnance fragments were found on the runway beneath the umbilicals. Several of the EO-2 fitting retainer clips were missing. The EO-2 and EO-3 pyrotechnic shutters were fully closed.

The payload bay doors (PLBDs) were closed and latched for the first KSC landing opportunity on the nominal end-of-mission landing day at 168:13:20:49 G.m.t. (11:15:58:00 MET). All payload bay door close and latch operations occurred in dual motor time.

Both landing opportunities for the planned landing day were waved-off because the forecast and observed weather conditions were unacceptable. As a result, the PLBDs were reopened at 168:15:59:04 G.m.t. (11:17:36:15 MET).

At 168:15:47 G.m.t. (11:18:24 MET), the starboard forward-bulkhead latch-release A indication failed to turn on when the latches reached the released position. Approximately 40 minutes later, the switch began to toggle on and off, and did so 14 times over the next 1 minute and 33 seconds. The switch remained on after the last toggle. This failure had no impact on subsequent PLBD closure or re-opening operations.

At 168:15:58 G.m.t. (11:18:35 MET), when the port PLBD was driven open, all three port aft ready-to-latch (R-T-L) indications remained on (Flight Problem STS-111-V-03). The limit switches are contained in a switch module and actuated by a single paddle that contacts the door. The closed-2 limit switch, which is contained in the same switch module and actuated by the same paddle, operated properly. During door opening, the closed limit switch is deactivated before the three R-T-L switches. It is likely that the paddle was stuck between the closed and R-T-L positions. The starboard and port doors were successfully opened. The three R-T-L indications subsequently turned off over a period of several hours. This failure had no impact on subsequent PLBD closure or re-opening operations.

For the landing attempts on the first extension day, the payload bay doors (PLBDs) were closed and latched for the first KSC landing opportunity at 169:12:10:13 G.m.t. (12:14:47:24 MET). All payload bay door close and latch operations occurred in dual motor time.

Both landing opportunities for the first extension day were waved off because the forecasted and observed weather conditions were unacceptable. As a result, the PLBDs were reopened at 169:14:55:41 G.m.t. (12:17:32:52 MET).

The PLBD opening following the wave-off of the first extension day landing opportunities was performed in the manual mode due to the limit switch anomalies encountered during the nominal end-of-mission landing-day door opening. After the port door was opened, the three portside aft ready-to-latch (R-T-L) indications once again remained on when they should have transferred off. The indications again transferred off after several hours. Postflight troubleshooting on the vehicle did not isolate a problem with the R-T-L switch module. However, the switch module will be removed and replaced.

The starboard forward-bulkhead latch-release A indication anomaly that occurred on the nominal end-of-mission landing day did not repeat.

For the landing attempts on the second extension day, the PLBDs were closed and latched for the first KSC landing opportunity at 170:11:06:51 G.m.t. (13:13:44:02 MET). All payload bay door close and latch operations occurred in dual motor time.

Both KSC landing opportunities of the second extension day was waved off because the forecasted and observed weather conditions were not acceptable for landing. As a

result, the landing was scheduled for the first landing opportunity for Edwards Air Force Base (EAFB) on the second extension day.

A post-landing walk-down of the runway was performed and no flight hardware was found. All components of the drag parachute were recovered and appeared to have functioned properly. Both reefing and line cutter pyrotechnic devices were expended.

Integrated Aerodynamics, Heating and Thermal Interfaces

The prelaunch thermal interface purges were normal with no problems noted. Likewise, the ascent aerodynamic heating and plume heating were nominal with no problems noted. The entry aerodynamic heating on the SSME nozzles had no evidence of higher heating (metal did not have a bluish discoloration due to outgassing or oxidization).

Thermal Control Subsystem

All Orbiter subsystems were maintained within the designed temperature limits and no thermally related problems or anomalies were identified from the review and analysis of the data. All heaters cycled within the established thermal limits throughout the mission.

At 158:13:27 G.m.t. (01:16:05 MET), the APU in fuel pump/line/GGVM system A heater started cycling with a lower amplitude. Cycling was normal on the system B thermostat.

As a result of the adverse weather at KSC that extended the mission two days, the Orbiter flew in the -ZLV +YVV attitude for both extension days. This attitude maintained the thermal gradients lower across the Orbiter structure. There were no entry problems observed. The best estimated trajectory (BET) was well within limits and did not contribute to the "ready to latch" anomaly.

Aerothermodynamics

Structural thermocouple temperature data, aileron deflection data, and yaw thruster firings all indicated an asymmetric drag around Mach 11.6. This drag data are associated with the onset of asymmetric transition from laminar flow to turbulent flow. However, wing structural temperature-rise data did not indicate asymmetric boundary layer transition.

The acreage heating data indicate that the vehicle experienced normal entry heating. Structural temperature data are within the range expected for this type of mission. Wing temperature data are on the high side for this vehicle because of a low initial temperature.

Local heating was also normal.

Thermal Protection Subsystem and Windows

The thermal protection subsystem (TPS) performed satisfactorily. The postlanding inspection of the Orbiter TPS identified a total of 79 damage sites of which 26 had a major dimension of 1-inch or larger. This total does not include the numerous damage sites on the base heat shield that are attributed to SSME vibration/acoustics, exhaust plume recirculation and the flame arrestment sparkler system. The distribution of these impacts on the vehicle is shown in the table on the following page.

TPS DAMAGE SITES

Orbiter Surfaces	Hits > 1 Inch	Total Hits
Lower Surface	21	47
Upper Surface	1	6
Window Area	3	19
Right Side	0	4
Left Side	1	3
Right OMS Pod	0	0
Left OMS Pod	0	0
Total	26	79

The Orbiter lower surface sustained 47 damage sites of which 21 had a major dimension of 1-inch or larger. A total of 19 damage sites occurred on the lower surface between the nose landing gear and the main landing gear doors. Eight of these lower surface damage sites had a major dimension of one inch or greater. Nine of the 19 damage sites between the landing gear doors occurred on the right-hand wing glove.

The largest damage site on the lower surface measured 3 inches by ½ inch by 3/8 inch, and was located to the left of the centerline between the main landing gear wheel wells. The second largest hit on the lower surface measured 3 inches by ¼ inch by 3/8 inch and was located aft of the nose landing gear door at approximately the same position to the left of the centerline. Both of these damage sites had relatively large length to width ratios. The similarity of the locations of the two hits and the large length-to width ratios suggests that the damage sites were caused by the same source.

A total of 14 damage sites on the lower surface were located in the vicinity of the LH₂ umbilical door. Most of these damage sites were caused by pieces of the umbilical purge barrier flailing in the airstream and impacting the TPS tiles before detaching.

A triangular-shaped tile corner (measuring 2 ½ inches by 2 ½ inches) was missing. The location of the missing tile piece was on the inboard end of the right-hand inboard elevon, approximately one-third of the elevon chord length downstream of the leading edge.

A comparison of lower surface damage sites for the previous 10 flights is shown in the following table.

COMPARISON OF LOWER SURFACE DAMAGE SITE DATA FROM LAST TEN FLIGHTS

Parameter	STS -97	STS -98	STS -102	STS -100	STS -104	STS -105	STS -108	STS -109	STS -110	STS -111
Lower surface, total hits	78	73	44	42	108	144	95	63	70	47
Lower surface, hits > 1 in.	10	8	10	4	4	25	22	14	18	21
Longest damage site, in.	3.0	3.0	1.0	2.5	4.5	5	8.0	3.5	3.5	3.0
Deepest damage site, in.	0.5	0.5	0.12	0.12	0.25	0.06	0.37	0.12	0.62	0.50

A total of 19 damage sites, with 3 having one dimension greater than one inch, were identified on the window perimeter tiles. The largest damage site in the window area was above window 3 and had dimensions of 2 inches long by 2 inches by 1/8 inch deep. Damage to the window perimeter tiles on the forward-facing windows is attributed to impacts made by the forward RCS paper covers with room temperature vulcanizing (RTV) material adhesive on the back. The hazing and streaking was moderate on forward-facing windows 2, 3, 4 and 5. In addition to hazing, streaks were observed on windows 3 and 4. These streaks may also be the result of impacts by RTV adhesive used on the forward RCS paper covers.

The vertical tail sustained damage at several debris damage sites, the largest of which was estimated to be 2 inches long by 2 inches wide by 1/4 inch deep,

There was less than usual tile damage on the Orbiter base heat shield. The SSME dome heat shield closeout blankets were in good overall condition. Slight fraying was observed on the SSME 1 blanket at the 6 o'clock position. Two large damage sites (approximately 3 inches by 3 inches) were located on the body flap upper surface tiles adjacent to the body flap stub. These two sites appeared to be failed repair sites.

In summary, both the total number of Orbiter TPS damage sites and the number of sites that were 1-inch or larger were well within the established family. The potential identification of debris damage sources for this mission will be based on laboratory analysis of the Orbiter postlanding microchemical samples, inspection of the recovered SRB components, film analysis and aerodynamic debris particle trajectory analysis. The results will be published in the STS-111 Debris/Ice/TPS Assessment and Integrated Photographic Analysis report.

Gas Sample Analysis

The analysis of the gas samples contained in the six bottles showed the samples to be acceptable and within the nominal range for percentage of hydrogen. Constituents present in each bottle greater than 0.1 percent were determined. Back pressure calculations of actual pressure assumed all bottles were a total volume of 250 cc.

The analysis was performed using an AeroVac Mass Spectrometer with a 0 to 1000 Torr capacitance manometer. The backup analysis was accomplished using a Finnegan 9001 Gas Chromatograph with Discharge Ionization Detection (DID). A backup analysis was made of all constituents with the exception of Helium.

The table showing the data measured from the bottles is presented in the Shuttle Flight Data and In-Flight Anomaly List (JSC 19413). This document may be accessed on the Space Shuttle Vehicle Engineering Office home page under the MER heading.

EXTRAVEHICULAR ACTIVITY

The crew performed three extravehicular activities (EVAs) successfully with all planned tasks completed. The total EVA time was 19 hours 30 minutes for a total man hours EVA of 39 hours.

FIRST EXTRAVEHICULAR ACTIVITY

The first EVA was successfully completed with a total EVA time of 7 hours and 14 minutes. The EVA was conducted from the International Space Station (ISS) airlock and officially started when the extravehicular mobility units (EMUs) were placed on internal battery power at 160:15:26 G.m.t. (03:18:03 MET). The objectives of the EVA were the installation of a PDGF on the P6 truss, the transfer of Service Module debris panels (SMDPs) onto a temporary location on the ISS pressurized mating adapter (PMA), and the removal of the thermal blankets from the mobile base system (MBS) in preparation for removal from the Orbiter payload bay. An additional task was a visual and photographic inspection of the failed ISS control moment gyro (CMG) -1 on the Z1 truss segment. The EVA concluded when repressurization of the airlock was initiated at 160:22:40 G.m.t. (04:01:17 MET).

During the first EVA, no biomedical data were received from the EV1 crewmember's operational bioinstrumentation system (OBS). Good biomedical data was received during EMU checkout but the data was lost at the initiation of the EVA. This failure had no impact on the EVA as the Surgeon relied on metabolic rate and voice call-downs to monitor the health status of the EV1 crewmember. During the second EVA preparations, an early OBS checkout showed no biomedical data was received from the EV1 crewmember's EMU. The EVA cable was determined to be faulty (from the signal conditioner to the EMU electrical harness). The cable was replaced with serial number 1039. The suspect hardware was returned to JSC for troubleshooting.

SECOND EXTRAVEHICULAR ACTIVITY

The second EVA was successfully completed with a total EVA time of 5 hours. The EVA was conducted from the ISS airlock and officially started when the EMUs were placed on internal battery power at 162:15:19 G.m.t. (05:17:58 MET). The objectives of the EVA were the installation of the MBS to the MT, and deployment of the wrist roll joint in preparation for installation during the third EVA. The MBS camera configuration was established during this EVA. The EVA concluded when repressurization of the airlock was initiated at 162:20:19 G.m.t. (05:22:58 MET).

During the EVA 2 preparation when the intravehicular activity (IVA) crewmember powered off the switch to both of the EMUs to support the EVA crew in disconnecting their umbilical from the power supply assembly (PSA), an over-voltage indication was observed. Since the EMU batteries had sufficient charge, the decision was made to continue with the EVA. The IVA crewmember cycled power to the PSA and it successfully came back on line. During the EVA, EMU battery (S/N 2022) discharged at an increased rate resulting in a battery alarm at 5 hours. During airlock repressurization, the PSA was not used and the crew remained on EMU battery power. Due to the problems encountered during EVA 2, EVA 3 was reassessed to determine if any changes were required to the PSA or battery plan.

THIRD EXTRAVEHICULAR ACTIVITY

The third EVA was successfully completed with a total EVA time of 7 hours and 16 minutes. The EVA was conducted from the ISS airlock and officially started when the EMUs were placed on internal battery power at 164:15:16 G.m.t. (07:17:53 MET). The objective of the EVA was the removal of the defective Space Station remote manipulator system (SSRMS) wrist roll joint (WRJ) and installation of the replacement WRJ. The Shuttle RMS was used to maneuver the crew between the SSRMS and the payload bay during the removal and replacement activities. The EVA concluded when repressurization of the airlock was initiated at 164:22:32 G.m.t. (08:01:09:11MET).

During the prebreathe-period prior to the third EVA, a loud constant noise was heard on the air-to-ground and space-to-ground radio links. Troubleshooting included beginning radio frequency (RF) communications early as well as switching the Space-to-Space Orbiter Radio (SSOR) strings. Neither of these steps resolved the problem. It was subsequently determined that one of the extravehicular crewmember's (EV1) microphone booms had been inadvertently moved out of position. Airflow was apparently constantly tripping the voice-operated (VOX) circuitry and this was causing the noise. The EV1 crewmember repositioned his microphone boom and the noise was eliminated. The EVA began on time and communications were satisfactory throughout the EVA.

REMOTE MANIPULATOR SYSTEM

The remote manipulator system (RMS) performed satisfactorily throughout the mission.

The RMS checkout began at 157:15:10:01 G.m.t. (00:17:47:12 MET), and the RMS checkout was completed at 157:16:31 G.m.t. (00:19:08 MET). No anomalies were detected. The single/direct-drive switch override was performed during the RMS power-up to minimize the use of this switch. The functions of the single/direct-drive switch were transferred to the proceed/stop switch. The override was performed because of concerns over the cycle life of the single/direct-drive switch. Following the checkout, the RMS was used to perform an abbreviated survey of the payload bay.

The RMS was powered up and uncradled at approximately 159:12:14:32 G.m.t. (02:14:41:43 MET). Following an inspection of the Node 1 active common berthing mechanism (ACBM), the RMS was maneuvered to the Multi Purpose Logistics Module (MPLM) pre-capture position. The MPLM was captured and unberthed from the Orbiter payload bay and maneuvered to a low-hover position. Installation of the MPLM to Node 1 was successfully completed at 159:14:27:30 G.m.t. (02:17:04:41 MET). Approximately fifteen minutes later, the RMS ungrappled the MPLM and the RMS was commanded in the single-joint mode to the power and data grapple fixture (PDGF) installation-viewing overnight park position.

During the first EVA (flight day 5), the RMS was used to provide camera views of the power and data grapple fixture (PDGF) installation on P6 truss. At 160:18:35 G.m.t. (03:21:12 MET), the RMS was maneuvered to the mobile transporter capture latch (MTCL) viewing position to view mating of the MBS to the mobile transporter (MT).

On flight day 6, the RMS was maneuvered to the Mobile Base System (MBS) install viewing position to view the latching of the MBS to the Mobile transporter (MT). After the successful latching, the RMS was cradled and powered down.

The RMS supported the third EVA as well as the returning the MPLM to the Orbiter payload bay.

GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

The government furnished equipment/flight crew equipment (GFE/FCE) performed nominally. Minor problems were noted and these are discussed in the following paragraphs.

Early in the mission, the crew voice as received on the ground was weak. As a result of the low output, the crew switched to another hand-held microphone (HHM) and the change produced satisfactory audio levels on the ground. The problem did not impact the mission. The HHM will be returned to the Johnson Space Center (JSC) for troubleshooting.

During the initial setup of photographic/television equipment, the crew reported a problem with a camcorder-to-advanced video interface unit (AVIU) cable. The crew replaced the serial number 1045 cable with the serial number 1035 cable. The video image was restored to the downlink and to the cabin monitors. The AVIU cable will be returned to JSC for troubleshooting.

During the first EVA, no biomedical data were received from the EV1 crewmember's operational bioinstrumentation system (OBS). Good biomedical data was received during EMU checkout but the data was lost at the initiation of the EVA. This failure had no impact on the EVA as the Surgeon relied on metabolic rate and voice call-downs to monitor the health status of the EV1 crewmember. During the second EVA preparations, an early OBS checkout showed no biomedical data was received from the EV1 crewmember's EMU. The EVA cable was determined to be faulty (from the signal conditioner to the EMU electrical harness). The cable was replaced with serial number 1039. The suspect hardware was returned to JSC for troubleshooting.

The crew reported that pressing the transmit/intercommunication (XMIT/ICOM) key on the battery power speaker microphone unit (BPSMU) caused the video on the camcorder to flicker. The crew disconnected the audio cable from the camcorder and that corrected the problem. With this configuration, the crew was not able to record voice on the camcorder. When the crew required audio, alternate configurations were used to recover the function. The suspect hardware will be returned to JSC for troubleshooting.

During the prebreathe-period prior to the third EVA, a loud constant noise was heard on the air-to-ground and space-to-ground radio links. Troubleshooting included beginning radio frequency (RF) communications early as well as switching the Space-to-Space Orbiter Radio (SSOR) strings. Neither of these steps resolved the problem. It was subsequently determined that one of the extravehicular crewmember's (EV1) microphone booms had been inadvertently moved out of position. Airflow was apparently constantly tripping the voice-operated (VOX) circuitry and this was causing the noise. The EV1 crewmember repositioned his microphone boom and the noise was eliminated. The EVA began on time and communications were satisfactory throughout the EVA.

The TCS was activated and initialized at a range of approximately 25,000 ft., and began acquiring the ISS at approximately 159:02:58 G.m.t. (02:05:35 MET) at a range of about 10,000 ft. The TCS began tracking the ISS at a range of 4,520 ft., and the tracking continued until post-capture at a range of approximately 4.2 ft. The performance of the TCS was nominal.

The TCS began tracking at 5.5 ft. from the ISS and continued to track to a range of 606 ft. The performance and the TCS was nominal.

POSTLAUNCH PAD INSPECTION

The postlaunch inspection of the mobile launch platform (MLP) -1, Launch Pad A flight service structure (FSS), and rotating service structure (RSS) was conducted from Launch + 1.5 to 3.0 hours. No flight hardware was found.

Orbiter lift-off lateral acceleration data used to predict stud hang-ups were inconclusive and data evaluation is continuing. Evaluation of the MLP zero-level was performed and the south holddown studs were visually assessed as having no indication of hang-up. Erosion was typical on both the north and south posts. The north holddown post blast covers and the T-0 umbilical exhibited minimal exhaust plume damage. Both SRB aft-skirt GN₂ purge lines were intact; however, the protective tape layering was partially eroded on both the right-hand and left-hand sides.

The LO₂ and LH₂ tail service masts (TSMs) appeared undamaged with both bonnets closed properly. The MLP deck was generally in good shape.

The GH₂ vent line latched on the eighth of eight teeth on the FSS latching mechanism. The vent line was centered in the latching mechanism. The ground umbilical carrier plate (GUCP) and 7-inch quick-disconnect (QD) probe had no damage; the poppet was observed to be intact. The deceleration cable was in its nominal configuration, and the vent-line blanket was sooted and torn.

The Orbiter access arm (OAA) appeared to be intact with no evidence of plume impingement. All slide-wire baskets were secured with no evidence of damage.

The gaseous oxygen (GO₂) vent arm, ducts and structure appeared to be in nominal shape with no evidence of plume damage. The GO₂ vent seals were inspected and found to be in good shape with only a slight indication of ET paint residue present.

Debris findings included:

- A. An OTV camera was pointed straight up on the FSS 115-foot level; and
- B. A "Do Not Operate" tag that had been taped to preclude debris concern had the tape and tag heat-shrunk and remained attached.

Overall damage to the pad appeared to be normal.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DEVELOPMENT TEST OBJECTIVES

DTO 694 - Biotechnology Water Treatment System - Twelve water samples were successfully retrieved from the Orbiter galley (fuel cell water) in support of this DTO. This DTO is an experiment to test the water purification system to allow use of Shuttle fuel cell water on future flights of biotechnology cell-culture experiments. Currently, pure ionized water that is used by these experiments must be launched with the experiment. The purpose of this DTO was to test a prototype unit in the microgravity environment with the Shuttle hardware. Samples will be tested following the flight, and the results of these tests will be published in separate documentation.

DTO 700-14 - Single String Global Positioning System - The DTO 700-14 was completely successful. The miniature airborne global position system (GPS) receiver (MAGR) payload and general support computer (PGSC) status was provided virtually every day. These reports indicated that the MAGR PGSC recorded data properly. The PGSC was nearly filled with MAGR engineering data for detailed analysis of MAGR performance, which was nominal. Although the MAGR gave a failed self-test indication during the flight control system (FCS) checkout, this was a known MAGR condition and all other MAGR parameters indicated nominal receiver operation. The MAGR was used during entry to demonstrate its most critical operating period. The MAGR demonstration during entry was designed to show that it can be used to replace the current Orbiter tactical air navigation (TACAN) system for entry performance.

DTO 805 - Crosswind Landing Performance - DTO 805 is a DTO of Opportunity, and was not performed as winds were below the minimum requirements of this DTO.

DETAILED SUPPLEMENTARY OBJECTIVES

DSO 498 - Space Flight and Immune Function - Samples were taken from the crew preflight and postflight. The results for this process will be reported in separate documentation.

DSO 499 - Eye Movements and Motion Perception Induced by Off-Vertical Axis Rotation - Tests were performed with the crew preflight and postflight. The results for this process will be reported in separate documentation.

DSO 500 - Space Flight-Induced Reactivation of Latent Epstein-Barr Virus - Samples were taken from the crew preflight and postflight. The results for this process will be reported in separate documentation.

DSO 503S - Tests of Midodrine as a Countermeasure Against Postflight Orthostatic Hypotension - Samples were taken from the crew preflight and postflight. The results for this process will be reported in separate documentation.

DSO 634 - Sleep/Wake Actigraphy and Light Exposure during Space Flight - Data were acquired during the flight. The results from this DSO will be reported in separate documentation.

DSO 635 - Spatial Reorientation Following Space Flight - Tests were performed with the crew preflight and postflight. The results for this process will be reported in separate documentation.

DSO 631B –Integrated Measurement of Cardiovascular Effects of Space Flight (Protocol B) - Tests were performed with the crew preflight and postflight. The results for this process will be reported in separate documentation.

PHOTOGRAPHY AND TELEVISION ANALYSIS

The launch videos and films were reviewed and evaluated following the STS-111 launch. A total of 24 launch videos and all launch films were reviewed and no anomalous events or conditions were noted.

In addition, films from the 16mm umbilical camera as well as the hand-held 35mm and video cameras onboard the Orbiter provided good coverage of the ascent and ET after separation. No anomalous conditions were noted.

No anomalous events were noted in the review of the landing videos. All aspects of the landing appeared to be normal.

TABLE I.- STS-111 SEQUENCE OF EVENTS

EVENT	DESCRIPTION	ACTUAL
APU Activation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	156:21:17:59.764 156:21:18:02.832 156:21:18:05.382
*SRB HPU Activation	LH HPU System A start command LH HPU System B start command RH HPU System A start command RH HPU System B start command	156:21:22:20.928 156:21:22:21.088 156:21:22:21.248 156:21:22:21.408
*Main Propulsion System Start	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	156:21:22:42.464 156:21:22:42.565 156:21:22:42.692
*SRB Ignition Command (Liftoff)	SRB Ignition command	156:21:22:49.008
*Throttle to 104.5 Percent	ME-2 Command accepted ME-1 Command accepted ME-3 Command accepted	156:21:22:52.845 156:21:22:52.852 156:21:22:52.864
*Throttle to 98 Percent	ME-2 Command accepted ME-1 Command accepted ME-3 Command accepted	156:21:23:06.765 156:21:23:06.772 156:21:23:06.784
*Throttle to 72 Percent	ME-2 Command accepted ME-1 Command accepted ME-3 Command accepted	156:21:23:22.925 156:21:23:22.933 156:21:23:22.945
*Throttle to 104.5 Percent	ME-2 Command accepted ME-1 Command accepted ME-3 Command accepted	156:21:23:37.165 156:21:23:37.173 156:21:23:37.185
Maximum Dynamic Pressure	Derived ascent dynamic performance	156:21:23:48
*Both RSRMs Chamber Pressure at 50 psi	LH RSRM chamber pressure RH RSRM chamber pressure	156:21:24:47.368 156:21:24:48.208
*End RSRM Action Time	LH RSRM chamber pressure RH RSRM chamber pressure	156:21:24:49.898 156:21:24:50.818
*SRB Physical Separation	LH APU B turbine speed – LOS	156:21:24:52.928
SRB Separation Command	SRB separation command flag	156:21:24:53
OMS Assist Maneuver ignition	Left engine bi-prop valve position Right engine bi-prop valve position	156:21:25:03.2 156:21:25:03.2
OMS Assist Maneuver Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	156:21:25:51.6 156:21:25:51.6
*Throttle Down for 3g Acceleration	ME-2 Command accepted ME-1 Command accepted ME-3 Command accepted	156:21:30:11.890 156:21:30:11.903 156:21:30:11.913
3g Acceleration	Total load factor	156:21:30:56.0
*Throttle Down to 67 Percent for Cutoff	ME-2 Command accepted Closed ME-3 Command accepted	156:21:31:06.290 156:21:31:06.305 156:21:31:06.314
*SSME Shutdown	ME-2 Command accepted ME-1 Command accepted ME-3 Command accepted	156:21:31:12.650 156:21:31:12.665 156:21:31:12.674
MECO	MECO Command Flag MECO Confirmed Flag	156:21:31:13 156:21:31:14
ET Separation	ET separation command flag	156:21:31:34
APU Deactivation	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	156:21:38:22.020 156:21:38:36.713 156:21:38:49.637

TABLE I.- STS-111 SEQUENCE OF EVENTS (CONTINUED)

EVENT	DESCRIPTION	ACTUAL
OMS 1 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Not Performed – direct insertion
OMS 1 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	Trajectory flown
OMS 2 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	156:22:01:34.0 156:22:01:34.0
OMS 2 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	156:22:02:37.0 156:22:02:37.0
Payload Bay Doors	Right payload bay door open 1 Left payload bay door open 1	156:22:57:55 156:22:59:14
OMS 3 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	157:00:57:20.3 157:00:57:20.3
OMS 3 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	157:00:59:10.7 157:00:59:10.7
OMS 4 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	N/A 157:14:29:47.9
OMS 4 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	N/A 157:14:29:55.9
OMS 5 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	157:23:31:18.7 157:23:31:18.7
OMS 5 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	157:23:31:49.5 157:23:31:49.5
OMS 6 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	158:12:23:58.5 158:12:23:58.5
OMS 6 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	158:12:25:19.9 158:12:25:20.1
OMS 7 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	158:13:56:49.3 N/A
OMS 7 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	158:13:57:01.9 N/A
Docking Ring Capture	Capture	158:16:24:54
Docking with ISS	Docking ring final position	158:17:26:51
MPLM Grapple	End Effector capture command issued	159:13:23:55
MPLM Grapple	End effector rigidized	159:13:24:12
MPLM Ungrapple	End effector rigidized	159:14:47:37
MPLM Grapple	End effector derigidize command issued	159:14:47:53
MPLM Ungrapple	End effector extended	159:14:47:53
MPLM Grapple	End effector rigidized command issued	165:16:48:53
MPLM Grapple	End Effector rigidized	165:16:49:10
MPLM Ungrapple	End effector derigidize command issued	165:20:22:18
MPLM Ungrapple	End effector extended	165:20:22:34
Undocking Completed	Undock Complete	166:14:31:49
OMS 8 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	166:17:57:49.3 166:17:57:49.3
OMS 8 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	166:17:58:16.7 166:17:58:16.7

TABLE I.- STS-111 SEQUENCE OF EVENTS (CONCLUDED)

EVENT	DESCRIPTION	ACTUAL
Flight Control Subsystem Checkout		
APU 1 Start	APU-1 GG chamber pressure	167:11:46:18.431
APU 1 Stop	APU-1 GG chamber pressure	167:11:50:21.479
OMS 9 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	167:15:30:00.3 167:15:30:00.3
OMS 9 CUTOFF	Left Engine bi-prop valve position Right engine bi-prop valve position	167:15:30:10.5 167:15:30:10.5
Payload Bay Doors Closed	Left payload bay door closed Right payload bay door closed	168:13:18:11 168:13:19:48
Payload Bay Doors Open	Right payload bay door open Left payload bay door open	168:15:56:51 168:15:59:05
Payload Bay Doors Closed	Left payload bay door closed Right payload bay door closed	169:12:07:39 169:12:09:13
Payload Bay Doors Open	Right payload bay door open Left payload bay door open	169:14:53:19 169:14:55:42
Payload Bay Doors Closed	Left payload bay door closed Right payload bay door closed	170:11:04:20 170:11:05:51
APU Activation	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	170:16:44:44.164 170:17:13:45.191 170:17:13:47.064
Deorbit Burn Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	170:16:50:26.2 170:16:50:26.2
Deorbit Burn Cutoff	Right Engine bi-prop valve position Left engine bi-prop valve position	170:16:53:23.4 170:16:53:23.6
Entry Interface	Current orbital altitude above ellipsoid	170:17:26:32
Blackout End	Data locked (High sample rate)	No blackout
TAEM	Major mode cold (305)	170:17:51:41
Main Landing Gear Contact	MLG Left-hand inboard tire pressure MLG right-hand inboard tire pressure	170:17:57:42 170:17:57:42
Main Landing Gear Weight on Wheels	MLG left-hand weight on wheels MLG right-hand weight on wheels	170:17:57:43 **
Drag Chute Deployment	Drag Chute Deployment	170:17:57:44.9
Nose Landing Gear Contact	NLG right-hand inboard tire pressure	170:17:57:53
Nose Landing Gear at Weight-on-wheels	NLG weight-on-wheels	170:
Drag chute jettison	Drag chute jettison	170:18:58:23
Wheel stop	Velocity with respect to runway	170:17:58:46
APU Deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	170:18:18:53.780 170:18:19:04.823 170:18:19:12.715

* MSFC Supplied data.

** Data not available at time of publication.

TABLE II- STS-111 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-111-V-01	Left OME GN ₂ Regulator Leakage	150 22:20 G.m.t. PR LP04-25-0947 SPR KB4705	<p>Following activation of the OME arm/pressurization (A/P) switches at 150:22:19:31 G.m.t. during the first launch attempt, the left OME GN₂ regulator leaked at a rate of approximately 680 cc/min as evidenced by an abnormal GN₂ accumulator pressure increase (pressure rise rate = approximately 32 psi/minute). The crew closed the GN₂ isolation valve (A/P valve to Off) to avoid depleting the GN₂ supply tank. At that time, accumulator pressure had reached 494 psia. Note that the nominal GN₂ lockup pressure is 340 to 350 psia and the relief valve on this regulator cracks at about 495 psia. Subsequent actions involved momentarily opening the purge valves to vent the GN₂ accumulator to less than 50 psia and repressurizing the accumulator by cycling the left OME A/P valve. Leakage through the regulator stopped and the accumulator pressure stabilized at 349 psi. To confirm functionality, the accumulator pressure was vented and the A/P valve was cycled a second time with similar results. The most probable cause of this incident was considered to be transient contamination on the regulator poppet or seat. Subsequent to this event, the launch attempt was scrubbed due to the weather.</p> <p>KSC: During the stand-down for the weather, the decision was made to top off the GN₂ tank and perform another functional test of the regulator. The regulator again leaked, failing to lock-up. The regulator was removed and replaced. Subsequent flight operations of the regulator were nominal, and no further post-flight action on the vehicle is required.</p>
STS-111-V-02	FES Failure on Primary B Controller	158:10:44 G.m.t. 01:13:44 MET IPR 113V-0003 SPR 111RF01	<p>At 158:10:49 G.m.t. (01:13:26 MET), the FES topper was operating on the primary B controller, and the FES failed to come out of the standby mode (Flight Problem STS-111-V-02). At approximately 158:12:08 G.m.t. (01:14:45 MET), a restart of the FES on the primary B controller was attempted, but the FES again failed to respond. About 10 minutes later, a successful attempt was made to restart the FES topper using the primary A controller. The FES had been running successfully, shifting in and out of standby a number of times, before it failed to come out of standby. Since icing of the FES core was considered to be a possible explanation of the problem encountered with the primary B controller, a core flush procedure was recommended. At approximately 158:21:27 G.m.t. (02:00:04 MET), the FES topping core flush procedure was initiated and was completed at 26 minutes later. No ice signatures were observed from the topping duct temperatures. The evaporator outlet temperatures during the flush were nominal. After the flush, two restart attempts using the primary B controller were made, both of which were unsuccessful. The first attempt showed no evaporator outlet reaction. The second attempt showed</p>

TABLE II- STS-111 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-111-V-02 (Continued)	FES Failure on Primary B Controller (Continued)	158:10:44 G.m.t. 01:13:44 MET IPR 113V-0003 SPR 111RF01	<p>a slight evaporator outlet change, but there was some small amount of feedline B water movement. The flush showed that the system B isolation and pulser valves on the FES were mechanically sound and that there was no obstruction in the feedline B system.</p> <p>At 158:22:05 G.m.t. (02:00:42 MET), the FES topper was restarted successfully using the primary A controller. The FES was disabled 8 minutes later so that it would be inactive, as planned, for the entire docked period.</p> <p>There was no additional troubleshooting or checkouts performed using the primary B controller for the remainder of the mission. The attitude timeline was adequate for minimizing FES operations and there were no constraints on using the FES as required for water dumps. In the unlikely event that the primary A controller failed, thermal analyses determined that no Orbiter hardware temperature limits would be violated using the current procedures. The only violations were the cabin temperature (which would peak at 91 °F at landing) and the dewpoint (which would peak at 68 °F). Typically, the cabin temperature is managed to remain below 75 °F to ensure crew comfort and performance. Additional analysis cases identified other actions could be taken to reduce the cabin temperature.</p> <p>After undocking with the ISS, the primary A controller operated the FES satisfactorily for the rest of the flight. Testing of the primary B controller system was performed during the postflight turnaround activities. The problem was isolated to a failure of the primary B coil in the topper isolation valve.</p>
STS-111-V-03	Port Aft PLBD Ready-to-Latch Indications Failed On	168:25:58 G.m.t. 011:18:35 MET	<p>At 168:15:58 G.m.t. (11:18:35 MET), when the port PLBD was driven open, all three port aft ready-to-latch (R-T-L) indications remained on (Flight Problem STS-111-V-03). The limit switches are contained in a switch module and actuated by a single paddle that contacts the door. The closed-2 limit switch, which is contained in the same switch module and actuated by the same paddle, operated properly. During door opening, the closed limit switch is deactivated before the three R-T-L switches. It is likely that the paddle was stuck between the closed and R-T-L positions. The starboard and port doors were successfully opened. The three R-T-L indications subsequently turned off over a period of several hours. This failure had no impact on subsequent PLBD closure or re-opening operations.</p> <p>The PLBD opening following the wave-off of the first extension day landing opportunities was performed in the manual mode due to the limit switch</p>

TABLE II- STS-111 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-111-V-03 (Continued)	Port Aft PLBD Ready-to-Latch Indications Failed On	168:25:58 G.m.t. 011:18:35 MET	anomalies encountered during the nominal end-of-mission landing-day door opening. After the port door was opened, the three portside aft ready-to-latch (R-T-L) indications once again remained on when they should have transferred off. The indications again transferred off after several hours. Postflight troubleshooting on the vehicle did not isolate a problem with the R-T-L switch module. However, the switch module will be removed and replaced.

DOCUMENT SOURCES

In an attempt to define the official as well as the unofficial sources of data for the STS-111 Mission Report, the following list is provided.

1. Flight Requirements Document
2. Public Affairs Press Kit
3. Customer Support Room (CSR) Daily Reports and Final CSR Report
4. MER Daily Reports
5. MER Mission Summary Report
6. SSVEO In-Flight Anomaly List
7. MER Funny/Problem Tracking List
8. MER Event Times
9. Subsystem Manager Reports/Inputs
10. MOD Systems Anomaly List
11. MSFC Flash and Executive Summary Reports
12. MSFC Event Times
13. MSFC Interim Report
14. Crew Debriefing comments
15. Shuttle Operational Data Book
16. STS-111 Summary of Significant Events
17. Contractor Reports of Subsystem Operation

ACRONYMS AND ABBREVIATIONS

The following is a list of the acronyms and abbreviations and their definitions as these items are used in this document.

ABS	Ammonia Boiler System
ACBM	active common berthing mechanism
ADVASC	Advanced Agriculture
A/P	arm/pressurization
APCU	Assembly Power Control Unit
APU	auxiliary power unit
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
ATCS	active thermal control system
AVIU	advanced audio interface unit
BCSS-CS	Biotechnology Cell Science Stowage-Commercial Stelys
BET	best estimate trajectory
BPS	Biomass Production System
BTU	British thermal unit
CDRA	carbon dioxide removal assembly
CEI	contract end item
CETA	crew and equipment translation aid
CGBA	Commercial Generic Bioprocessing Apparatus
CID	computer interface device
CMG	Control Moment Gyroscope
CPCG-H	Commercial Protein Crystal Growth-High Density System
CRIM-CS	Commercial Refrigeration Incubator module-Commercial Stelys
CWC	contingency water container
DCPCG	Dynamically Controlled Protein Crystal Growth
DDU	data display unit
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
ΔP	differential pressure
ΔV	differential velocity
EAFB	Edwards Air Force Base
ECLSS	environmental control and life support system
e.d.t.	eastern daylight time
EMU	extravehicular mobility unit
EO	External Tank/Orbiter
EPDC	electrical power distribution and control
ET	External Tank
EV	extravehicular
EVA	extravehicular activity
EVARM	extravehicular activity radiation monitoring
EXPRESS	Expedite the Processing of Experiments to the Space Station
FCE	flight crew equipment
FCMS	fuel cell monitoring system
FCP	fuel cell powerplant
FCS	flight control system/subsystem

FCV	flow control valve
FES	flash evaporator system
FMBMT	flexible bearing mean bulk temperature
FSS	Fixed Service Structure
ft	feet
ft/sec	feet per second
GAS	Getaway Special
GFE	Government furnished equipment
GGVM	gas generator valve module
G.m.t.	Greenwich mean time
GH ₂	gaseous hydrogen
GN ₂	gaseous nitrogen
GO ₂	gaseous oxygen
GPC	general-purpose computer
GPS	Global Positioning System
GSE	ground support equipment
GUCP	ground umbilical carrier plate
HDP	hold-down post
HDTV	high definition television
HED	high-energy damper
HGDS	hazardous gas detection system
HHM	hand-held microphone
ICAPC	Increased capacity adaptive payload container
IELK	Individual Equipment Liner Kit
IMU	inertial measurement unit
ISPR	international standard payload rack
I_{sp}	specific impulse
ISS	International Space Station
ISSP	International Space Station Program
ITCS	Internal thermal control system
IVA	intravehicular activity
JSC	Johnson Space Center
keas	knots estimated air speed
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt/hour
lbm/hr	pound per hour
lbm/min	pound per minute
lbm	pound mass
LCC	Launch Commit Criteria
LH ₂	liquid hydrogen
LiOH	lithium hydroxide
LMSO	Lockheed Martin Space Operations
LO ₂	liquid oxygen
LON	launch on need
LP	Launch Package
MAGR	miniature air-to-ground receiver
Max $q\alpha$	maximum dynamic pressure
MBS	Mobile Base System
MC	midcourse correction (rendezvous maneuver)

MECO	main engine cutoff
MET	mission elapsed time
MLP	Mobile Launch Platform
Mlbf	million pounds force
mmHg	millimeter mercury
MMT	Mission Management Team
MPLM	Multi-Purpose Logistics Module
MPS	main propulsion system
MRS	Mobile Remote Services
MSG	microgravity science glovebox
MT	Mobile Transporter
MTCL	Mobile Transporter capture latch
NASA	National Aeronautics and Space Administration
NC1, NC2	circularization maneuvers (rendezvous maneuver)
NC3, NC4	circularization maneuvers (rendezvous maneuver)
NCC	rendezvous circularization maneuver
nmi	nautical mile
OAA	Orbiter Access Arm
OBS	Operational Bioinstrumentation
OCS	operations control software
ODS	Orbiter Docking System
OME	orbital maneuvering engine
OMM	Orbiter Major Modification
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OPS	Operations
ORU	orbital replacement unit
OV	Orbiter Vehicle
Pc	chamber pressure
PCG-STES	Protein Crystal Growth-Single Thermal Control System
PCG-EGN	Protein Crystal Growth-Enhanced GN ₂
PCS	pressure control system/portable computer system
PGDF	Power Data Grapple Fixture
PGME	Propylene Glycol Monomethyl Ether
PGSC	payload and general support computer
PLBD	payload bay door
PMA	pressurized mating adapter
PMBT	propellant mean bulk temperature
ppCO ₂	partial pressure carbon dioxide
ppm	parts per million
PRSD	power reactant storage and distribution/Prototype Synchrotron Radiation Detector
PSA	power supply assembly
psia	pound per square inch absolute
psid	pound per square inch differential
PWR	payload water reservoir
QD	quick disconnect
RAMBO	ram burn observations
RCS	reaction control subsystem
RF	radio frequency

RMS	Remote Manipulator System
RPC	remote power controller
RSP	resupply stowage platform
RSR	resupply stowage rack
RSRM	Reusable Solid Rocket Motor
RSS	rotating service structure/range safety system
R-T-L	ready-to-latch
RTV	room temperature vulcanizing (material)
S&A	safe and arm
SKV/SRVK	Russian air conditioner
SLWT	super lightweight tank
SMDP	service module debris panel
S/N	serial number
SO	starboard zero (truss)
SODB	Shuttle Operational Data Book
SRB	Solid Rocket Booster
SRMS	Shuttle Remote Manipulator System
SRSS	Shuttle range safety system
SSME	Space Shuttle main engine
SSOR	Space-to-space Orbiter Radio
SSRMS	Space Station Remote Manipulator System
STS	Space Transportation System
SUPA	Shuttle Urine Pretreat Assembly
SWAR	Sea-water activated release
T-	Time minus minutes to launch
TACAN	Tactical air navigation
TCS	Trajectory control sensor
Ti	terminal initiation maneuver
TPS	thermal protection system/subsystem
TSM	tail service mast
UF	Utilization Flight
Vdc	Volts direct current
VOX	voice operated
WCL	water coolant loop
WRJ	wrist roll joint
WSB	water spray boiler
ZCG-SS	Zeolite Crystal Growth-Sample Stowage