

# **STS-108 SPACE SHUTTLE MISSION REPORT**

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February 2002



**National Aeronautics and  
Space Administration**

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

**NOTE**

The STS-108 Space Shuttle Mission Report was prepared from inputs received from the responsible Space Shuttle Program offices as well as other organizations. The following personnel may be contacted should questions arise concerning the technical content of this document.

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STS-108  
SPACE SHUTTLE

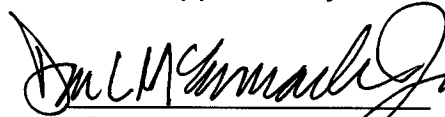
MISSION REPORT

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## INTRODUCTION

The Space Transportation System (STS) -108 Space Shuttle Program Mission Report presents a discussion of the Orbiter activities during 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 seventh mission of the Space Shuttle Program. The STS-108 flight was the twelfth flight to the International Space Station (ISS). STS-108 was the eighty-second mission since the return to flight, and the seventeenth 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-111; two Block IIA SSMEs that were designated as S/Ns 2049, and 2043 in positions 1, and 2, respectively, and one Block II SSME that was located in position 3; and two SRBs that were designated BI110. The two RSRMs were designated RSRM-82 with one installed in each SRB. The individual RSRM serial numbers were 360W082A for the left SRB and 360W082B for the right SRB.

The primary objective of the STS-108 mission was the delivery and integration the Utilization Flight (UF) -1 launch package (LP) to the orbiting ISS Stage 7A.1, and also included ISS crew rotation of three crewmembers. The LP consisted of a Multi-Purpose Logistics Module (MPLM), the lightweight Mission Peculiar Experiment Support Structure (MPeSS) Carrier (LMC), two Assembly Power Converter Units (APCUs), three ISS utilization payloads that were delivered to ISS, three ISS payloads that were returned from the ISS, as well as ISS equipment and supplies carried in the Orbiter crew compartment. Additionally, in the cargo bay, was the Multiple Application Customized Hitchhiker-1 (MACH-1) payload, and in the middeck the Avian Development Facility (ADF) subsystem operation and the in-flight anomalies that were identified during the mission.

The MPLM is a pressurized module that transports the U. S. Laboratory system racks, resupply/return stowage platforms (RSPs), and Resupply Stowage Racks (RSRs). The LMC is a cross-the-bay carrier that was mounted in Bay 13 of the Orbiter, and the LMC carried one Space Experiment module (SEM) and three Get-Away Special (GAS) canisters, which were one SEM and one GAS on top and two GAS canisters underneath the structure. Two GAS canisters were also mounted in Bay 3 on the starboard side. Should the ISS Program have required the launch-on-need (LON) capability for the ISS Program Orbiting Replacement Unit (ORU), the GAS canister on top of the LMC structure could have been removed to accommodate the LON ORU. Mission unique impacts were to be determined at LON call-up.

The Shuttle Ionospheric Modification with Pulsed Local Exhaust (SIMPLEX) payload objectives were met when a suitable target was identified.

The STS-108 flight was planned as an 11 day, plus 2-contingency-day flight, of which six days were to be docked to the ISS. The two contingency days were available for weather avoidance for landing or other Orbiter contingency operations. The mission was extended one day by the Mission Management Team (MMT) to complete the docked activities. 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-108 mission consisted of the four Shuttle crewmembers, and six ISS-rotation crewmembers (three Expedition 4 crewmembers (ascent) and three Expedition 3 crewmembers (descent)). The four-person crew of the STS-108 Shuttle flight consisted of Dominic L. Gorie, Captain, U. S. Navy, Commander; Mark Kelly, Lt. Cdr., U. S. Navy, Pilot; Linda M. Godwin, Ph. D., Civilian, Mission Specialist 1; and Daniel M. Tani, Civilian, Mission Specialist 2. The Expedition 3 crew, returning from over 129 days on the ISS, consisted of Frank L. Culbertson, Captain, U. S. Navy (Retired), Expedition 3 Commander; Vladimir N. Dezhurov, Cosmonaut, Lt. Col., Russian Air Force, Flight Engineer; and Mikhail Tyurin, Cosmonaut, Civilian, Flight Engineer. The Expedition 4 crew, who were taking up residence in 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.

STS-108 was the fourth space flight for Mission Specialist 1, the third space flight for the Shuttle Commander, and the first space flight for the Pilot and Mission Specialist 2. The Expedition 3 Commander completed his fourth space flight. The Expedition 3 flight engineer Dezhurov completed his second long-duration space flight, and flight engineer Tyurin completed his first long-duration space flight. The Expedition 4 Commander began his first ISS space flight with his first flight in a Space Shuttle after having completed one long-duration space flight on the Russian Mir 21; flight engineer Bursch began his first long-duration mission on the ISS with his fourth space flight in the Space Shuttle; and Walz also began his first long-duration space flight on the ISS with his fourth space flight on Space Shuttle.

## MISSION SUMMARY

The initial launch countdown for the STS-108 mission was scrubbed on November 29, 2001, because the Progress resupply vehicle was not hard-docked to the International Space Station (ISS). The two Russian crewmembers of the ISS crew performed an extravehicular activity (EVA) to remove the obstacle, a docking mechanism seal that was preventing the docking sequence from being completed. Following the successful EVA, the launch was rescheduled for December 4, 2001. The launch was again scrubbed during the T-9 minute hold on December 4, 2001, because of unacceptable weather in the launch area. The launch was rescheduled for December 5, 2001.

During the prelaunch period for the first launch attempt (November 29, 2001) a column parity error was received in the Space Shuttle main engine (SSME) 2 60-kilobit data stream. The error was seen on the launch processing system (LPS). After the initial evaluation, the problem was determined to be in either the 60-kilobit circuitry portion of the engine interface unit (EIU), which is a criticality 3 function, or in the transmission circuitry between the EIU and the LPS. KSC troubleshooting isolated the problem to the LPS and no vehicle troubleshooting was required.

During the prelaunch period for the STS-108 launch attempt on December 4, 2001, the auxiliary power unit (APU) 2 service line temperature cycled lower than observed on previous missions and approached the lower Launch Commit Criteria (LCC) limit. The temperature was approximately 6 °F lower than on the previous flight (STS-100) of this vehicle, and the lowest temperature reading observed was 45.2 °F and the lower LCC limit was 45 °F. The heater was cycling nominally within an acceptable range and the temperature sensor appeared to be operating properly. The heater performance was determined to be adequate with warmer temperatures expected on-orbit due to the lack of a convective environment. The heater and temperature sensor were removed and reinstalled during the turnaround flow for the STS-108 flight because of a required modification. Initial indications were that this activity influenced the temperature response. The installation of the sensor, heater and insulation was inspected postflight and determined to be out of configuration. The configuration will be corrected during the postflight turnaround activities. This condition did not impact the mission.

The launch of the STS-108 mission was completed after a flawless final countdown. The time of launch 339:22:19:27.987 G.m.t. (4:19:27 p.m. c.s.t. on December 5, 2001).

The orbital maneuvering subsystem (OMS) assist maneuver was performed at 339:22:21:42 G.m.t. [00:00:02:15 mission elapsed time (MET)] following Solid Rocket Booster (SRB) separation. The maneuver was 50.8 seconds in duration, and the OMS performed satisfactorily.

Orbiter subsystems performance during ascent was nominal except for reaction control subsystem (RCS) primary thruster R4U that failed off at 339:22:28:06 G.m.t (00:00:08:39 MET) and was subsequently auto-deselected by the redundancy management (RM) during mated coast. The reaction jet driver output was nominal, however, the chamber pressure reached only 15.8 psia prior to the thruster being deselected. The thruster did not leak propellant following the fail-off. The thruster remained deselected for the remainder of the flight. The most likely cause of the failure was pilot-valve-only flow from either the fuel or the oxidizer valve. All thrusters on the R4 manifold were removed and replaced during the postflight turnaround activities.



The OMS 2 maneuver was performed at 339:22:57:14 G.m.t. (000:00:37:47 MET) and was 107.8 seconds in duration. The differential velocity ( $\Delta V$ ) was 163.4 ft/sec, and the resulting orbit was 122.0 by 124.6 nautical miles (nmi.). The OMS performed satisfactorily throughout the maneuver.

The payload bay doors were opened at 340:00:00:40 G.m.t. (00:01:41:13 MET). All voltages were nominal and the motors opened the doors in nominal dual-motor time.

The flight control team reported that three two-second data dropouts were experienced during the dumping of Orbiter ascent data from operations (OPS) recorder 2. The data were played back at least three times in both the forward and reverse direction and the dropouts were consistent. Two of the dropouts were on track 1 at the 58-percent location and one was on track 4 at the 26-percent location. The recorder was used throughout the mission and the suspect tape segments were monitored. It was reported that the recorder continued to occasionally display two-second dropouts, most of them in the 26- to 58-percent segment of the tape on tracks 1, 2 and 4. The occasional and brief data dropouts did not warrant the avoidance of using the recorder. There was no mission impact from these dropouts. Postflight testing verified the data dropout but the decision was made to fly the recorder in the as-is condition.

The Orbiter docking system (ODS) was satisfactorily powered on at 340:20:20 G.m.t. (00:22:00 MET), and the ring extension was completed nominally. As a result, the ODS was ready for rendezvous and docking operations.

The remote manipulator system (RMS) was powered up at 340:02:25 G.m.t. (00:04:05:33 MET) and uncradled at 340:17:48 G.m.t. (00:19:28:33 MET). RMS checkout was performed and completed satisfactorily and following the checkout, a payload bay survey was performed. The RMS was cradled and powered down at 340:20:10 G.m.t. (00:21:50:33 MET).

Extravehicular mobility unit (EMU) checkout was completed with both units performing nominally. As a result, the two EMUs were ready to support the planned EVA for this flight.

The Orbiter subsystems performed nominally during the rendezvous and docking with the exception of the failure of primary RCS thruster F3F, which failed off following the initial firing of the thruster for a series of three consecutive 0.080-second firings (Flight Problem STS-108-V-02). The chamber pressure reached a maximum value of 6.4 psia on the first 80-msec pulse. The next two pulses peaked at 5.6 psia. The RM software deselected the thruster at 341:20:03:25 G.m.t. (01:21:43:58 MET), after it failed to reach the minimum threshold pressure (~26 psia) within the allotted time (3 cycles). The thruster did not leak propellant following the fail-off. Primary thruster F3F remained deselected for the remainder of the flight and there was no mission impact. The most likely cause of the failure is pilot-valve-only flow from either the fuel or the oxidizer valve. All thrusters on the F3 manifold were removed and replaced during the postflight turnaround activities.

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

<b>Maneuver</b>	<b>Time, G.m.t./MET</b>	<b><math>\Delta V</math>, ft/sec</b>	<b>Firing time, sec</b>	<b>Orbit, nmi.</b>
NC1 (OMS-3 (Dual OMS))	340:01:33:28 00:03:14:00	155.8	100.9	122.6 by 210.1
NC2 (OMS-4) (Dual OMS)	340:17:26:08 00:04:05:33	17.5	19.4	139.0 by 209.0
NC3/NPC (+X RCS)	341:00:30:58 01:02:11:31	2.8	12.8	139.5 by 210.1
NC4 (OMS-5) (Dual OMS)	341:16:11:50.3 01:17:52:23	92.9	59.4	191.9 by 209.2
NCC (Multi-axis RCS)	341:16:46:44.1 01:18:27:17	1.0	4.4	191.9 by 209.6
Ti (+X RCS)	341:17:44:26.04 01:19:24:59	5.0	20.9	194.7 by 209.6
Out of Plane Null (RCS)	341:18:28:16.9 01:20:08:49			
MC-2 (+X RCS)	341:18:34:22 01:20:14:55	0.2	0.9	194.8 by 209.6
MC-3 (+X RCS)	341:18:51:22.5 01:20:20:13	5.9	20.9	195.2 by 209.8
MC-4 (+X RCS)	341:19:01:22.19 01:20:41:55	1.6	6.9	195.8 by 209.7

During the rendezvous, the Ku-band radar acquired the ISS at 341:16:52 G.m.t. (01:18:32 MET) at a range of 130,000 feet (approximately 21.7 nmi.). At 341:17:35 G.m.t. (01:19:15 MET), at a range of 48 feet, the Ku-band system was placed in the standby mode to conserve power. The Ku-band system was powered back on at 341:17:51 G.m.t. (01:19:31 MET). The system was placed in the communications mode at 341:19:29 G.m.t. (01:21:09 MET).

The ODS captured the ISS at 341:20:03:25 G.m.t. (01:21:43:58 MET). Initial ring retraction was stopped, apparently due to a stuck high-energy damper. A second retraction attempt was stopped due to loss of ring alignment, again due to a stuck high-energy damper. The ring was then extended to the forward position, retraction was initiated, and alignment was again lost. Data assessment indicates that residual motion between the ISS and Orbiter caused this loss of ring alignment. The ring was again extended to the forward position and retracted using single motor drive to reduce the potential for misalignment. Alignment was maintained, and docking was successfully completed. The cause of the performance is known and understood; consequently postflight testing was not required.

During orbit 33 at 342:00:02 G.m.t. (02:01:42 MET) while using Tracking and Data Relay Satellite (TDRS) West for support, the S-band power amplifier (PA) 2 radio frequency (RF) output went low causing a systems management (SM) message. The event lasted approximately 20 seconds and did not recur. With the exception of a 24-hour period on S-band string 1 for the redundant system checkout, PA 2 was used for the remainder of the mission and performed nominally. The PA 2 output low message was inhibited during crew sleep periods. There was no mission impact.

At 342:15:26 G.m.t. (02:17:06 MET), the RMS was powered up and uncradled in preparation for Multi-Purpose Logistics Module (MPLM) operations. The RMS successfully grappled the MPLM at 342:16:14 G.m.t. (02:17:54 MET) and at 342:17:00 G.m.t. (02:18:40 MET) the MPLM was un-berthed from the payload bay. After

the MPLM was moved into position and installed to the Node, the RMS ungrappled the MPLM at 342:18:09 G.m.t. (02:19:49 MET). The RMS was cradled and latched at 342:18:31 G.m.t. (02:20:11 MET).

The direct transfer of gaseous nitrogen (GN<sub>2</sub>) from the Orbiter to ISS was attempted on this mission. The crew configured the hardware and initiated flow but apparently there was a blockage in the system. The crew performed troubleshooting procedures that indicated proper GN<sub>2</sub> flow from the Orbiter and that existed a blockage in the ISS hardware. On a subsequent mission day, additional troubleshooting resolved the problem with the identification of a quick-disconnect (QD) that was out of configuration. The QD, which is located in the ISS airlock, was correctly configured and the successful flow of GN<sub>2</sub> was demonstrated. However, GN<sub>2</sub> was not transferred because the Orbiter GN<sub>2</sub> tanks were at a pressure lower than the ISS GN<sub>2</sub> tanks at that point in the mission.

After attitude control was transferred from the ISS to the Orbiter, the first reboost session was started at 343:15:11:40.45 G.m.t. (03:16:52:12 MET) when RCS thrusters L1A and R1A were fired. The reboost maneuver lasted one hour. The primary thruster pulse widths were 160 ms and the firing period was 11.6 seconds from the start of one pulse to the start of the next pulse. Approximately eight breaks for vernier-thruster attitude maintenance occurred during the maneuver, thus limiting the number of thruster pulses to 252. The aft down-firing vernier thrusters had an average duty cycle of 8.08 seconds on and 3.56 seconds off. The reboost maneuver resulted in a  $\Delta V$  of 6.3 ft/sec and an overall average altitude increase of 1.9 nmi. and the resulting orbit of 210.6 by 199.0 nmi.

Cabin depressurization to 10.2-psia in preparation for the planned extravehicular activity (EVA) was completed at 344:01:30 G.m.t. (04:03:11 MET). The crew completed all equipment checkout requirements in preparation for the EVA.

During the EVA-preparations communications checkout, loud white noise was heard on air-to-ground (A/G) 2 and at the Space-to-Space EVA Radio (SSER). Troubleshooting was performed, and switching from Space-to-Space Orbiter Radio (SSOR) 1 to SSOR 2 cleared the problem. During the EVA there were no communications issues, and the crew commented on the high quality of their communications. EMU checkout was successfully performed using SSOR 1, and SSOR 1 performed nominally during the rendezvous, docking and undocking. The crew, to aid in resolving this problem, answered questions on the configuration of the system. A postflight-troubleshooting plan has been developed and testing is planned.

After a pre-breathe period of approximately 75 minutes, the EVA began at 344:19:34 G.m.t. (04:21:14 MET). EMU performance during the EVA was excellent and no anomalies were noted. The EVA lasted 4 hours and 11 minutes.

The RMS was powered at 344:15:33 G.m.t. (04:17:13 MET) and uncradled in preparation for the EVA operations. The RMS was cradled and latched at 344:22:18 G.m.t. (04:23:58 MET). RMS operation was nominal throughout the EVA.

The Mission Management Team (MMT) approved a one-day mission extension, which provided an additional docked day at the ISS. The nominal landing date was established as Monday, December 17<sup>th</sup>.

After attitude control was transferred from the ISS to the Orbiter, the second reboost session was started at 345:16:19:40.45 G.m.t. (05:18:00:12 MET), when RCS thrusters

L1A and R1A were fired. The reboost session lasted one hour. The primary thruster pulse widths were 160 ms and the firing period was 11.6 seconds from start of one pulse firing until the next firing. Approximately eight breaks for vernier-thruster attitude maintenance occurred during the maneuver, thus limiting the number of pulses to 246. The aft down-firing vernier thrusters had an average duty cycle of 8.08 seconds on and 3.56 seconds off. The reboost provided a  $\Delta V$  of 6.5 ft/sec, and an overall average altitude increase of 1.8 nmi for a resulting orbit of 211.3 by 201.2 nmi.

Two runs of the hydraulic system 1 circulation pump during this mission had a slower increase of circulation pump pressure than was expected. The pumps required 12 to 15 seconds for the pressure to reach a nominal level. Data review indicates that this behavior has been observed on previous missions of this and other vehicles. Additionally, the review of circulation pump qualification data revealed that a slow response of up to 20 seconds could be expected when the pump-body temperature is in the +20 to +35 °F range at start-up, due to the higher oil viscosity at the lower temperatures. This condition is not detrimental to the pump and had no impact on hydraulic system operation.

After attitude control was transferred from the ISS to the Orbiter, the third reboost session was started at 346:15:22:32 G.m.t. (06:17:03:04 MET) when RCS vernier thrusters F5L, F5R, L5D and R5D were fired. The reboost maneuver lasted one hour. There was no predefined duty cycle. The thrusters were turned off as necessary to maintain attitude within the 5-degree deadband. The reboost maneuver resulted in a  $\Delta V$  of 14.1 ft/sec and an overall average altitude increase of 4.0 nmi. for a resulting orbit of 213.4 by 206.9 nmi.

The left RCS oxidizer B regulator had a low flow-pressure, 238-psia, during the third reboost maneuver. This was the first use of this regulator by itself this flight. Low regulated pressures have been seen on this regulator since it came out of the Orbiter Maintenance Down Period (OMDP) in 1998 for the STS-89 flight; however, the pressure degradation was not to the extent seen on this mission. During the ISS flyaround-maneuver on the last flight of this vehicle (STS-100), the ullage pressure was maintained at approximately 241 psia. During the turnaround flow following the last flight, the regulator checkout data were nominal. Due to this degraded performance, a reconfiguration to the A regulator was performed and it was used for the remainder of the mission. A nominal entry configuration, using both the A and B regulators, was implemented.

At 347:05:39:41 G.m.t. (07:07:20:13 MET), an inertial measurement unit (IMU) built-in test equipment (BITE) fault message was annunciated against IMU 2, when the IMU experienced platform fail and redundant rate fail BITEs (Flight Problem STS-108-V-03). These indications were the result of a high redundant rate resulting from degraded performance of the IMU 2 Z-axis/redundant axis gyroscope. The crew reactivated IMU 1, which had previously been deactivated to conserve cryogenics, to increase redundancy. The crew then deselected IMU 2 and masked the BITE to prevent nuisance alarms during the crew sleep period. Approximately 45 minutes later, the excessive rate decreased to nominal values, and the BITE cleared. The IMU was left in operate but deselected for the remainder of the on-orbit portion of the mission. The anomaly did not repeat.

Due to a damaged outlet line in the ISS oxygen recharge compressor assembly (ORCA), the transfer of oxygen from the Orbiter to the ISS was terminated. The damaged outlet line was returned on the Orbiter.

The RMS performed satisfactorily in supporting the MPLM operations. The RMS was powered up at 348:17:52 G.m.t. (08:19:32 MET), and the MPLM was uninstalled from the ISS Node at 348:21:54 G.m.t. (08:23:34 MET). The MPLM was berthed in the payload bay at 348:22:45 G.m.t. (09:00:25 MET). The RMS was cradled and latched at 348:23:11 G.m.t. (09:00:51 MET).

Two closed-circuit television (CCTV) cameras exhibited performance degradation. The focus of CCTV camera B stuck at 29 feet, resulting in a fuzzy picture when zoomed in. Repeated attempts to adjust the focus both far and near failed. Intermittent red streaks were observed in the downlink image from CCTV camera C during low-light conditions, resulting in an image that was barely visible.

A fourth ISS reboost maneuver was performed for collision avoidance. After attitude control was transferred from the ISS to the Orbiter, the fourth reboost session was started at 349:14:55:40 G.m.t. (09:16:36:13 MET) when RCS primary thrusters L1A and R1A were fired. The reboost maneuver lasted 20 minutes. The primary thruster pulse widths were 160 ms and the firing period was 11.6 seconds from start of one pulse firing until the start of the next firing. Two breaks for attitude maintenance, performed using the vernier thrusters, limited the number of pulses to 86 pulses. The aft down-firing vernier thrusters had an average duty cycle of 8.08 seconds on and 3.56 seconds off. RCS performance was nominal. The reboost maneuver resulted in a  $\Delta V$  of 2.1 ft/sec and an overall average altitude increase of 0.6 nmi. for a resulting orbit of 213.8 by 206.3 nmi.

Successful undocking from the ISS was completed at 349:17:28 G.m.t. (09:19:08 MET). Following the undocking, the initial ISS separation was initiated with a +Z-axis pulse of primary RCS thrusters at 349:17:28:35 G.m.t. (09:19:09:08 MET). The ISS half-lap flyaround operations were nominal. Final separation from the ISS was accomplished with an 18.4-second +X-axis pulse of primary RCS thrusters L1A and R1A at 349:18:52:28 G.m.t. (09:20:33:01 MET). The  $\Delta V$  was 4.3 ft/sec and the resulting orbit was 212.6 by 203.9 nmi.

After undocking, the Ku-band system was placed in the radar mode at 349:18:12 G.m.t. (09:19:52 MET) and acquired the ISS at a range of 400 ft. The radar maintained lock-on the ISS during flyaround operations. The Ku-band system was placed in the communications mode at 349:18:56 G.m.t. (09:20:36 MET) at a range of 8760 ft.

The TCS was used following undocking and performed nominally. It provided valid data throughout the flyaround activities and to a range of 438 ft where it lost track of the ISS. The TCS was deactivated and configured for entry.

A 14.2-second orbit-adjust maneuver was performed on the left OMS engine at 349:23:29:28 G.m.t. (10:01:10:01 MET). The  $\Delta V$  was 23.1 ft/sec and the resulting orbit was 191.9 by 211.8 nmi.

The flight control subsystem (FCS) checkout was performed using auxiliary power unit (APU) 1 with a start time of 350:12:59:57 G.m.t. (10:14:40:30 MET). The run time was 4 minutes, 08 seconds, and 13 pounds of fuel were used during the APU 1 operation. The total run time was too short to require the water spray boiler (WSB) to provide spray cooling. FCS, APU and hydraulics performance was nominal.

Following FCS checkout, the RCS hot-fire was performed nominally. The hot-fire began at 350:13:49:55 G.m.t. (10:15:30:28 MET) and ended at 350:13:55:04 G.m.t. (10:15:35:37 MET). A review of thruster chamber pressure data confirmed that all of the firings were satisfactory. Each thruster, with the exception of R4U and F3F thrusters that had failed-off earlier in the mission, performed at least one pulse of 320-millisecond duration.

A 9.8-second Shuttle Ionosphere Modification with Pulsed Local Exhaust (SIMPLEX) firing was performed using both OMS engines at 350:18:51:37 G.m.t. (10:20:32:10 MET). The  $\Delta V$  was 15.6 ft/sec and the resulting orbit was 191.1 by 203.8 nmi.

During the flash evaporator system (FES) checkout beginning at 351:13:52 G.m.t. (11:15:32 MET), with the FES high-load evaporator enabled, the secondary controller failed to control the evaporator outlet temperature within the specified range of  $62 \pm 2$  °F (Flight Problem STS-108-V-04). The outlet temperature oscillated in a range from approximately 45 to 80 °F, slightly increasing with time. After several cycles, the FES topping evaporator was selected and the outlet temperature control was satisfactory on the secondary controller. Checkout of the FES in the full-up mode on the primary B controller was also satisfactory. The FES performed nominally during entry. Postflight troubleshooting isolated the problem to the control temperature sensor.

The payload bay doors were closed and latched for the first Kennedy Space Center (KSC) landing opportunity at 351:14:19:56 G.m.t. (11:16:00:28 MET). All payload bay door closure and latch operations occurred in dual motor time.

The IMU 2 Z-axis/redundant axis gyro degradation discussed earlier in the report did not recur. With the continued satisfactory performance IMU 2 was reselected and the built-in test equipment (BITE) mask removed after the final approval was given for deorbit. This IMU configuration maximized redundancy for deorbit and entry operations. The IMU performed nominally throughout entry and landing.

The deorbit maneuver for the first KSC landing opportunity, a two-engine straight-feed OMS firing, was performed on orbit 185 at 351:16:48:13.132 G.m.t. (11:18:28:45.145 MET). The maneuver was 188.40 seconds in duration with a  $\Delta V$  of 316.8 ft/sec.

Entry interface occurred at 351:17:23:14.92 G.m.t. (11:19:03:46.93 MET), and entry was completed satisfactorily. Main landing gear touchdown occurred on KSC concrete runway 15 at 351:17:55:12 G.m.t. (11:19:35:44 MET) on December 17, 2001. The drag chute was deployed at 351:17:55:16.1 G.m.t. The nose gear touchdown occurred at 351:17:55:24.5 G.m.t. The drag chute was jettisoned at 351:17:55:48.4 G.m.t. Wheels stop occurred at 351:17:56:17.8 G.m.t. The rollout was normal in all respects. The flight duration was 11 days 19 hours 35 minutes 12 seconds. The APU's were shut down approximately 16 minutes 37 seconds after landing.

During air data probe deployment, the right-hand probe began driving approximately one-second later than the left-hand probe. After approximately one-second of operation, the right-hand probe turned off for about one second and then began driving again. As a result, the right-hand probe was deployed a total of 2.7 seconds later than the left-hand probe. Data review is continuing; however, it is estimated that the File IX limit of 14 seconds for dual motor operation was still satisfied. A switch tease caused the motor to stop driving.

The postflight investigation identified three additional anomalies, two of which involved the drag parachute system. The first drag parachute anomaly, identified in the landing video review, was a hole in the main parachute. The hole did not affect parachute performance. The second drag chute anomaly was the partial failure of the ties that connect the sabot to the pilot parachute bag. This anomaly had no impact on parachute performance. The third anomaly identified during the postflight inspection was a "white powder" residue on a liquid hydrogen feedline near the SSME 2 pre valve. Extensive evaluation has determined that this powder was ultimately the result of feedline insulation damage sustained during prelaunch processing.

## **PAYLOADS AND EXPERIMENTS**

### **SUMMARY**

The twelfth Space Shuttle mission to the International Space Station (ISS) consisted of a seven-member crew, three of whom performed a crew rotation with the crew that was onboard the ISS for 129 days. After successfully docking with the ISS, the Multi-Purpose Logistics Module (MPLM) was successfully installed on Node 1 of the ISS. During the docked days, the Expedition 4 crew handover and scheduled extravehicular activity (EVA) were successfully performed and all transfers between the Shuttle middeck, MPLM, and ISS were completed. Four ISS reboost maneuvers, the fourth the result of a collision avoidance maneuver, were performed with the Shuttle reaction control subsystem (RCS) and the overall orbit of the ISS was raised 7.7 nautical miles. A one-day extension was approved by the Mission Management Team (MMT) to add one additional day for the docked activities.

The direct transfer of gaseous nitrogen (GN<sub>2</sub>) from the Orbiter to the ISS was unsuccessful because a quick disconnect (QD) in the ISS Airlock module was not in the correct configuration. After successfully reconfiguring the QD, GN<sub>2</sub> flow was demonstrated. However, GN<sub>2</sub> could not be transferred because the Orbiter GN<sub>2</sub> tanks were at a lower pressure than the ISS GN<sub>2</sub> tanks when the problem was corrected. A damaged outlet line in the ISS oxygen recharge compressor assembly (ORCA) caused the transfer of oxygen to the ISS to be terminated. The damaged line was returned with the Orbiter for postflight evaluation.

With all preplanned objectives of this logistics mission completed, the MPLM was returned and berthed in the cargo bay. Following the completion of all ISS major mission objectives, the Orbiter was undocked from the ISS and a partial flyaround of the ISS was completed.

### **ISS UTILIZATION PAYLOADS**

All Utilization Flight (UF) -1 flight mission objectives for the ISS payloads were accomplished. Shuttle and MPLM payload transfer items both to and from the ISS were completed. The powered payloads located within the Shuttle middeck operated as expected with no issues or anomalies noted. The transfer of the Advanced Astroculture Growth Chamber (ADVASC GC), the Biotechnology Cell Science Stowage (BCSS), the Protein Crystal Growth-Single Thermal Enclosure System (PCG-STES) no. 8 and 10, and the contents of the Biotechnology Refrigerator 3 (BTR 3) to the ISS was completed successfully. In addition, the Expedition 4 crew conducted the Human Life Sciences (HLF) Hoffmann Reflex (H-Reflex) experiment. Also, the Expedition 3 crew performed the Treadmill Vibration Isolation System (TVIS) maintenance task.

The utilization payloads that were returned to Earth from the ISS were the Advanced Protein Crystallization Facility (APCF), the Dynamic Protein Crystal Growth - Vapor (DCPCG-V), and the BTR 3 with contents transferred from the ISS).

### **MULTI-PURPOSE LOGISTICS MODULE**

The Multi-Purpose Logistics Module (MPLM) was successfully grappled by the remote manipulator system (RMS) at 342:16:14 G.m.t. (02:17:54 MET), and at 342:17:00 G.m.t. (02:18:40 MET) the MPLM was un-berthed from the payload bay. After the MPLM was



moved into position and installed to the International Space Station (ISS) Node, the MPLM was ungrappled by the RMS at 342:18:09 G.m.t. (02:19:49 MET).

The MPLM was uninstalled from the ISS Node at 348:21:54 G.m.t (08:23:34 MET). The MPLM was berthed in the payload bay at 348:22:45 G.m.t. (09:00:25 MET).

### **MULTIPLE APPLICATIONS CUSTOMIZED HITCHHIKER – 1**

Overall, the Multiple Applications Customized Hitchhiker-1 (MACH-1) payload accomplished more than 100 percent of the science objectives and a successful deployment of the STARSHINE 2 satellite. The MACH-1 payload consisted of seven experiments. These were:

1. Prototype Synchrotron Radiation Detector (PRSD);
2. Ejectable Student Tracked Atmospheric Research Satellite for Heuristic International Networking Experiment -2 (STARSHINE-2) satellite;
3. Capillary Pumped Loop Experiment -3 (CAPL-3);
4. Collisions into Dust Experiment (COLLIDE-2);
5. Get Away Special (GAS) payload 761 (G761);
6. Space Experiment Module -11; and
7. Space Experiment Module -15.

The PRSD experiment accomplished 154 percent of the required minimum objectives that included an additional 38.6 hours of docked data and an additional 37.9 hours of data during undocked operations. The CAPL-3 experiment was able to accomplish all minimum required tests and the majority of the secondary tests. The remainder of the experiments on MACH-1 operated nominally.

The only MACH-1 in-flight anomaly reported was the loss of the master control unit synchronization that resulted in loss of telemetry data and commanding to the MACH-1 package. The anomaly occurred twice during the flight, but satisfactory operation was regained each time when the crew power-cycled the avionics.

### **LIGHTWEIGHT MISSION PECULIAR EXPERIMENT SUPPORT STRUCTURE CARRIER**

The lightweight mission peculiar experiment support structure (MPRESS) carrier (LMC) operated satisfactorily on the first flight of this piece of hardware. The hardware attached to the LMC was the three Get Away Special experiments (G-730, G-785 and G-064) and SEM-12. All experiments were reported to have operated properly.

### **BAY 3 SIDEWALL WITH GET AWAY SPECIAL EXPERIMENTS**

The Bay 3 sidewall with GAS experiments (G-221 and G-775) operated nominally with no reported anomalies.

### **AVIAN DEVELOPMENT FACILITY**

The middeck Avian Development Facility (ADF) payload was nominal. Based on crew reports, the ADF payload operated nominally and successfully completed its mission objective.

## **COMMERCIAL BIOMEDICAL TESTING MODULE**

The Commercial Biomedical-Testing Module (CBTM), located on the Orbiter middeck, operated nominally as reported by the crew.

## **SHUTTLE IONOSPHERIC MODIFICATION WITH PULSED LOCAL EXHAUST**

A 9.8-second two-engine orbital maneuvering subsystem (OMS) firing over the Millstone Hill facility was performed for the Shuttle Ionospheric Modification with Pulsed Local Exhaust (SIMPLEX) experiment. Preliminary results show that the payload customer obtained data. The capability to use the pre-planned Orbiter OMS maneuvers for the Ram Burn Observations (RAMBO) experiment was unsuccessful, primarily because of the location of the pre-planned maneuvers.

## **MICRO-WIRELESS TRIAXIAL ACCELERATION UNIT**

The JSC-sponsored micro-wireless triaxial accelerators (Micro-TAU) were installed on the MACH-1 trunnion, the MPLM longeron and keel trunnion and corresponding locations on the Orbiter to determine longeron/payload interaction. Data from the units were obtained during the postflight turnaround activities.

## **VEHICLE PERFORMANCE**

### **LAUNCH DELAY**

The initial launch countdown for the STS-108 mission was scrubbed on November 29, 2001, because the Progress resupply vehicle was not hard-docked to the International Space Station (ISS). The two Russian crewmembers of the ISS crew performed an extravehicular activity (EVA) to remove the obstacle, a docking mechanism seal, preventing the docking sequence from being completed. Following the successful EVA, the launch was rescheduled for December 4, 2001. The launch was again scrubbed during the T-9 minute hold on December 4, 2001, because of unacceptable weather in the launch area. The launch was rescheduled for December 5, 2001.

### **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.

STS-108 was the fourth flight of the C-band controller (CBC). All data indicate that the new system performed as designed, except for the unexpected 0.6-volt variation seen on the right SRB CBC. The voltage remained well within the operational limits and was not considered to be a problem. The hardware will be examined to determine the cause of the variation.

This was the second flight of the single mission fuel isolation valve (SMFIV). All flight data and the postflight assessment information indicate that the valve performed as designed.

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

Both SRB's 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. All eight booster separation motor (BSM) aero heat shield covers had fully opened and were locked; however, one right-hand and two left-hand cover attachment rings were bent at the hinge by parachute risers.

The forward skirts exhibited no debonded or missing thermal protection system (TPS) insulation, The range safety system (RSS) antenna covers/phenolic base plates were intact, although one layer of the left and right SRB +Z axis antenna phenolic base plate was delaminated on the edge.

The holddown post debris containment system appeared to have functioned normally except for HDP no. 1, which was full obstructed by the frangible nut halves. This condition most likely occurred at water impact. No indication of stud hang-up was found.

## 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 0.611 percent at 70.5 seconds and 0.770 percent at 68.5 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 59 minutes during the final launch countdown and 28 hours 1 minute during the three launch countdowns. Power was applied to the heating elements an average of 36 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 50 minutes during the final launch countdown and 25 hours 35 minutes during the three launch countdowns. Power was applied to the heating elements 48 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 seven times during the time of recorded data. Two aft-skirt purge-activations were performed during the final countdown and both lasted for a total of 4 hours and 24 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 77 °F to 88 F on both motors. The final flex bearing mean bulk temperature (FBMBT) was determined to be 82 °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 74 °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 0.3685 and 0.3675 in/sec for the left and right motors, respectively.

All ground environmental instrumentation and operational flight instrumentation performed within established requirements. All available data were recorded, transmitted and analyzed without incident.

## MOTOR PERFORMANCE PARAMETERS

Parameter	CEI Specification Limit (60 °F)	Left Motor Delivered	Right Motor Delivered
Web time, seconds	105.4 – 116.7	110.7	111.1
Action time, seconds	115.2 – 131.2	122.9	123.8
Head end pressure, psia	847.9 – 965.7	913.0	911.5
Maximum sea level thrust, MLbf	2.88 – 3.26	3.09	3.08
Web time average pressure, psia	629.9 – 700.5	666.8	665.5
Web time average vacuum thrust, MLbf	2.46 – 2.74	2.61	2.61
Web time total impulse, MLbf sec	285.8 – 291.6	289.0	289.6
Action time impulse, MLbf seconds	293.7 – 299.7	296.9	297.4
ISP average delivered, Lbf sec/Lbm	266.5 – 270.3	268.6	269.0
Loaded propellant weight, Lbm	>1103750	1106041	1106191

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

## RSSM PROPULSION PERFORMANCE

Parameter	Left motor, 74 °F		Right motor, 74 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10 <sup>6</sup> lbf-sec	64.98	65.98	64.91	65.77
I-60, 10 <sup>6</sup> lbf-sec	174.19	175.64	174.03	175.24
I-AT, 10 <sup>6</sup> lbf-sec	297.04	297.24	297.08	297.70
Vacuum Isp, lbf-sec/lbm	268.6	268.7	268.6	269.1
Burn rate, in/sec @ 60 °F At 625 psia	0.3666	0.3685	0.3663	0.3675
Event times, seconds <sup>a</sup>				
Ignition interval	0.232	N/A	0.232	N/A
Web time <sup>b</sup>	109.9	109.1	110.0	109.5
50 psia cue time	120.0	118.8	120.1	119.5
Action time <sup>b</sup>	122.2	121.1	122.3	122.0
Separation command	124.5	-	124.5	-
PMBT, °F	74	74	74	74
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	3.2	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.

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

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

## 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.

During liquid oxygen (LO<sub>2</sub>) loading, a stop flow was manually initiated when the Orbiter inlet temperature 2 exceeded the OMRSD limit during the transition from slow-fill to fast-fill. After a revert and a repeat of slow-fill operation, fast-fill operations were successfully resumed 37 minutes later. This condition did not impact the countdown or cause any hold in the countdown.

The pressurization systems functioned properly throughout engine start and flight. The minimum LO<sub>2</sub> ullage pressure experienced during the ullage pressure slump was 14.0 psid.

Development Test Objective (DTO) 312 was to be performed following main engine cutoff (MECO); however, because separation was performed in darkness little or no usable data were obtained.

ET separation was confirmed. The postflight analysis of the impact point showed the ET impact to be 73 nautical miles downrange from the preflight predicted impact point.

### **SPACE SHUTTLE MAIN ENGINES**

During prelaunch operations prior to the first launch attempt, a column parity error was received in the Space Shuttle main engine (SSME) 2 60-kilobit data stream. The error was seen on the launch processing system (LPS). After evaluation, it was determined that the problem was either in the 60-kilobit circuitry portion of the engine interface unit (EIU), which is a criticality 3 function, or in the transmission circuitry between the EIU and the LPS. The problem is not in the EIU circuitry that provides the interface functions between the general-purpose computers (GPCs) and the SSME 2 controller. Postflight testing and data evaluation indicated that the most likely source of the problem was in the transmission circuitry between the Orbiter/ground interface and the LPS. No vehicle troubleshooting will be performed.

Prelaunch operations of the 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 511.85, 511.97, and 512.07 seconds for SSMEs 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 453.07 seconds based on trajectory data. The Block IIA 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<sub>d</sub>) 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. No LCC violations were noted during the two loadings, and no in-flight anomalies were identified from the analysis of the data. One OMRSD violation was noted during liquid oxygen (LO<sub>2</sub>) loading and one problem was identified from the data. These conditions are discussed in later paragraphs.

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 concentration during the first loading sequence was nominal.

The liquid hydrogen (LH<sub>2</sub>) loading operations were normal throughout the entire process. The peak hydrogen concentration during the second loading was 150 ppm, which compares favorably with previous data from this vehicle. Based on an analysis of loading system data, the LH<sub>2</sub> load at the end of replenish was 231,042 lbm. Compared to the predicted inventory load of 231,129 lbm, this assessment yields a difference of 0.038 percent, which is well within the MPS loading accuracy requirements.

The second loading of LO<sub>2</sub> was completed satisfactorily, except a stop-flow occurred in the loading during fast-fill operations because of an Orbiter inlet temperature violation that exceeded the OMRSD temperature limit of 291 °F. After resumption of the flow, again the temperature was too high. The third attempt to load LO<sub>2</sub> was successful.

In addition, about two hours into the second LO<sub>2</sub> fast-fill loading phase, both the prime and backup hazardous gas detection system (HGDS) indicated increasing oxygen levels in the aft compartment. The levels increased from 25 ppm to 140 ppm with a slight downward drift after reaching the peak levels. The backup system was configured to calibration gases, and 30 minutes later the prime HGDS was configured to zero calibration gases. Within five minutes of the switch to the prime HGDS system, the oxygen concentration had significantly decreased. About nine minutes later, the prime HGDS system was switched back to monitoring the aft and both the prime and aft concentration showed the oxygen concentration back at the 25-ppm level. The increase of the oxygen concentration was well below the LCC limit of 500 ppm, and there were no further concentration excursions for the remainder of the prelaunch operations.

Based on the analysis of predicted inventory load of 1,384,475 lbm, the oxygen load at the end of replenish was 1,384,421 lbm. This assessment yielded a difference of 0.004 percent, which is well within the required MPS loading accuracy.

The overall gaseous hydrogen (GH<sub>2</sub>) system performance during the ascent phase was nominal. All three flow-control valves (FCVs) performed nominally. The gaseous oxygen (GO<sub>2</sub>) 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 61 7 lbm, which is well within the allowable requirements.

During the postflight inspection of the Orbiter, an anomaly was noted with the foam insulation on the LH<sub>2</sub> feedline near the engine 2 pre valve. A white powder was found and the foam was soft to the touch. Chemical analysis of the powder revealed materials compatible with the foam and foam-patching compound. Analysis of all of the data concerning this white powder has led to the conclusion that there are no concerns for the pressure carrier or vacuum jacket on this line. The damaged foam and resulting white powder deposit were most likely caused by external impact during the previous flow. The damage will be repaired and this anomaly will be closed.

### **Reaction Control Subsystem**

The reaction control subsystem (RCS) performed acceptably throughout the mission. A total of 11 translation maneuvers, which included 4 reboost periods that raised the apogee altitude of the ISS approximately 4.1 nautical miles (nmi.) and the perigee by 10.5 nmi., were completed satisfactorily. Two in-flight anomalies were identified during the mission and these are discussed later in this section of the report. Neither of these anomalies impacted the successful completion of the planned mission.

A total of 4908.8 lbm propellants (3045.6 lbm - oxidizer, 1863.2 lbm - fuel) were used from the RCS during the mission. In addition, a total of 2188.8 lbm of the orbital maneuvering subsystem (OMS) propellants were used by the RCS during interconnect operations. The primary RCS thrusters had 3951 firings and a total firing time of approximately 944.56 seconds. The vernier RCS thrusters had 11,407 firings and a total firing time of 44,246.84 seconds.

The RCS window protect maneuver was initiated at 339:22:21:33.09 G.m.t. (00:00:02:08 MET) and was terminated 2.08 seconds later. This maneuver provides a method of protecting the windows of the Orbiter from booster separation motor exhaust products. This maneuver results in improved clarity during the mission and a reduction in the turnaround effort following the mission.

RCS primary thruster R4U failed off at 339:22:28:06 G.m.t (00:00:08:39 MET) and was subsequently auto-deselected by the redundancy management (RM) during mated coast (Flight Problem STS-108-V-01). The reaction jet driver output was nominal, however, the chamber pressure reached only 15.8 psia prior to the thruster being deselected. The thruster did not leak propellant following the fail-off. The thruster remained deselected for the remainder of the flight. The most likely cause of the failure was pilot-valve-only flow from either the fuel or the oxidizer valve. All thrusters on the R4 manifold were removed and replaced during the postflight turnaround activities.



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

### RCS RENDEZVOUS MANEUVERS

Maneuver	Time, G.m.t./MET	$\Delta V$ , ft/sec	Firing time, sec	Orbit, nmi.
NC3/NPC (+X RCS)	341:00:30:58.7 01:02:11:31.7	2.8	12.8	139.5 by 210.1
NCC (Multi-axis RCS)	341:16:46:44.1 01:18:27:17	1.0	4.4	191.9 by 209.6
Ti (+X RCS)	341:17:44:26.04 01:19:24:59	5.0	20.9	194.7 by 209.6
Out of Plane Null (RCS)	341:18:28:16.9 01:20:08:49	N/A	N/A	N/A
MC-2 (+X RCS)	341:18:34:22 01:20:14:55	0.2	0.9	194.8 by 209.6
MC-3 (+X RCS)	341:18:51:22.5 01:20:20:13.5	5.9	20.9	195.2 by 209.8
MC-4 (+X RCS)	341:19:01:22.19 01:20:41:55	1.6	6.9	195.8 by 209.7

During the rendezvous and docking, primary RCS thruster F3F failed off following the initial firing of the thruster for a series of three consecutive 0.080-second firings (Flight Problem STS-108-V-02). The chamber pressure reached a maximum value of 6.4 psia on the first 80-msec pulse. The next two pulses peaked at 5.6 psia. The RM software deselected the thruster at 341:20:03:25 G.m.t. (01:21:43:58 MET), after it failed to reach the minimum threshold pressure (~26 psia) within the allotted time (3 cycles). The thruster did not leak propellant following the fail-off. Primary thruster F3F remained deselected for the remainder of the flight and there was no mission impact. The most likely cause of the failure is pilot-valve-only flow from either the fuel or the oxidizer valve. All thrusters on the F3 manifold were removed and replaced during the postflight turnaround activities. Both of the failed thrusters will undergo failure analysis at the White Sands Test Facility.

The left RCS oxidizer B regulator had a low flow-pressure, 238-psia, during the third reboost maneuver. This was the first use of this regulator by itself this flight. The Shuttle Operational Data Book (SODB) states that the flow-pressure requirement is 245 +4/-6 psia. Because of the degraded performance, the A regulator was used for the remainder of the flight. A nominal entry configuration, using both the A and B regulators, was implemented. Low regulated pressures have been seen on this regulator since it came out of the Orbiter Maintenance Down Period (OMDP) in 1998 for the STS-89 flight; however, the pressure degradation was not to the extent seen on this mission. During the ISS flyaround- maneuver on the last flight of this vehicle (STS-100), the ullage pressure was maintained at approximately 241 psia. During the turnaround flow following the last flight, the regulator checkout data were nominal. Due to this degraded performance, a reconfiguration to the A regulator was performed and it was used for the remainder of the mission. A postflight checkout of this regulator showed that the pressure was near the lower end of the pressure ban. Based on this finding, the decision was made to fly the regulator as-is.

The first reboost session was started at 343:15:11:40.45 G.m.t. (03:16:52:12 MET) when RCS thrusters L1A and R1A were fired. The reboost maneuver lasted one hour. The primary thruster pulse widths were 160 ms and the firing period was 11.6 seconds from the start of one pulse to the start of the next pulse. Approximately eight breaks for vernier-thruster attitude maintenance occurred during the maneuver, thus limiting the number of thruster pulses to 252. The aft down-firing vernier thrusters had an average duty cycle of 8.08 seconds on and 3.56 seconds off. The reboost maneuver resulted in a  $\Delta V$  of 6.3 ft/sec and an overall average altitude increase of 1.9 nmi., and the resulting orbit of 210.6 by 199.0 nmi.

The second reboost session was started at 345:16:19:40.45 G.m.t. (05:18:00:12 MET), when RCS thrusters L1A and R1A were fired. The reboost session lasted one hour. The primary thruster pulse widths were 160 ms and the firing period was 11.6 seconds from start of one pulse firing until the next firing. Approximately eight breaks for vernier-thruster attitude maintenance occurred during the maneuver, thus limiting the number of pulses to 246. The aft down-firing vernier thrusters had an average duty cycle of 8.08 seconds on and 3.56 seconds off. The reboost provided a  $\Delta V$  of 6.5 ft/sec, and an overall average altitude increase of 1.8 nmi for a resulting orbit of 211.3 by 201.2 nmi.

The third reboost session was started at 346:15:22:32.5 G.m.t. (06:17:03:04.5 MET) when RCS vernier thrusters F5L, F5R, L5D and R5D were fired. The reboost maneuver lasted one hour. There was no predefined duty cycle. The thrusters were turned off as necessary to maintain attitude within the 5-degree deadband. The reboost maneuver resulted in a  $\Delta V$  of 14.1 ft/sec and an overall average altitude increase of 4.0 nmi. that resulted in an orbit of 213.4 by 206.9 nmi.

A fourth ISS reboost maneuver was performed for collision avoidance. The reboost session was started at 349:14:55:40.4 G.m.t. (09:16:36:13.4 MET) when RCS primary thrusters L1A and R1A were fired. The reboost maneuver lasted 20 minutes. The primary thruster pulse widths were 160 ms and the firing period was 11.6 seconds from start of one pulse firing until the start of the next firing. Two breaks for attitude maintenance, performed using the vernier thrusters, limited the number of pulses to 86 pulses. The aft down-firing vernier thrusters had an average duty cycle of 8.08 seconds on and 3.56 seconds off. RCS performance was nominal. The reboost maneuver resulted in a  $\Delta V$  of 2.1 ft/sec and an overall average altitude increase of 0.6 nmi. that resulted in an orbit of 213.8 by 206.3 nmi.

Following the undocking, the initial ISS separation was initiated with a +Z-axis pulse of primary RCS thrusters at 349:17:28:35 G.m.t. (09:19:09:08 MET). The ISS half-lap flyaround operations were nominal. Final separation from the ISS was accomplished with an 18.4-second +X-axis pulse of primary RCS thrusters L1A and R1A at 349:18:52:28 G.m.t. (09:20:33:01 MET). The  $\Delta V$  was 4.3 ft/sec and the resulting orbit was 212.6 by 203.9 nmi.

A dual OMS engine 14.2 second orbit-adjust maneuver was performed at 349:23:29:28 G.m.t. (10:01:10:01 MET). The  $\Delta V$  was 23.1 ft/sec and the resulting orbit was 191.9 by 211.8 nmi.

Following FCS checkout, the RCS hot-fire was performed nominally. The hot-fire began at 350:13:49:55 G.m.t. (10:15:30:28 MET) and ended at 350:13:55:04 G.m.t. (10:15:35:37 MET). A review of thruster chamber pressure data confirmed that all of the firings were satisfactory. Each thruster, with the exception of R4U and F3F thrusters that

had failed-off earlier in the mission, performed at least one pulse of 320-millisecond duration.

### Orbital Maneuvering Subsystem

The OMS performed satisfactorily throughout the mission. A total of eight maneuvers were performed during the mission. The OMS performed satisfactorily throughout the mission.

A total of 23,313 lbm (14,615 lbm - oxidizer and 8698 lbm - fuel) of OMS propellants were consumed during the mission. Of this total, the OMS provided 2188.8 lbm of propellants to the RCS during interconnect operations, and this represents 15.9 percent of the OMS propellants used during the mission.

The following table shows the pertinent data for all of the OMS maneuvers performed during the mission.

#### **OMS MANEUVERS**

<b>Maneuver</b>	<b>Time, G.m.t./MET</b>	<b><math>\Delta V</math>, ft/sec</b>	<b>Firing time, sec</b>	<b>Orbit, nmi.</b>
OMS Assist	339:22:21:42 00:00:02:15	-	50.8	-
OMS-2	339:22:57:14 00:00:37:47.	163.4	107.8	122.0 by 124.6
NC1 (OMS-3 (Dual OMS)	340:01:33:28 00:03:14:00	155.8	100.9	122.6 by 210.1
NC2 (OMS-4) (Dual OMS)	340:17:26:08 00:04:05:33	17.5	19.4	139.0 by 209.0
NC4 (OMS-5) (Dual OMS)	341:16:11:50.3 01:17:52:23	92.9	59.4	191.9 by 209.2
OMS-6 Orbit Adjust (Dual OMS)	349:23:29:28 10:01:10:00	23.1	14.6	191.9 by 211.8
OMS-7 SIMPLEX (Dual OMS)	350:18:51:34 10:20:32:10	15.6	9.8	191.1 by 203.8
Deorbit (Dual OMS)	351:16:48:13 11:18:28:45	316.8	188.40	-

The deorbit maneuver for the first KSC landing opportunity, a two-engine straight-feed OMS firing, was performed during orbit 185.

### Power Reactant Storage and Distribution

The power reactant storage and distribution (PRSD) subsystem performance was nominal throughout the STS-108 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 2687 lbm of oxygen and 338 lbm of hydrogen for the production of 3912 kWh of electrical energy. In addition, the environmental control and life support system (ECLSS) was supplied 166 lbm of oxygen

for life support. The average power level for the mission was 13.8 kW. A 78-hour mission extension was possible at the average power level with the reactants remaining at landing.

PRSD tanks 4 and 5 were depleted to residual quantities during the mission. The Orbiter landed with 1072 lbm of oxygen and 110 pounds of hydrogen remaining.

A 30-ppm oxygen indication was detected by the HGDS prior to the canceled launch attempt. It was detected above the payload bay liner. A manifold decay leak check was made by the PRSD, and no indication of a leak was noted.

A minute amount of hydrogen gas (approximately 15 ppm) was detected during the cryogenic top-off for the canceled launch attempt. No source of the leak could be detected.

### **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 13.8 kW and 450 amperes. The fuel cells produced 3025 lbm of potable water and 3912 kWh of electrical energy while using 2687 lbm of oxygen and 338 lbm of hydrogen.

Four 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 0.15 V above the predicted for fuel cell 1, 0.2 V above predicted for fuel cell 2, and 0.15 V above the 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 V for fuel cell 1, 1.1 V for fuel cell 2, and 0.8 V 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 6.125 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 15 minutes beginning at 223:20:22:05 G.m.t. (00:23:11:51 MET) and all of the cell voltages were nominal. Cell 59 of fuel cell 1 was biased 12 mV high and cell 25 of fuel cell 2 was biased 12 mV low due to an FCMS instrumentation bias. Each of the fuel cells had the soldered connections.

### **Auxiliary Power Unit Subsystem**

The auxiliary power unit (APU) subsystem performed nominally during the mission with no in-flight anomalies or significant problems identified. The APU run times as well as fuel consumption for the mission are shown in the following table.

Flight phase	APU 1 (S/N 405)		APU 2 (S/N 303)		APU 3 (S/N 409)	
	(a) (b) Time, Min:sec	Fuel consumption, lb	(a) Time, Min:sec	Fuel consumption, lb	(a) Time, min:sec	Fuel consumption, lb
Ascent	19:32	49	19:39	54	19:44	50
FCS checkout	4:08	13				
Entry <sup>a</sup>	60:59	110	88:27	189	80:52	120
Total	84:39	172	108:06	243	80:52	170

<sup>a</sup> APUs were shut down 16 minutes 37 seconds after landing.

The APU 2 service line sensor cycled near its 45 °F (45.2 °F) lower LCC limit during prelaunch for the scrubbed Dec. 4<sup>th</sup> launch date. A waiver was processed to move the LCC down to 42 °F. The temperature was approximately 6 °F lower than observed on the previous flight of this vehicle. The sensor cycled down to 45°F again on the actual Dec 5<sup>th</sup> launch date. The thermostat on the service line controls the heater for both itself and the test line. A complete discussion of this condition is contained in the Thermal Control Subsystem section of this report.

### **Hydraulics/Water Spray Boiler Subsystem**

The hydraulics/water spray boiler (WSB) subsystem performed satisfactorily throughout the mission. One item of interest was noted in the review of the data and it is discussed in the following paragraph. STS-108 was the second flight of the OV-105 vehicle with the water additive, Propylene Glycol Monomethyl Ether (PGME), added to all three WSBs.

Two runs of the hydraulic system 1 circulation pump during this mission had a slower increase of circulation pump pressure than was expected. The pumps required 12 to 15 seconds for the pressure to reach a nominal level. Data review indicates that this behavior has been observed on previous missions of this and other vehicles as well as pumps. Additionally, the review of circulation pump qualification data has revealed that a slow response of up to 20 seconds can be expected when the pump-body temperature is in the +20 to +35 °F range at start-up, due to the higher oil viscosity at the lower temperatures. This condition is not detrimental to the pump and had no impact on hydraulic system operation.

### **Electrical Power Distribution and Control Subsystem**

The electrical power distribution and control (EPDC) subsystem performed nominally throughout the mission. No in-flight anomalies were identified from the data analysis, and all File IX requirements were satisfied.

### **Orbiter Docking System**

The Orbiter docking system (ODS) performed nominally. As has been noted on previous flights, stuck high-energy dampers caused a delay during docking.

The ODS was powered on at 340:20:20 G.m.t. (00:22:00 MET) and the ring extension was completed nominally. As a result, the ODS was ready for rendezvous and docking operations. The active system monitor parameters indicated normal output throughout the duration of the flight.

The ODS captured the ISS at 341:20:03:25 G.m.t. (01:21:43:58 MET). Initial ring retraction was stopped, apparently due to a stuck high-energy damper. A second retraction attempt was stopped due to loss of ring alignment, again due to a stuck high-energy damper. The ring was then extended to the forward position, retraction was initiated, and alignment was again lost. Initial data assessment indicates that residual motion between the ISS and Orbiter caused this loss of ring alignment. The ring was again extended to the forward position and retracted using single-motor drive to reduce the potential for misalignment. Alignment was maintained, and docking was successfully completed. The cause of this performance is known and understood and postflight testing was not required.

The ODS valves were used during the docked operation and for EVAs. The Orbiter was docked to the ISS pressurized mating adapter 2 (PMA 2) and the vestibule was pressurized from the ISS and the post-docking vestibule leak check was nominal. The vestibule depressurization valves were used to depressurize the vestibule to vacuum before undocking and the pre-undocking vestibule leak check was nominal. Successful undocking from the ISS was completed at 349:17:28 G.m.t. (09:19:08 MET).

The external airlock waterline heater reconfiguration from string A heaters to string B heaters was performed as part of the in-flight checkout. String C heaters were not required.

### **Atmospheric Revitalization Pressure Control Subsystem**

The atmospheric revitalization pressure control subsystem (ARPCS) performed normally throughout the duration of the flight. The active system monitor parameters indicated normal output throughout the duration of the flight.

A change to normal procedures isolated the 14.7-psia regulators until just prior to ISS docking and thus maximized the GN<sub>2</sub> available for transfer to the ISS. Cabin pressure was allowed to bleed down until 341:14:19 G.m.t. (01:16:00 MET) when the cabin was repressurized to 14.4 psia using oxygen (O<sub>2</sub>) in preparation for ISS docking. After docking with the ISS, the hatches were opened at 341:22:52 G.m.t. (02:00:33 MET), and the equalization pressure was 14.19 psia.

During this first hatch-open period, the Orbiter-to-ISS N<sub>2</sub> transfer system hose was hooked up and the transfer of GN<sub>2</sub> was attempted. It was later determined that GN<sub>2</sub> was not transferred. After implementing several troubleshooting procedures to isolate the problem, it was discovered that one of the quick disconnects on the ISS side of the transfer line was disconnected. By the time the problem was identified and corrected, a 14.7-psia repressurization had been performed and the nitrogen pressure in the Orbiter GN<sub>2</sub> tanks was lower than the ISS GN<sub>2</sub> storage pressure. Consequently, the transfer of GN<sub>2</sub> to the ISS was not possible.

Hatches accessing the ISS were closed at 341:23:00 G.m.t. (04:00:41 MET), and the crew commenced the cabin depressurization to 10.2 psi at 342:00:45 G.m.t. (04:02:26 MET) in preparation for the planned extravehicular activity (EVA). Cabin depressurization was completed at 344:01:30 G.m.t. (04:03:11 MET). The cabin remained at 10.2 psia until the crew had egressed the airlock for EVA. The cabin was repressurized to 14.7 psia and the airlock repressurization for crew ingress was performed at 14.7 psia.

Pressure was equalized and the hatches common to the ISS were opened. ARPCS 1 was configured to maintain pressure for overnight while the hatches were open. For the remaining docked time, the Orbiter performed pressure control for the entire stack.

After the cabin repressurization at 345:03:19 G.m.t. following the EVA, the system 1 nitrogen flow sensor indication decreased to zero and remained at zero for the rest of the mission. Postflight testing has indicated that the ARPCS system nitrogen flow sensor failed.

The GN<sub>2</sub> transfer line and the valves on the docking-base transfer panel were used to pressurize the ISS stack using GN<sub>2</sub>, and the Orbiter/ISS stack was pressurized to 14.9 psia prior to undocking.

Hatches to the ISS were closed for the final time at 337:13:15 G.m.t. (09:14:56 MET). Normal pressure control was maintained by ARPCS system 1 for the remainder of the mission.

Due to GN<sub>2</sub> conservation and an extended docked period, switchover on ARPCS system 1 and ARPCS system 2 was not observed on this mission.

### **Atmospheric Revitalization Subsystem**

The atmospheric revitalization subsystem (ARS) performed nominally throughout the duration of the flight. All file IX checkout requirements were performed and satisfied.

At approximately 340:00:44 G.m.t. (00:02:25 MET), the airlock booster fan A successfully powered up on all three phases. Fan A was the only fan operated during the flight. The crew has the option of powering either the A or B fan and remaining on the same fan at each power-on interval. For the additional power-on cycles during the mission, the fan operated satisfactorily on all three phases.

During the mission, the partial pressure of carbon dioxide (ppCO<sub>2</sub>) peaked at an indicated sensor value of 6.0 mmHg at 344:03:35 G.m.t. (04:05:16 MET). The peak occurred while the cabin pressure was at 10.2 psia in support of the EVA. The Orbiter was isolated from the ISS approximately 3.5 hours prior to the indicated reading of elevated CO<sub>2</sub> value. The preflight decision for the ISS to provide primary control of ppCO<sub>2</sub> levels for both the Orbiter and the ISS during periods when the hatches were open proved to be effective. Both the ISS and Orbiter ppCO<sub>2</sub> levels were controlled with the ISS hardware maintaining the majority of CO<sub>2</sub> level, therefore resulting in a reduction in Orbiter LiOH cartridge changes. Based on the LiOH change-out schedule, a total of 12 LiOH canisters were not expended because of the operation of both pieces of ISS hardware. With the proven maintainability of the majority of ppCO<sub>2</sub> control by ISS hardware, several LiOH cartridges will be removed from future Orbiter-mission manifests, freeing up middeck space for additional payloads.

The ppCO<sub>2</sub> Development Test Objective (DTO) supported two intervals of the flight. The first time interval started at 341:22:52 G.m.t. (02:00:33 MET) and ended with hatch closure at 344:00:43 G.m.t. (04:02:24 MET). During the 2-day period of CO<sub>2</sub> control, the Orbiter-indicated ppCO<sub>2</sub> level peaked to 4.69 mmHg, while the ISS Laboratory ppCO<sub>2</sub> sensor peaked to 5.5 mmHg. The second interval started at 344:23:53 G.m.t. (05:01:34 MET) with hatch opening and ended with hatch closure at 349:13:20 G.m.t. (09:15:01 MET). During this interval, the Orbiter-indicated ppCO<sub>2</sub> level peaked to 5.38 mmHg, while the ISS Laboratory ppCO<sub>2</sub> sensor peaked to a reading of 5.46 mmHg.

The floodlight coldplate temperature location on the 576 bulkhead remained above 60 °F for the duration of the flight. The minimum temperature of 64.3 °F occurred at 359:20:23 G.m.t. (10:20:04 MET).

Approximately midway through the flight, the crew performed the cabin temperature controller reconfiguration by de-pinning the linkage at controller 1 and pinning the linkage at controller 2. During this time, the cabin temperature selector was positioned to the full-bypass position driving the temperature controller away from the full heat-exchanger flow. This reduces the force on the linkage and subsequently reduces the amount of force required by crewman to remove and install the linkage pip pin. The secondary controller operated nominally for the remainder of the flight.

The water coolant loop 1 bypass valve functional checkout was successfully performed at 351:12:56 G.m.t. (11:14:37 MET).

During the launch phase, the crew compartment temperature was 77.7 °F and climbed to 79.8 °F, 55 minutes and 24 seconds into the flight. The temperature continued to rise and it peaked at 83.8 °F 3 hours and 23 minutes into the flight. Cabin humidity peaked to 42 percent 5 minutes and 34 seconds after launch. The heat exchanger outlet air temperature peaked to 71.1 °F 3 minutes 6 seconds after launch.

During the on-orbit phase of the mission, the cabin temperature averaged 75 °F. While the cabin was operating at 10.2-psia, the cabin temperature peaked to 76.6 °F, which is below the preflight prediction of 82 °F. The ppCO<sub>2</sub> peaked to 5.38 mmHg ppCO<sub>2</sub> cabin pressure was at 14.7 psia.

During 10.2-psia cabin pressure operations, the sensor indicated a ppCO<sub>2</sub> concentration of 6.02 or an equivalent ppCO<sub>2</sub> of 9.35 per the Hamilton Sundstrand provided equivalency value.

Cabin humidity averaged 32.0 percent for the flight, peaking to 50 percent during the crew exercise period of flight day 2 at approximately 340:23:59 G.m.t. (01:01:40. MET).

During the landing phase of the flight, the heat exchanger outlet temperature peaked to 61.4 °F 6 minutes and 13 seconds after wheel stop, with the cabin air temperature peaking to 77.7 °F at 19 minutes and 37 seconds after wheel stop. The temperature at landing was 76.9 °F, violating the 75 °F cabin air temperature limit. The cabin humidity peaked near 46.4 percent approximately 8 minutes and 30 seconds after wheel stop.

Due to a damaged outlet line in the ISS oxygen recharge compressor assembly (ORCA), the transfer of oxygen from the Orbiter to the ISS was terminated. The damaged outlet line was returned on the Orbiter.

### **Active Thermal Control Subsystem**

The active thermal control subsystem (ATCS) performed nominally throughout the mission with the exception of the FES high load in secondary mode failing the in-flight checkout.

During the flash evaporator system (FES) checkout beginning at 351:13:52 G.m.t. (11:15:32 MET), with the FES high-load evaporator enabled, the secondary controller failed to control the evaporator Freon outlet temperature within the specified range. The FES checkout is performed by having the high-load FES produce an outlet temperature



of  $62 \pm 2$  °F within 2.5 minutes after the crew has switched to FES secondary control. The outlet temperature oscillated in a range from approximately 45 to 80 °F for about 11 minutes, slightly increasing with time. At 351:14:05 G.m.t. (11:15:43 MET), the crew proceeded with the FES checkout by switching the FES secondary mode from high load to topping. The topper responded nominally with FES outlet temperatures hovering between 61 °F and 62 °F, thus meeting the checkout requirement. The topper in secondary mode was allowed to run for 4 minutes to ensure a good check of the secondary controller. At 351:14:09 G.m.t. (11:15:47 MET), the crew concluded the checkout by transitioning to the primary B full-up mode for the FES; and that included a brief operation of the FES in secondary high-load mode again. The brief operation back to secondary high-load mode produced an outlet oscillation that dipped to as low as 41°F. At 352:14:11 G.m.t. (11:15:49 MET), the FES was placed in primary B full-up mode and the FES operated nominally for the rest of the flight.

A visual inspection of the FES did not identify an obvious problem. Troubleshooting of the secondary high-load control sensor at a single point produced satisfactory results, as did a checkout of the controller. A ramp test of the control sensor showed an approximate 2-second delay between the secondary high-load control sensor and the primary A and primary B midpoint sensors that are located in the same block. An evaluation of the data concluded that the cause of the problem was the control temperature sensor. The sensor has been removed and replaced.

Other highlights of the ATCS performance include a significant amount of FES pre-evaporative cooling during ascent. The FES outlet temperature peaked at 87.5 °F and dropped to 61.5 °F before warming up again from the effects of the bypassed radiators. This event indicates that significant water from condensation and an accumulation from rain had collected in the cores. The FES was able to handle the transient with no unusual temperature signatures in the ducts or in the Freon loop outlet temperature. For post-insertion, the radiators were switched from bypass to the flow position. The FES was inhibited for a major portion of the flight except for a few times that included two water dumps. The first FES water dump lasted 4 hours 20 minutes; the second FES water dump lasted 8 hours 4 minutes. The radiators were not deployed during the flight.

On deorbit day, the radiator cold soak was started at 351:12:53 G.m.t. (11:14:34 MET). The radiator was placed in bypass mode at the beginning of the bypass/FES checkout at 351:13:51 G.m.t. (11:15:32 MET). The radiators were placed back in flow position at 351:17:42 G.m.t. (11:19:23 MET) or about 13 minutes before landing. At 351:18:01 G.m.t., about 6 minutes after touchdown, the radiators were configured to high set-point and the ammonia boiler subsystem was placed in system B secondary control. The ammonia system B secondary control was deactivated at 36 minutes later and ground cooling was established about 4 minutes later. Tank A of the ammonia system was not used.

### **Supply and Waste Water Subsystem**

The supply water and waste management systems performed nominally throughout the mission and all of the scheduled in-flight checkout requirements were satisfied. Supply water was managed through the use of the flash evaporator system, water transfer to the International Space Station and the overboard nozzle dump system. Seven supply water nozzle dumps were performed at a nominal dump rate of 1.9 percent (3.12 lb/min). The line heater maintained the supply-water dump-line temperature between 75.8 °F and 98.3 °F throughout the mission.

Three wastewater nozzle dumps at an average rate of 2.06 percent/min (3.4 lb/min) were performed. During this mission, four contingency water containers (CWCs) containing ISS-Lab condensate and two payload water reservoirs (PWRs) containing expired iodinated water were nominally dumped through the wastewater dump nozzle. This was the first flight for dumping PWRs. Dumping was performed following a nominal wastewater dump by closing the waste isolation valve. The dump nozzle was reheated between PWR dumps. The wastewater dump line temperature was maintained between 51.6 °F and 85.5 °F throughout the mission.

The Shuttle Urine Pre-treat Assembly (SUPA) was manifested for the first time since STS-97, and condensate collection in a CWC was implemented to minimize waste dumps while docked with the ISS. The SUPA was redesigned to resolve the formation of the unexpected materials detected in the STS-97 waste collection system. It incorporated the design requirements needed to prevent the formation of both alkaline and acidic urine solids.

As a result of the water condensate separation/collection performed on this flight, two CWCs were filled with Orbiter condensate and dumped overboard through the Orbiter wastewater dump nozzle. Nominally, the wastewater-dump isolation valve is closed prior to connecting the CWC into the wastewater cross-tie quick disconnect (QD) to prevent flow from the waste tank into the CWC. However, when preparing to dump the ISS condensate CWC, the CWC was connected to the wastewater cross-tie QD prior to closing the waste dump isolation valve and about 14 lb of urine from the waste tank was introduced into the CWC. Cabin pressure was at 14.7 psia during the condensate CWC and PWR dumps.

Two CWCs were filled with technical water and transferred to the ISS, for a total of 195 lb. The calculated average fill rate was 108 lb/hr. In addition, four PWRs of iodinated water (88.7 lb) were filled and transferred to the ISS. Vacuum vent line temperature was maintained between 57.7 °F and 80°F.

### **Waste Collection Subsystem**

The waste collection subsystem (WCS) performed satisfactorily throughout the mission. The crew noted no anomalous performance.

### **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**

During the prelaunch period of the first launch attempt, a column parity error was received in the SSME 2 60-kilobit data stream. The error was seen on the launch processing system (LPS). After the initial evaluation, it was determined that the problem was either in the 60-kilobit circuitry portion of the engine interface unit (EIU), which is a criticality 3 function, or in the transmission circuitry between the EIU and LPS. Therefore, the problem was not in the EIU circuitry that provides the interface functions between the general-purpose computers (GPC) and the SSME 2 controller. Further data evaluation indicated that the most likely source of the problem was in the transmission circuitry between the Orbiter/ground interface and the LPS. Vehicle troubleshooting was not performed because KSC troubleshooting isolated the problem to the LPS.

The flight data subsystem performed satisfactorily throughout the mission with the exception, which is discussed in the following section. Entry interface occurred at 351:17:23:14.92 G.m.t. (11:19:03:46.93 MET), and entry was completed satisfactorily.

### **Flight Control Subsystem**

The flight control subsystem (FCS) performed satisfactorily throughout the mission. The FCS checkout was performed using auxiliary power unit (APU) 1 with a start time of 350:12:59:57 G.m.t. (10:14:40:30 MET). The FCS performance was nominal.

At 347:05:39:41 G.m.t. (07:07:20:13 MET), an inertial measurement unit (IMU) built-in test equipment (BITE) fault messages were annunciated against IMU 2, when the IMU experienced platform fail and redundant rate fail BITEs (Flight Problem STS-108-V-03). These indications were the result of a high redundant rate resulting from degraded performance of the IMU 2 Z-axis/redundant axis gyroscope. The crew reactivated IMU 1, which had previously been deactivated to conserve cryogenics, to increase redundancy. IMU 1 and IMU 2 were aligned to IMU 3. The crew then deselected IMU 2 and masked the BITE to prevent nuisance alarms during the crew sleep period. Approximately 45 minutes later, the excessive rate decreased to nominal values, and the BITE cleared. The IMU remained in operate but was deselected. The IMU 2 Z-axis/redundant axis gyro degradation did not recur. With the continued satisfactory IMU 2 performance, IMU 2 was reselected and the built-in test equipment (BITE) mask removed after the final approval was given for the deorbit operations. This IMU configuration maximized redundancy for deorbit and entry operations. The IMU performed nominally throughout the entry and landing phases. Postflight testing of the IMU was in progress as this section was being written.

### **Displays and Controls Subsystem**

The displays and control subsystem performed satisfactorily throughout the mission. No problems or in-flight anomalies were identified from the review of the data.

### **Communications and Tracking Subsystem**

The communications and tracking subsystem performed satisfactorily throughout the mission. No significant problems or in-flight anomalies were identified from the analysis of the data.

During the rendezvous, the Ku-band radar acquired the ISS at 341:16:52 G.m.t. (01:18:32 MET) at a range of 130,000 feet (approximately 21.7 nmi.). At 341:17:35 G.m.t. (01:19:15 MET), at a range of 48 feet, the Ku-band system was placed in the standby mode to conserve power. The Ku-band system was powered back on at 341:17:51 G.m.t. (01:19:31 MET). The system was placed in the communications mode at 341:19:29 G.m.t. (01:21:09 MET). After undocking, the Ku-band system was placed in the radar mode at 349:18:12 G.m.t. (09:19:52 MET) and acquired the ISS at a range of 400 ft. The radar maintained lock-on the ISS during flyaround operations. The Ku-band system was placed in the communications mode at 349:18:56 G.m.t. (09:20:36 MET) at a range of 8760 ft.

During orbit 33 at 342:00:02 G.m.t. (02:01:42 MET) while operating through Tracking and Data Relay Satellite (TDRS) West, the S-band power amplifier (PA) 2 radio frequency (RF) output decreased below 60 watts causing a systems management (SM) message.

were observed in the downlink image from CCTV camera C during low-light conditions, resulting in an image that was barely visible.

During orbit 33 at 342:00:02 G.m.t. (02:01:42 MET) while operating through Tracking and Data Relay Satellite (TDRS) West, the S-band power amplifier (PA) 2 radio frequency (RF) output decreased below 60 watts causing a systems management (SM) message. The event lasted approximately 20 seconds and did not recur. After an evaluation of the data/performance history of the component, no other similar events have been identified, and this condition is apparently an isolated single event. With the exception of a 24-hour period on S-band string 1 for the redundant system checkout, PA 2 was used for the remainder of the mission and performed nominally. The PA 2 output low message was inhibited during crew sleep periods. There was no mission impact. It was decided that the only postflight troubleshooting would be to monitor the RF output during a planned transponder test. No anomalies or problems were noted and the PA will be flown as-is.

During the EVA-preparations communications checkout, loud white noise (static) was heard on air-to-ground (A/G) 2 and at the Space-to-Space EVA Radio (SSER). Power cycling the Space-to-Space Orbiter Radio (SSOR) temporarily (10 to 15 seconds) cleared the noise. SSOR 1 (primary string) showed good frame synchronization and base-band signal processor (BSP) during the anomaly. Troubleshooting was performed, and switching from SSOR 1 to SSOR 2 cleared the problem. During the EVA, there were no communications issues, and the crew commented on the high quality of their communications.

EMU checkout was successfully performed using SSOR 1, and SSOR 1 performed nominally during the rendezvous, docking and undocking. The EMU biomedical data was pulled during the period when the audio was bad. It shows that the SSOR was outputting good biomedical data at the time, and this is evidence that the SSOR BSP, which also handles the transmit-and-receive audio functions, was operating properly. Therefore, it is not considered likely that the SSOR is the source of the noise. There was a six-minute period between switching from SSOR 1 to SSOR 2 when the two systems were locked to the International Space Station (ISS) radio and no problem was reported. The crew, to aid in resolving this problem, responded to questions on the configuration of the system. A postflight-troubleshooting plan has been developed and troubleshooting will be performed.

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

The operational instrumentation/modular auxiliary data system (MADS) performed nominally. One minor problem was noted; however the condition did not impact the conduct of the flight. The problem is discussed in the following paragraph.

Three 2-second data dropouts were experienced during the dumping of Orbiter ascent data from operations (OPS) recorder 2 early in the flight. The data were played back at least three times in both the forward and reverse direction and the dropouts were consistent. Two of the dropouts were on track 1 at the 58-percent location and one was on track 4 at the 26-percent location. The recorder was used throughout the mission and the suspect tape segments were monitored. It was reported that the recorder continued to occasionally display two-second dropouts, most of them in the 26- to 58-percent segment of the tape on tracks 1, 2 and 4. The occasional and brief data dropouts did not warrant the avoidance of using the recorder. There was no mission impact from these dropouts. Postflight testing verified the dropout and the recorder but the decision was made to fly the recorder in the as-is condition.

## Structures and Mechanical Subsystems

The structures and mechanical subsystems performed satisfactorily throughout the mission. The following table provides pertinent data concerning the landing of the Orbiter vehicle.

### LANDING PARAMETERS

Parameter	From Threshold, ft	Speed, Keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	3121.0	200.3	-1.30	N/A
Nose gear touchdown	6910.0	144.2	N/A	-5.4
Brake initiation speed		63.5 keas		
Brake-on time		40.47 seconds		
Rollout distance		8919.5 feet		
Rollout time		66.28 seconds		
Runway		15 (Concrete) KSC		
Orbiter weight at landing		226,441.6 lb		
Brake sensor Location	Peak Pressure, Psia	Brake assembly	Gross energy, million ft-lb	
Left-hand inboard 1	743.5	Left-hand inboard	12.77	
Left-hand inboard 3	743.5			
Left-hand outboard 2	658.8	Left-hand outboard	11.80	
Left-hand outboard 4	658.8			
Right-hand inboard 1	815.3	Right-hand inboard	14.70	
Right-hand inboard 3	815.3			
Right-hand outboard 2	720.0	Right-hand outboard	11.65	
Right-hand outboard 4	720.7			

The payload bay doors were opened at 340:00:00:40 G.m.t. (00:01:41:13 MET). All voltages were nominal and the motors opened the doors in nominal dual-motor time.

The payload bay doors were closed and latched for the first Kennedy Space Center (KSC) landing opportunity at 351:14:19:56 G.m.t. (11:16:00:28 MET). All payload bay door closure and latch operations occurred in dual motor time.

During air data probe deployment prior to landing, the right-hand probe began driving approximately one second later than the left-hand probe. After approximately one second of operation, the right-hand probe turned off for about one second, then began driving again. As a result, the right-hand probe was deployed 2.7 seconds later than the left-hand probe. Because of a data dropout at the beginning of the driving of the probe, an exact drive-time calculation cannot be made. However, it is estimated that the File IX limit of 14 seconds for dual motor operation was still satisfied. The interrupted drive period was caused by a "tease" of the switch.

All other mechanisms operated nominally from the beginning of deorbit preparations through completion of post-landing activities. Main landing gear touchdown occurred on KSC concrete runway 15 at 351:17:55:12 G.m.t. (11:19:35:44 MET) on December 17,

2001. The drag chute was deployed at 351:17:55:16.1 G.m.t. The nose gear touchdown occurred at 351:17:55:24.5 G.m.t. The drag chute was jettisoned at 351:17:55:48.4 G.m.t. Wheels stop occurred at 351:17:56:17.8 G.m.t. The rollout was normal in all respects.

The postflight investigation identified two drag parachute system anomalies. The first drag parachute anomaly, identified in the landing video review, was a hole in the main parachute. The postflight inspection revealed that five ribbons were torn and two were stretched (ribbons 34 through 40) along the same radial gore (gore 31). The ribbons had very minor indications of friction burning from contact with other nylon elements. It is suspected that the ribbons were torn during deployment. This parachute hole had a negligible effect on vehicle dynamics. Investigation of this anomaly is continuing.

The second drag parachute anomaly was the partial failure of the ties that connect the sabot to the pilot parachute bag. The postflight inspection revealed that two of the four Kevlar ties that secure the sabot to the pilot parachute bag had failed. One of the ties was loose (apparently came untied) and the becket (loop of material) attaching the second failed tie to the bag had been completely torn from the bag. The remaining two becketts had broken stitching, one being much more severe than the other. It appears that after the one tie came loose, it caused an overload condition on the remaining three becketts. It is speculated that the knot was not sufficiently tightened and came loose during the initial load. The anomaly continues to be investigated.

### **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 was nominal with no problems noted. The entry aerodynamic heating on the SSME nozzles was also normal with no bluing of the metal noted during the postflight inspection.

### **Thermal Control Subsystem**

The mission beta profile ranged from +19.8° to -34 degrees. The docked-phase beta angle ranged from +13 degrees to -20 degrees, thus allowing the docked attitudes to be flown primarily as the biased -X axis local vertical (-XLV) +Z axis on the velocity vector (+ZVV) torque equilibrium attitude (TEA); and no X axis perpendicular to the orbital plane (XPOP) attitude was required. Although the TEA provided a generally benign thermal environment for the docked mission phase, the main landing gear (MLG) tires were colder than predicted. This caused several attitude revisions to the nominal end-of-mission (NEOM) timeline and extension days. Finally, a change to the planned Prototype Synchrotron Radiation Detector (PSRD) attitude and the addition of some +Z axis solar inertial (+ZSI) allowed for adequate warming of the MLG tires.

The APU 2 service line sensor cycled near its 45 °F (45.2 °F) lower LCC limit during prelaunch for the scrubbed Dec. 4<sup>th</sup> launch date. A waiver was processed to move the LCC down to 42 °F. The temperature was approximately 6 °F lower than observed on the previous flight of this vehicle. The sensor cycled down to 45°F again on the actual Dec 5<sup>th</sup> launch date. The thermostat on the service line controls the heater for both itself and the test line. The heater was cycling nominally within an acceptable range and the temperature sensor also appeared to be operating properly. The heater performance was adequate and it was known that it would result in warmer temperatures while on-orbit because of the lack of a convective environment. The sensor cycled about 10 to 15 °F lower than it had during the on-orbit phase of previous flights. During the vehicle

flow prior to this flight, the APU system quick disconnects (QDs) on the test line and the nitrogen (N<sub>2</sub>) line had been replaced. It was suspected and has been verified that the reinstallation of the sensor influenced the temperature response. The installation of the sensor, heater and insulation will be corrected during postflight turnaround activities.

There was one EVA performed from the Orbiter external airlock during STS-108. The external airlock service lines remained well within limits during the EVA because of the benign TEA attitude that the Orbiter was in at that time.

There were 3 reboost maneuvers performed on STS-108 and 1 collision avoidance (COLA) maneuver. Temperatures remained within established limits throughout the maneuvers.

During the mission, it was determined that a COLA maneuver may be necessary during the docked phase. Because this COLA maneuver would violate the 3-hour limit on vernier RCS reboost firings during a mission, the viability of an additional 15 to 30 minutes of reboost operations to avoid the debris was assessed. The assessment enables the COLA maneuver providing that a cool-off period (with no vernier firings) of no less than three hours performed following the final planned reboost. The COLA maneuver was performed nominally the morning of undocking and all temperatures remained within limits.

### **Aerothermodynamics**

Structural thermocouple temperature data, aileron deflection data, and yaw thruster firings all indicated a slightly asymmetric boundary layer transition. The data indicate that right-side transition was slightly earlier than the left-side transition with onset at approximately Mach 10.7 and ending about Mach 8.6. The wing-skin temperature rise on the right side was 4.6 °F higher than on the left side. All centerline fuselage thermocouples recorded similar onset times.

The acreage heating data indicate that the vehicle experienced higher-than-normal entry heating. The Orbiter weight at entry was higher than normal and the Orbiter was entering from a higher inclination orbit. Both the maximum temperature and temperature rise on the skin (structural) were higher than normal along the lower surface midbody. The structural temperature rise was the highest recorded for the OV-105 vehicle in two locations: the lower surface right-wing skin, and the lower fuselage right of centerline in the mid-aft location. The temperature rises were within the experience of the Space Shuttle fleet.

Local heating was also normal.

### **Thermal Protection Subsystem and Windows**

The thermal protection subsystem (TPS) performed satisfactorily. Structural thermocouple temperature data, aileron deflection data, and yaw thruster firings all indicated a slightly asymmetric boundary layer transition.

The postlanding inspection of the Orbiter TPS identified a total of 95 damage sites of which 22 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 the flame arrestment sparkler system, SSME vibration/acoustics and exhaust plume recirculation. The distribution of these impacts on the vehicle is shown in the following table.

### TPS DAMAGE SITES

Orbiter Surfaces	Hits > 1 Inch	Total Hits
Lower Surface	17	81
Upper Surface	1	1
Window Area	4	13
Right Side	0	0
Left Side	0	0
Right OMS Pod	0	1
Left OMS Pod	0	0
Total	22	95

The Orbiter lower surface sustained 81 damage sites of which 12 had a major dimension of 1-inch or larger. The majority of the hits (49 damage sites with 11 larger than 1-inch in length) were located in the area aft of the main landing gear wheel wells on both the left and right chines. Film analysis will be used to determine the source of the debris.

Approximately 11 of the total lower surface hits were around the LH<sub>2</sub> umbilical area and 24 were around the LO<sub>2</sub> umbilical. Most of these damage sites around the ET/Orbiter umbilical were most likely caused by pieces of the umbilical purge barrier flailing in the airstream and contacting tiles before pulling loose and falling aft. The largest lower-surface tile damage site was located inboard of the right-hand main landing gear door and measured 8.5-inches long by 1.5 inches wide by 3/8-inch deep.

Typical amounts of tile damage occurred on the base heat shield. All SSME dome heat shield closeout blankets were in good condition. A total of 13 damage sites, with 4 having one dimension greater than one inch, were identified on the window perimeter tiles. The hazing and streaking of the forward-facing windows appeared to be less than normal.

In summary, the total number of Orbiter TPS damage sites and the number of sites that were 1-inch or larger were within the established family; however, the number of damage sites between the main landing gear wheel well and the nose landing gear wheel well was higher than normal.

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 -103	STS -101	STS -92	STS -97	STS -98	STS -102	STS -100	STS -104	STS -105	STS -108
Lower surface, total hits	84	70	86	78	73	44	42	108	144	95
Lower surface, hits > 1 in.	13	19	14	10	8	10	4	4	25	22
Longest damage site, in.	1.5	8.0	2.0	3.0	3.0	1.0	2.5	4.5	5	8.0
Deepest damage site, in.	0.25	0.75	0.75	0.5	0.5	0.12	0.12	0.25	0.06	0.37



The post-landing walkdown of runway 15 was performed immediately after landing and no foreign object damage (FOD) or flight hardware, other than the drogue parachute components, were found on the runway.

### **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.

The analysis was performed using an AeroVac Mass Spectrometer and the backup analysis was accomplished using a new Finnegan 9001 Gas Chromatograph with Discharge Ionization Detection.

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

## EXTRAVEHICULAR ACTIVITY

Extravehicular mobility unit (EMU) checkout was completed with both units performing nominally. As a result, the two EMUs were ready to support the planned EVA for this flight.

After a pre-breathe period of approximately 75 minutes, the EVA began at 344:19:34 G.m.t. (04:21:14 MET). EMU performance during the EVA was excellent and no anomalies were noted.

The EVA lasted 4 hours and 11 minutes, and the EVA equipment performed satisfactorily. During the EVA, the crewmembers completed the primary objective of the EVA by successfully wrapping insulation blankets around two solar array drive motors. However, the one solar array truss that did not latch properly when the solar arrays were deployed during a previous flight could not be latched by the crewmembers. After each crewmember made an unsuccessful attempt to latch the solar array, the exercise was stopped at the request from Mission Control. Other tasks completed during the EVA were retrieval of the S-band antenna structure assembly blanket, photographic documentation of heat pipe radiators on Z1 truss, and inspection of direct current switching unit. The maintenance task on the starboard solar array 4 bar linkage was attempted but was not successful. As a result, some of the other minor tasks were canceled and those tasks will be accomplished on a later flight.

## REMOTE MANIPULATOR SYSTEM

On this 64<sup>th</sup> flight of the remote manipulator system (RMS), the RMS was a mass-handling arm for all robotic operations. The Shuttle RMS performed three major tasks, all of which were completed:

1. Multi-purpose logistics module (MPLM) removal from the payload bay and installation on the common berthing mechanism (CBM);
2. Extravehicular activity (EVA) support to install the beta gyro assembly (BGA) thermal blankets and assist the crew in performing some get-ahead tasks; and
3. MPLM un-installation from the CBM and berthing in the Shuttle payload bay.

The RMS performed satisfactorily throughout the mission. No in-flight anomalies were identified from the analysis of the data.

The RMS was powered up at 340:02:25 G.m.t. (00:04:05:33 MET) and uncradled at 340:17:48 G.m.t (00:19:28:33 MET). RMS checkout was performed and completed satisfactorily and following the checkout, a payload bay survey was performed.

At 342:15:26 G.m.t. (02:17:06 MET), the RMS was powered up and uncradled in preparation for Multi-Purpose Logistics Module (MPLM) operations. The RMS successfully grappled the MPLM at 342:16:14 G.m.t. (02:17:54 MET) and at 342:16:14:10 G.m.t. (02:17:54:42 MET) the MPLM was un-berthed from the payload bay. After the MPLM was moved into position and installed to the Node, the RMS ungrappled the MPLM at 342:18:09 G.m.t. (02:19:49 MET).

The RMS was powered at 344:15:33 G.m.t. (04:17:13 MET) and uncradled in preparation for the EVA operations. The RMS was cradled and latched at 344:22:18 G.m.t. (04:23:58 MET). RMS operation was nominal throughout the EVA.

The RMS performed satisfactorily in supporting the MPLM operations. The RMS was powered up at 348:17:52 G.m.t. (08:19:32 MET), and the MPLM was uninstalled from the ISS Node at 348:21:54 G.m.t (08:23:34 MET). The MPLM was berthed in the payload bay at 348:22:45 G.m.t. (09:00:25 MET). The RMS was cradled and latched at 348:23:11 G.m.t. (09:00:51 MET).

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

The government furnished equipment/flight crew equipment (GFE/FCE) performed satisfactorily and supported all aspects of the mission as planned.

The TCS was used following undocking and performed nominally. It provided valid data throughout the flyaround activities and to a range of 438 ft where it lost track of the ISS. The TCS was deactivated and configured for entry.

At 348:21:16 G.m.t. (08:22:56 MET), intermittent red streaks were observed in the downlink video image from closed circuit television (CCTV) camera C during low-light conditions. As a result, the image was barely visible when those conditions existed. This condition did not affect the success of the mission.

At 349:03:21 G.m.t. (09:05:01 MET), the crew reported that the focus on CCTV camera B, which was set at 29 feet, resulted in a fuzzy picture when zoomed in. Repeated attempts to adjust the focus, both at far or near distances, were unsuccessful. This problem did not affect the success of the mission.

The robotic situational awareness display (RSAD) performed satisfactorily on flight day 2 and 4. On flight day 6 the RSAD, running on the STS5 payload and general support computer (PGSC), stopped receiving telemetry data. The crew reported the loss of data and the receipt of a couple of error messages. On flight day 10, the STS2 PGSC stopped receiving RSAD data but the STS5 PGSC RSAD application started to receive telemetry data from the manipulator controller interface unit (MCIU), but was not receiving pulse code modulation master unit (PCMMU) data. It was determined that there was no impact to the mission as a result of this anomaly. The crew was able to resolve the issue on flight day 10 by manually inputting data that would normally be automatically updated by the PCMMU. Postflight testing will be performed in an effort to isolate the cause of the anomaly.

## POSTLAUNCH PAD INSPECTION

The postlaunch inspection of the mobile launch platform-1 (MLP-1), launch pad B fixed service structure (FSS) and rotating service structure (RSS) was completed within 4.5 hours of launch. No flight hardware was found, and the overall damage to the launch complex was slightly greater than normal.

The Orbiter lift-off lateral acceleration data, which was used to determine if stud hang-ups had occurred, indicated that no SRB holddown stud hang-up had occurred. Evaluation of the MLP zero-level was performed and the south holddown studs were visually assessed as having no indication of stud hang-up. Erosion was typical on the north posts with some evidence of missing room temperature vulcanizing (RTV) material at the holddown post interface with the haunch. The north holddown post blast covers and T-0 umbilical exhibited minimal exhaust plume damage. Both Solid Rocket Booster (SRB) aft-skirt gaseous nitrogen ( $\text{GN}_2$ ) purge lines were intact, protective tape layering was partially eroded on the right-hand side and the metal braid was partially eroded on the liquid hydrogen purge line.

The liquid oxygen ( $\text{LO}_2$ ) and liquid hydrogen ( $\text{LH}_2$ ) tail service masts (TSMs) appeared undamaged and the  $\text{LO}_2$  bonnet had closed properly. The MLP deck was in generally good condition. All MLP deck communications connector caps were intact and secured.

The gaseous hydrogen ( $\text{GH}_2$ ) vent line did not latch on the FSS latching mechanism. It appears that the vent line impacted the south side of the FSS structure, thus preventing the latching to occur. Substantial damage resulted to the saddle structure. The south side bridle cable was sheared from the southern tang on the yoke. Pieces of debris (bolts and clevis leg) were found on and in the grating and vent line structure. The ground umbilical carrier plate (GUCP) 7-inch quick disconnect sealing surface exhibited no damage. The deceleration cable was in nominal configuration with the vent line blanket sooted and torn.

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

The gaseous oxygen vent arm, hood, ducts and structure were in generally good shape with no indications of plume damage. The access door window on the north side of the hood was broken with loss of material. A major hydraulic leak was observed on the gaseous oxygen vent arm/FSS structure hinge on the 255-foot level.

The debris findings were numerous and are presented as follows:

- a. On the FSS 235-foot level, a loose cable tray cover was noted;
- b. On the RSS 215-foot level, a broken light fixture was noted;
- c. On the FSS 215-foot level, an electrical box shorted and burned through the box;
- d. On the FSS 175-foot level, a pressure gage cover was found near the gage on the grating;
- e. On the FSS 155-foot level, a pressure gage cover was noted in the cable tray;
- f. On the MLP deck, a piece of steel cable with swedge was found on the east side;
- g. On the pad surface, a 7/8-inch facility nut was found near the MLP northwest pedestal; and

- h. On the pad surface, numerous pieces of fragmented 1/16-inch aluminum were found.

## **DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES**

### **DEVELOPMENT TEST OBJECTIVES**

**DTO 262 - On-Orbit Bicycle Ergometer Loads Measurement** - The On-Orbit Bicycle Ergometer Loads Management Development Test Objective (DTO) was successfully performed. The test consisted of a crewmember pedaling the ergometer from the minimum expected to maximum expected frequency range while acquiring vibration data from the combined Space Shuttle and International Space Station (ISS) vehicle. The ISS microgravity data system was active during the test and acquired several high quality data streams for postflight processing. The postflight processing will enable confirmation of predicted structural frequencies and damping and removal of uncertainty in the parameters is expected, thus reducing future flight-predicted loads and associated operations constraints.

**DTO 312 - External Tank Thermal Protection Subsystem Performance** - This photographic documentation of the External Tank (ET) following main engine cutoff was planned to provide visual documentation of the ET thermal protection subsystem surface charring during ascent. However, because of the lack of satisfactory lighting, the DTO did not provide any useful data.

**DTO 700-14 - Single-String Global Positioning System Operations** - The miniature airborne Global Positioning System (GPS) receiver (MAGR) along with the payload and general support computer (PGSC) operated nominally during the ascent, on-orbit and entry phases of operation.

During flight day 1, the crew opened the MAGR PGSC locker door and proper cooling was verified. Because of cable-routing problems, the PGSC was restowed back in the locker. The cable routing problem was later resolved by rerouting the cables, and the PGSC remained out of the locker until entry day.

The MAGR receiver experienced a self-test bit failure during the flight control subsystem, checkout that was identified as a common occurrence. This failure did not impact MAGR receiver performance.

**DTO 701-22 - Crew Return Vehicle Space Integrated Global Positioning System/Inertial Navigation System** - Although the crew return vehicle (CRV) Space Integrated GPS/Inertial Navigation System (SIGI) PGSC was accidentally powered off and locked up twice, all on-orbit objectives were achieved. The main objective was to record data during entry.

**DTO 805 - Crosswind Landing Performance** - The crosswind conditions did not meet the criteria, consequently this DTO was not performed.

**ISS DTO 15004-U - ISS Control of Partial Pressure of Carbon Dioxide Levels in the Space Shuttle** - The test results of the ISS DTO 15004-U showed that approximately six lithium hydroxide (LiOH) canisters were not used.

## DETAILED SUPPLEMENTARY OBJECTIVES

**DSO 490 – Bioavailability and Performance Effects of Promethazine During Space Flight** - Detailed Supplementary Objective (DSO) 490 was to be conducted each day during the flight. Based on the lack of crew reports, it has been assumed that the DSO was conducted as planned with no anomalies.

**DSO 498 Spaceflight and Immune Function** - Samples were collected from the crew during the preflight and postflight periods as planned. The results will be reported in other documentation when the postflight analysis is complete.

**DSO 500 - Space Flight Induced Reactivation of Latent Epstein-Barr Virus -** Samples were collected from the crew during the preflight and postflight periods as planned. The results will be reported in other documentation when the postflight analysis is complete.

**DSO 503 – ISS Test of Midodrine as a Countermeasure Against Postflight Orthostatic Hypotension** - Samples were collected from the crew during the preflight and postflight periods as planned. The results will be reported in other documentation when the postflight analysis is complete.

**DSO 632 – Pharmacokinetics and Contributing Physiologic Changes During Space Flight** - Samples were collected from the crew during the preflight and postflight periods as planned. The results will be reported in other documentation when the postflight analysis is complete.



## **PHOTOGRAPHY AND TELEVISION ANALYSIS**

The launch videos and films were reviewed and evaluated following the STS-108 launch. One anomalous event was noted during the evaluation of the video and film.

The gaseous hydrogen (GH<sub>2</sub>) vent arm contacted the south side of the support structure at or near the saddle plate. A large-appearing piece of dark-colored debris was seen falling almost vertically downward toward the left Solid Rocket Booster (SRB) flame trench as a result of the vent arm contact. The vent arm did not latch-back and the ground umbilical carrier plate (GUCP) was seen to rebound beyond the fixed service structure (FSS) a distance equal to approximately one-half the length of the GUCP (estimated to be about one foot). The left SRB was the closest part of the launch vehicle to the vent arm during the rebound; however, the rebound motion did not bring the GH<sub>2</sub> vent arm significantly close to the launch vehicle. Using the left SRB (approximately 12-feet in diameter) for scaling, it appears that the distance between the vent arm at the point of maximum rebound and the left SRB was at least 13 to 15 feet during liftoff. Neither the rebounded vent arm/GUCP nor the debris from the impact contacted the launch vehicle.

No anomalous events were noted in the review of the landing videos. All aspects of the landing appeared to be normal. However, one unusual event was seen on the drag parachute canopy during the landing rollout. The drag parachute appeared to have a defect (tear or hole) on the canopy during parachute disreef until drag parachute release. An evaluation of the video by engineering personnel indicated that two of the drag parachute ribbons had failed and a postflight evaluation of the parachute will be made.

**TABLE I.- STS-108 SEQUENCE OF EVENTS**

<b>Event</b>	<b>Description</b>	<b>Actual time, G.m.t.</b>
APU Activation	APU-1 GG chamber pressure	339:22:14:40.548
	APU-2 GG chamber pressure	339:22:14:41.873
	APU-3 GG chamber pressure	339:22:14:42.954
SRB HPU Activation <sup>a</sup>	LH HPU System A start command	339:22:18:59.987
	LH HPU System B start command	339:22:19:00.147
	RH HPU System A start command	339:22:19:00.307
	RH HPU System B start command	339:22:19:00.467
Main Propulsion System Start <sup>a</sup>	ME-3 Start command accepted	339:22:19:21.438
	ME-2 Start command accepted	339:22:19:21.543
	ME-1 Start command accepted	339:22:19:21.670
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	339:22:19:27.987
Throttle up to 104.5 Percent Thrust <sup>a</sup>	ME-1 Command accepted	339:22:19:31.858
	ME-3 Command accepted	339:22:19:31.879
	ME-2 Command accepted	339:22:19:31.883
Throttle down to 93 Percent Thrust <sup>a</sup>	ME-1 Command accepted	339:22:19:45.770
	ME-3 Command accepted	339:22:19:45.778
	ME-2 Command accepted	339:22:19:45.803
Throttle down to 72 Percent Thrust <sup>a</sup>	ME-1 Command accepted	339:22:20:00.490
	ME-3 Command accepted	339:22:20:00.499
	ME-2 Command accepted	339:22:20:00.523
Throttle up to 104.5 Percent Thrust <sup>a</sup>	ME-1 Command accepted	339:22:20:14.570
	ME-3 Command accepted	339:22:20:14.579
	ME-2 Command accepted	339:22:20:14.604
Maximum Dynamic Pressure (q)	Derived ascent dynamic pressure	339:22:20:31
Both RSRM's Chamber Pressure at 50 psi <sup>a</sup>	RH SRM chamber pressure mid-range select	339:22:21:26.787
	LH SRM chamber pressure mid-range select	339:22:21:27.467
End RSRM <sup>a</sup> Action <sup>a</sup> Time	LH SRM chamber pressure mid-range select	339:22:21:29.307
	RH SRM chamber pressure mid-range select	339:22:21:30.227
SRB Physical Separation <sup>a</sup>	LH rate APU turbine speed - LOS	339:22:21:31.947
SRB Separation Command	SRB separation command flag	339:22:21:32
OMS Assist Maneuver Ignition	Left engine bi-prop valve position	339:22:21:42.2
	Right engine bi-prop valve position	339:22:21:42.2
OMS Assist Maneuver Cutoff	Left engine bi-prop valve position	339:22:22:33.6
	Right engine bi-prop valve position	339:22:22:33.8
Throttle Down for 3g Acceleration <sup>a</sup>	ME-1 command accepted	339:22:26:51.818
	ME-3 command accepted	339:22:26:52.830
	ME-2 command accepted	339:22:26:52.911
3g Acceleration	Total load factor	339:22:27:38.8
Throttle Down to 67 Percent Thrust <sup>a</sup>	ME-2 command accepted	339:22:27:46.893
	ME-1 command accepted	339:22:27:46.899
	ME-3 command accepted	339:22:27:46.852
SSME Shutdown <sup>a</sup>	ME-2 command accepted	339:22:27:53.493
	ME-1 command accepted	339:22:27:53.500
	ME-3 command accepted	339:22:27:53.511

<sup>a</sup>MSFC supplied data

**TABLE I.- STS-108 SEQUENCE OF EVENTS  
(Continued)**

<b>Event</b>	<b>Description</b>	<b>Actual time, G.m.t.</b>
MECO	MECO command flag	339:22:27:54
	MECO confirm flag	339:22:27:54
ET Separation	ET separation command flag	339:22:28:16
APU Deactivation	APU-1 GG chamber pressure	339:22:34:09.809
	APU 2 GG chamber pressure	339:22:34:17.842
	APU 3 GG chamber pressure	339:22:34:24.657
OMS-1 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Not performed - direct insertion trajectory flown
OMS-1 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	Not performed
OMS-2 Ignition	Left engine bi-prop valve position	339:22:57:14.8
	Right engine bi-prop valve position	339:22:57:14.8
OMS-2 Cutoff	Right engine bi-prop valve position	339:22:59:02.6
	Left engine bi-prop valve position	339:22:59:02.8
Payload Bay Doors (PLBDs) Open	PLBD right open 1	339:23:59:22
	PLBD left open 1	340:00:00:41
OMS-3 Ignition	Right engine bi-prop valve position	340:01:33:27.7
	Left engine bi-prop valve position	340:01:33:27.7
OMS-3 Cutoff	Right engine bi-prop valve position	340:01:35:08.9
	Left engine bi-prop valve position	340:01:35:08.9
OMS-4 Ignition	Left engine bi-prop valve position	340:17:26:08.1
	Right engine bi-prop valve position	340:17:26:08.1
OMS-4 Cutoff	Left engine bi-prop valve position	340:17:26:27.7
	Right engine bi-prop valve position	340:17:26:27.8
OMS-5 Ignition	Left engine bi-prop valve position	341:16:11:50.3
	Right engine bi-prop valve position	341:16:11:50.3
OMS-5 Cutoff	Left engine bi-prop valve position	341:16:12:49.9
	Right engine bi-prop valve position	341:16:12:49.9
Docking with ISS	Docking ring final position	341:20:03:26
MPLM Grappled	As reported	342:16:14:10
MPLM Ungrappled	As reported	342:18:09:20
First Reboost Maneuver (start)	As reported	343:15:11:40.5
Cabin Depressurization (start)	Cabin pressure	344:01:17:02
Airlock Depressurization (end)	Airlock differential pressure no. 1	344:17:49:58
Begin Extravehicular Activity	Airlock differential pressure no. 1	344:19:34
Cabin Repressurization (start)	Cabin pressure	344:20:34:21
Airlock Repressurization (start)	Airlock differential pressure no. 1	344:22:05:16
Second Reboost Maneuver (start)	As reported	345:16:19:40.5
Third Reboost Maneuver (start)	As reported	346:15:22:32.5
MPLM Grappled	As reported	348:19:22:43
MPLM Ungrappled	As reported	348:22:57:00
Fourth Reboost Maneuver (start) (Collision Avoidance)	As reported	349:14:55:40.4
Undocking from ISS	Undock complete	349:17:28:25
ISS Separation Maneuver (RCS)	As reported	349:18:52:28

**TABLE I.- STS-108 SEQUENCE OF EVENTS  
(Continued)**

<b>Event</b>	<b>Description</b>	<b>Actual time, G.m.t.</b>
OMS-6 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	349:23:29:28.3 349:23:29:28.3
OMS-6 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	349:23:28:42.9 349:23:28:42.9
Flight Control System Checkout APU Start APU Stop	APU 1 GG chamber pressure APU 1 GG chamber pressure	350:12:59:56.421 350:13:04:02.939
OMS-7 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	350:18:51:37.3 350:18:51:37.3
OMS-7 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	350:18:51:47.1 350:18:51:47.3
Payload Bay Doors Close	PLBD left close 1 PLBD right close 1	351:14:15:46 351:14:18:55
APU Activation for Entry	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	351:16:43:19.725 351:17:10:41.969 351:17:10:45.034
Deorbit Burn Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	351:16:48:13.2 351:16:48:13.2
Deorbit Burn Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	351:16:51:21.8 351:16:51:21.8
Entry Interface (400K feet)	Current orbital altitude above	351:17:23:15
Blackout end	Data locked (high sample rate)	No blackout
Terminal Area Energy Management	Major mode change (305)	351:17:48:32
Main Landing Gear Contact	LH main landing gear tire pressure 1 RH main landing gear tire pressure 2	351:17:55:12 351:17:55:12
Main Landing Gear Weight on Wheels	LH MLG weight on wheels RH MLG weight on wheels	351:17:55:12 351:17:55:13
Drag Chute Deployment	Drag chute jettison 1 CP Volts	351:17:55:16.1
Nose Landing Gear Contact	NLG LH tire pressure 1	351:17:55:24
Nose Landing Gear Weight On Wheels	NLG weight on wheels 1	351:17:55:25
Drag Chute Jettison	Drag chute jettison 1 CP Volts	351:17:55:48.4
Wheel Stop	Velocity with respect to runway	351:17:56:18
APU Deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	351:18 11:38.077 351:18:11:44.303 351:18:11:50.745

TABLE II- STS-108 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-108-V-01	RCS Thruster R4U Failed Off	339:22:28 G.m.t. 00:00:08 MET PR RP01-32-1216 SPR: 108RF01	<p>Primary RCS thruster R4U failed off when first commanded to fire and was automatically deselected by the RCS RM during mated coast. The reaction jet driver (RJD) output was nominal; however, the chamber pressure reached only 15.8 psia prior to the thruster being deselected. The thruster did not leak propellant following the failure. The thruster injector temperatures and chamber pressures suggest a problem with the thruster pilot-operated valve. From the data, it cannot be determined which of the valves failed. Since there were no additional failures of right RCS up-firing thrusters, the thruster remained deselected for the duration of the flight.</p> <p>KSC: The thruster will be removed and replaced during the postflight turnaround activities. This will include the removal and replacement of all thrusters on the R4 manifold. The removal of the right OMS pod will not be required. Spares are available on-site.</p>
STS-108-V-02	RCS Thruster F3F Failed Off	341:20:03 G.m.t. 01:21:43 MET PR FRC5-18-0268 SPR: 108RF02	<p>Primary RCS thruster F3F failed off following a series of three 0.080-second pulses. The chamber pressure reached a maximum value of 6.4 psia on the first 0.080j-second pulse. The next two pulses peaked at 5.6 psia. RM automatically deselected the thruster at 341:20:03:25 G.m.t. (01:21:43:58 MET), after it failed to reach the minimum threshold pressure (approximately 26 psia) within the allotted time (three cycles). The three pulses were the first use of this thruster on STS-108. The thruster is last priority and fires just prior to capture when thrusters F1F and F2F are deselected. The thruster did not leak propellant following the failure. The thruster injector temperatures and chamber pressures suggest a problem with a thruster pilot-operated valve. From the data, it cannot be determined which of the valves failed. Primary thruster F3F remained deselected for the remainder of the flight and there was not mission impact.</p> <p>KSC: The thruster will be removed and replaced during the postflight turnaround activities. This will include removal and replacement of all thrusters on the F3 manifold. FRC5 was removed and sent to the Hypergolic Maintenance Facility (HMF) for the thruster replacements. Spares are available on-site.</p>

TABLE II- STS-108 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-108-V-03	IMU 2 Z-Axis/Redundant Rate Anomaly	347:05:40 G.m.t. 07:07:20 MET PR GNC-5-18-0094 SPR: 108RF0	<p>At approximately 347:05:40 G.m.t. (07:07:20 MET), IMU BITE messages were annunciated against IMU 2 when the IMU experienced platform fail and redundant rate fail BITEs. The redundant rate fail BITE was the result of a high redundant axis drift rate (up to 3 deg/hr) in the IMU 2 Z-axis/redundant axis gyroscope. The Z-axis drift increased to approximately 0.7 deg/hr. The crew reactivated IMU 1, which had previously been deactivated to conserve cryogenics and thereby increase redundancy. IMUs 1 and 2 were aligned to IMU 3. The crew then deselected IMU 2 and masked the BITE to prevent nuisance alarms during the crew sleep period. Approximately 45 minutes later, the excessive rate decreased to nominal values, and the BITE cleared.</p> <p>IMU 2 remained in operate but was deselected until approval was given for the deorbit maneuver. There were no additional problems with the IMU and it was reselected for entry and the BITE was unmasked. IMU 2 performance during entry and landing was nominal.</p>
STS-108-V-04	FES Secondary High-Load Not Controlling	351:13:52 G.m.t. 11:15:52 MET IPR 111V-0008 SPR: 108RF04	<p>During the FES checkout beginning at 351:13:52 G.m.t. (11:15:32 MET), with the FES high-load evaporator enabled, the secondary controller failed to control the evaporator outlet temperature within the specified range of <math>62 \pm 2</math> °F. The outlet temperature oscillated in a range of approximately 45 to 80 °F, slightly increasing with time. After several cycles, the FES topping evaporator was selected and the outlet temperature control was good on the secondary controller. Checkout of the FES in the full-up mode on the primary B controller was also satisfactory. The FES performed nominally during entry.</p> <p>Troubleshooting of the anomaly was performed at KSC. A visual inspection of the FES did not identify an obvious problem. The secondary high-load control sensor was checked at a single point and the results were satisfactory. A checkout of the controller also produced nominal results. A ramp test of the control sensor was performed. An approximate 2-second delay was observed between the secondary high-load control sensor and the primary A and Primary B midpoint sensors that are located in the same block. A determination of whether the sensor should be removed and replaced or repacked is pending.</p>

## **DOCUMENT SOURCES**

In an attempt to define the official as well as the unofficial sources of data for the STS-108 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-108 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.

ADVASCGC	Advanced Astroculture Growth Chamber
ADF	Avian Development Facility
A/G	Air-to-Ground
APCF	Advanced Protein Crystallization Facility
APCU	Assembly Power Converter Units
APU	auxiliary power unit
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
ATCS	active thermal control system
BCSS	Biotechnology Cell Science Stowage
BGA	beta gyro assembly
BITE	built-in test equipment
BSM	Booster Separation Motor
BSP	base-band signal processor
BTR	Biotechnology Refrigerator
CAPL	Capillary Pumped Loop Experiment
CBC	C-band controller
CBM	common berthing mechanism
CBTM	Commercial Biological Testing Module
CCTV	closed-circuit television
CEI	contract end item
CO <sub>2</sub>	carbon dioxide
COLA	collision avoidance maneuver
COLLIDE	Collision into Dust Experiment
CRV	crew return vehicle
CWC	contingency water container
DCPCG-V	dynamically controlled protein crystal growth-vapor
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
$\Delta V$	differential velocity
ECLSS	environmental control and life support system
e.s.t.	eastern standard time
EIU	engine interface unit
EMU	extravehicular mobility unit
EPDC	electrical power distribution and control
ET	External Tank
EVA	extravehicular activity
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
FOD	foreign object damage



FSS	Fixed Service Structure
ft/sec	feet per second
GAS	Get-Away Special
GFE	Government furnished equipment
GH <sub>2</sub>	gaseous hydrogen
G.m.t.	Greenwich mean time
GN <sub>2</sub>	gaseous nitrogen
GO <sub>2</sub>	gaseous oxygen
GPC	general purpose computer
GPS	Global Positioning System
GUCP	ground umbilical carrier plate
HDP	hold-down post
HGDS	hazardous gas detection system
HLS	Human Life Sciences
H-Reflex	Hoffman-Reflex
ICD	Interface Control Document
IMU	inertial measurement unit
INS	inertial navigation system
In/sec	inch per second
$I_{sp}$	specific impulse
ISS	International Space Station
JSC	Johnson Space Center
keas	knots estimated air speed
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt/hour
lbf	pound force
lbm	pound mass
lb/min	pound per minute
LCC	Launch Commit Criteria
LDB	launch data bus
LH <sub>2</sub>	liquid hydrogen
LiOH	lithium hydroxide
LMC	lightweight MPES carrier
LMSO	Lockheed Martin Space Operations
LO <sub>2</sub>	liquid oxygen
LON	launch on need
LP	Launch Package
LPS	Launch Processing System
MACH-1	Multiple Application Customized Hitchhiker-1
MADS	Modular Auxiliary Data System
MAGR-S	Miniature Air to Ground Receiver-Shuttle
Max $q\alpha$	maximum dynamic pressure
MC	midcourse correction (rendezvous maneuver)
MECO	main engine cutoff
MET	mission elapsed time
Micro-TAU	micro-wireless triaxial accelerometers
MLP	Mobile Launch Platform
Mlbf	million pounds force
MMT	Mission Management Team

mmHg	millimeter mercury
MPSS	Mission Peculiar Equipment Support Structure
MPLM	Multi-Purpose Logistics Module
MPS	main propulsion system
MSFC	Marshall Space Flight Center
N <sub>2</sub>	nitrogen
NASA	National Aeronautics and Space Administration
NC1, NC2	circularization maneuvers (rendezvous maneuver)
NC3, NC4	circularization maneuvers (rendezvous maneuver)
NEOM	nominal end of mission
nmi.	nautical mile
O <sub>2</sub>	oxygen
OAA	Orbiter Access Arm
ODS	Orbiter Docking System
OMDP	Orbiter Maintenance Down Period
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OPS	Operations
ORCA	oxygen recharge compressor assembly
ORU	Orbital Replacement Unit
OV	Orbiter Vehicle
PCG-STES	Protein Crystal Growth-Single Thermal Enclosure System
PCMMU	pulse code modulation master unit
PCS	pressure control system
PGME	Propylene Glycol Monomethyl Ether
PGSC	payload and general support computer
PMBT	propellant mean bulk temperature
ppCO <sub>2</sub>	partial pressure carbon dioxide
ppm	parts per million
PRSD	power reactant storage and distribution/Prototype Synchrotron Radiation Detector
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
RM	redundancy management
RMS	Remote Manipulator System
RSAD	robotic situational awareness display
RSP	Resupply Stowage Platforms
RSR	Resupply Return Stowage Rack
RSRM	Reusable Solid Rocket Motor
RSS	rotating service structure/range safety system
RTV	room temperature vulcanizing (material)
S&A	safe and arm
SEM	Space Experiment Module
SIGI	Space Integrated GPS/INS
SIMPLEX	Shuttle Ionospheric Modification with Pulsed Local Exhaust

SLWT	super lightweight tank
SM	systems management
S/N	serial number
SMFIV	single-mission fuel isolation valve
SODB	Shuttle Operational Data Book
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSER	Space-to-Space EVA Radio
SSME	Space Shuttle main engine
SSOR	Space-to-Space Orbiter Radio
STARSHINE	Student Tracked Atmospheric Research Satellite for Heuristic International Networking Experiment
STS	Space Transportation System
SUPA	Shuttle Urine Pretreat Assembly
SWAR	Sea water activated release
TCS	trajectory control sensor
TDRS	Tracking and Data Relay Satellite
TEA	torque equilibrium attitude
TPS	thermal protection system/subsystem
TSM	tail service mast
TVIS	Treadmill Vibration Isolation System
UF	Utilization Flight
V	Volts
WCS	waste collection system
WSB	water spray boiler
XPOP	X-axis perpendicular to the orbital plane (attitude)
+ZSI	+Z-axis solar inertial (attitude)