

STS-109 SPACE SHUTTLE MISSION REPORT

May 2002



**National Aeronautics and
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**Lyndon B. Johnson Space Center
Houston, Texas**

NOTE

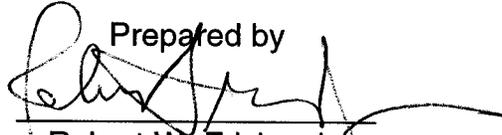
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STS-109
SPACE SHUTTLE

MISSION REPORT

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INTRODUCTION

The Space Transportation System (STS) -109 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 eighth mission of the Space Shuttle Program. The STS-109 flight was the fourth Hubble Space Telescope maintenance flight. STS-109 was the eighty-third mission since the return to flight, and the twenty-seventh flight of the OV-102 (Columbia) vehicle.

The flight vehicle consisted of the Orbiter vehicle (OV) -102 Orbiter; an ET, which was the fourteenth Super Lightweight Tank (SLWT), and it was designated ET-112; three Block IIA SSMEs that were designated as S/Ns 2056, 2053 and 2047 in positions 1, 2, and 3 respectively; and two SRBs that were designated B111. The two RSRMs were designated RSRM-83 with one installed in each SRB. The individual RSRM serial numbers were 360W083A for the left SRB and 360W083B for the right SRB.

The primary objective of this flight was to perform the operations necessary to fulfill the on-orbit servicing of the Hubble Space Telescope Servicing Mission 3B (HST SM3B). The main servicing tasks for this mission included the following EVA tasks: replacement of the Solar Array 2s (SA-2) with the Solar Array 3s (SA-3); replacement of the Power Control Unit (PCU); installation of the Advanced Camera for Surveys (ACS) and removal of the Faint Object Camera (FOC); and installation of the NICMOS Cooling System (NCS).

The STS-109 flight was planned as an 11 day, plus 2-contingency-day flight, of which six days were to be docked to the HST. The two contingency days were available for weather avoidance for landing or other Orbiter contingency operations. The sequence of mission events is shown in Table I, and the Orbiter In-Flight Anomaly List is shown in Table II.

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

The seven crewmembers that were on the STS-109 mission consisted of Scott D. Altman, CDR, U. S. Navy, Commander; Duane G. Carey, Lt. Col., U. S. Air Force, Pilot; John M. Grunsfeld, Ph. D., Civilian, Mission Specialist 1 and Payload Commander; Nancy J. Currie, Col., U. S. Army, Mission Specialist 2, Richard M. Linnehan, DVM, Civilian, Mission Specialist 3; James H. Newman, Ph. D., Civilian, Mission Specialist 4; and Michael J. Massimino, Ph. D, Civilian, Mission Specialist 5.

STS-109 was the fourth space flight for Mission Specialist 1 and Mission Specialist 4, the third space flight for the Commander and Mission Specialist 3, the second space flight for Mission Specialist 2, and the first space flight for the Pilot and Mission Specialist 5.

MISSION SUMMARY

The launch of the STS-109 mission was scheduled for February 28, 2002. However, acceptable weather conditions were not predicted and the launch was rescheduled for March 1, 2002. The temperature at the planned time of the first launch attempt was predicted to be below the acceptable level of 38 °F.

During the prelaunch External Tank (ET) liquid hydrogen (LH₂) pre-pressurization operation, the Space Shuttle main engine (SSME) 1 LH₂ ullage pressure transducer data were intermittently flat-lined. The SSME 1, 2 and 3 LH₂ ullage pressure transducers typically track each other as the pre-pressurization pulses maintain the LH₂ tank pressure within the control band. The SSME 1 transducer data were flat-lined for approximately 7 seconds at T-90 seconds and again for approximately 36 seconds starting at T-1 minute. At approximately T-24 seconds, the transducer output recovered and closely tracked the other two transducers throughout ascent. Through data review, it has been determined that this condition has been noted before and it is acceptable. The condition is explained by a stack-up of conditions specific to the unique transducer, mobile launch platform (MLP), and launch pad.

The countdown for the rescheduled launch on March 1, 2002, was flawless and resulted in a successful launch at 060:11:22.02.021 G.m.t. (6:22:02 a.m. e.s.t.). Orbiter systems performance during ascent was nominal.

Several seconds after main engine cutoff (MECO), the Freon coolant loop (FCL) 1 aft coldplate flow-rate decreased from 304 lb/hr to 226 lb/hr (Flight Problem STS-109-V-01). The FCL 1 interchanger flow and payload heat exchanger flow increased at the same time, which confirmed that a restriction was causing the reduction of flow in the aft coldplate branch. The Flight Rules state that the minimum acceptable flow-rate in the aft coldplate branch is 211 lb/hr actual, and 236 lb/hr when allowing for measurement uncertainty, for a one FCL entry. Analysis performed by the engineering team showed that despite the degraded flow, FCL 1 would be able to provide adequate cooling during entry in the event of a failure of FCL 2. The FCL 1 degraded aft cold-plate flow-rate remained stable throughout the mission.

The LH₂ engine 1 pre valve (PV) 4 open-position indicator A failed off approximately 14 minutes after the liquid hydrogen (LH₂) pre valves were opened for the LH₂ dump. The indication went off at 060:11:46 G.m.t. (00:00:24 MET) and remained off for 2 hours and 43 minutes, and then recovered to the expected on-state at 060:14:29 G.m.t. (00:03:07 MET). The PV4 closed indication and open indicator B were in their proper state during the entire time period. The pre valves remained in the open position for the remainder of the mission and this failure did not affect main propulsion system (MPS) on-orbit or entry operations.

Review of valve-timing data determined that the MPS LH₂ 4-inch recirculation-line disconnect hardware was slow to close when commanded at MECO (Flight Problem STS-109-V-03). The requirement is a maximum of 2.8 seconds from signal-to-switch (close power on to close indication on). The actual signal-to-switch time for the disconnection was 13.79 seconds. The disconnect-open indication was lost approximately 0.5 second after the loss of open power indicating partial movement of the disconnecting hardware. The close-indication on coincided with the ET/Orbiter umbilical retract implying a back-up mechanical closure. The 4-inch recirculation disconnect

hardware is not operated after closure at MECO, and this slow response had no mission impact.

The orbital maneuvering subsystem (OMS) 2 maneuver, performed with both OMS engines, was initiated at 060:12:05:59 G.m.t. (00:00:43:57 MET) and was 87.6 seconds in duration. The differential velocity (ΔV) imparted was 134 ft/sec, and the resultant orbit was 310.4 by 105.2 nautical miles (nmi.) following the maneuver. The OMS performed satisfactorily throughout the maneuver.

The payload bay doors were opened at 060:13:21:18 G.m.t. (00:01:59:16 MET). All voltages were nominal and the motors opened the doors in nominal dual-motor time.

On flight day (FD) 1, when the crew attempted to open the internal airlock hatch, or "A" hatch, they reported that it was difficult to move the hatch actuator-locking tab out of the locked position, and therefore the hatch could not be unlatched (Flight Problem STS-109-V-02). While "jiggling" the actuator handle, they were able to move it axially, or away from the actuator. When they pressed it back against the actuator, they were able to move the locking lever and unlatch the hatch. While this actuator handle is designed to be removable, it is to be fully seated for both the hatch latching and unlatching operations and should not have the looseness that was reported. For the duration of the flight, the crew left the "A" hatch actuator unlocked. A closeout technician had noted a similar condition prior to launch.

At 061:05:12:58 G.m.t (00:17:50:56 MET), channel C on the forward translational hand controller (THC) turned off earlier than expected during the -X NC-2 firing (Flight Problem STS-109-V-04). The problem did not repeat in subsequent -X pulses. The switch inside the THC is a snap-action rotary device using magnets and Hall-effect sensors to ensure simultaneous activation and deactivation of all three discrete channels. According to the manufacturer, it is impossible for one sensor to turn off by itself without a fault in the sensor, the signal path from the sensor to the multiplexer/demultiplexer (MDM), or momentary loss of power to the THC. There was no mission impact.

Following the NC-3 maneuver, the left OMS quantity gages started to exhibit abnormal behavior, eventually failing to zero. The left OMS fuel and oxidizer total and aft quantity indications experienced a sudden downward shift at approximately 061:14:35 G.m.t. (01:03:13 MET) followed approximately 99 seconds later by another downward shift. About 5 minutes and 40 seconds after the latter occurrence, the fuel and oxidizer total and aft quantity indications failed off-scale low. Analysis of the failure signature indicates a probable failure in the power-supply circuitry of the OMS quantity totalizer. The OMS gaging function is criticality 3/3 and the failure did not impact the mission.

At approximately 061:03:22 G.m.t. (00:16:00 MET), the auxiliary power unit (APU) 3 fuel-pump seal-cavity drain line pressure began to slowly decay (approximately 1.1 psi/day). It was determined that helium was left in the drain line following a preflight leak check. It is believed that the helium was permeating the Teflon in the flex-hose, thus accounting for the pressure decay. There was no mission impact. A revision of ground procedures to ensure a nitrogen purge is performed following the helium leak check is in work.

During remote manipulator system (RMS) checkout on FD 2, when the crew commanded the wrist yaw joint during the direct-drive (DD) test; a DD built-in test equipment (BITE) was annunciated. It is believed that this BITE is a nuisance alarm that was caused by a timing issue when DD switch contacts are opened/closed, that is, when the switch is actuated. In some conditions, if the switch status contact is open when the enable and

command contacts are closed, the DD BITE will be annunciated. DD is a contingency mode of operation, thus, there was no impact to nominal RMS operations.

The following table lists the pertinent data for each of the rendezvous maneuvers.

HST RENDEZVOUS AND SEPARATION MANEUVERS

Maneuver	Time, G.m.t./MET	ΔV , ft/sec	Firing time, sec	Orbit, nmi.
NC1A (OMS 3) (Right engine)	060:16:43:49 00:05:21:47	10.3	13.8	110.9 by 310.6
NC2 (-X RCS)	061:05:12:52 00:17:50:50	4.5	19.7	112.1 by 310.4
NC3 (Multi-axis RCS)	061:14:17:34 01:02:55:32	3.1	12.6	113.7 by 310.4
NH (OMS 4) (Dual Engine)	062:04:07:30 01:16:45:28	326.6	207	302.9 by 312.2
NC4 (Multi-axis RCS)	062:05:09:03 01:17:47:01	4.8	20.4	302.4 BY 309.3
NCC (Multi-axis RCS)	062:06:00:59 01:18:38:57	1.3	5.5	302.3 by 309.2
TI (OMS 5) (Left engine)	062:07:01:05 01:19; 39:03	8.4	10.8	303.5 BY 313.5
MC-1 (Multi-axis RCS)	062:07:21:06 01:19:59:04	0.8	3.2	303.6 by 313.5
Out of Plane Null (Multi-axis RCS)	062:07:33:51 01:20:11:49	N/A	0	No change
MC-2 (Multi-axis RCS)	062:07:56:29 01:20:34:27	0.4	1.79	303.4 by 313.5
MC-3 (+X RCS)	062:08:13:28 01:20:51:26	1.9	8.1	303.4 by 313.8
MC-4 (Multi-Axis RCS)	062:08:23:29 01:21:01:28	1.9	8.1	303.4 by 314.8
HST Separation (RCS)	068:10:05:08 07:22:43:06	1.2	Ten 0.48-second pulses	-
HST Separation (RCS)	068:10:37:16 07:23:15:14	2.5	10.24	309.4 by 314.6

The RMS was powered and uncradled at 062:06:08 G.m.t. (01:17:46 MET), and the Hubble Space Telescope (HST) was captured at 062:09:31:21 G.m.t. (01:22:09:19 MET). The HST was successfully berthed in the flight support structure (FSS) at 062:10:31 G.m.t. (01:23:10 MET). The RMS was then used to perform a video survey of the HST using the wrist camera.

The first extravehicular activity (EVA) was initiated at 063:06:37 G.m.t. (02:19:15 MET) to begin servicing of the HST. Extravehicular mobility unit (EMU) 1 did not send EMU data scans through the real-time data system (RTDS) at the expected 2-minute intervals. These data are typically sent by interrupting the EMU biomedical signal every two minutes. As a result, the EV1 crewmember provided Mission Control with verbal data from the EMU every hour. The EVA ended at 063:13:38 G.m.t. (03:02:16 MET) for a total EVA time of 7 hours and 1 minute. All planned tasks were completed. The EVA lasted about 30 minutes longer than planned; however, this delay in completing the EVA

had no impact on the mission. After the completion of the EVA, the RTDS power was cycled and satisfactory data were obtained from the EMU.

The fuel cell 3 alternate product-water line temperatures indicated a slight leak past the check valve. As a precaution, the supply water system was reconfigured to preclude water from the alternate line being used for the EMU recharges. Tanks C and D were isolated from tanks A and B. Tank B, used for EMU recharges, was dumped and then refilled with water from tank A, which did not contain hydrogen.

At 062:06:09 G.m.t. (01:18:47 MET), the crew reported what they called a multifunction electronic display system (MEDS) anomaly. While performing the RMS power-up, three expected messages were annunciated. When the crew pressed the aft keyboard message-reset key, the text portion of the message line cleared, but the time tag associated with the message did not clear. Pressing the message-reset key a second time cleared the time tag. A note in the Level A software requirements explains that this can occur due to software timing in certain situations.

The S-band system experienced more-frequent-than-expected dropouts on the forward and return links throughout the mission. The problem was seen on multiple antennas as well as Tracking and Data Relay Satellites (TDRS). As is typical, the mission was started on string 2. At approximately 062:16:07 G.m.t. (02:02:45 MET), the S-band system was switched to string 1. Dropouts were also observed on string 1. Data review indicated that the S-band dropouts have a variety of causes. These include Mission Control Center (MCC)/network data errors, Orbiter antenna look-angles to the TDRS, false lock, radio frequency (RF) "multipath" regions, the known interruption potential during antenna switching, short occasional radio frequency interference (RFI), and HST-rendezvous RFI (seen on other HST missions). No apparent on-board S-band system failure was identified.

The crew reported that when switching between the RMS wrist and elbow cameras on FD 3, the newly powered camera would come up with the video scene present, instead of with the iris closed as expected. The RMS camera problem was better characterized after receiving answers to questions sent to the crew. It was initially thought that when switching between the RMS wrist and elbow cameras, the newly powered camera would come up with the video scene present, instead of with the iris closed as expected. It was determined that when switching from the wrist to the elbow camera, the elbow camera performed nominally. However, when switching from the elbow to the wrist camera, the wrist camera came up with its iris open. The iris in the wrist camera did not close when the camera power was off. The problem occurred each time the wrist camera was selected. The crew was instructed to manually close the iris prior to powering the wrist camera down.

The second EVA was completed in 7 hours and 16 minutes. The crew completed all of their scheduled tasks plus several get-ahead tasks. The major tasks were the change-out of the +V2 solar array and the replacement of the reaction wheel assembly. The RMS performed nominally in support of the EVA.

During the second EVA, the biomedical data from EMU 2 was lost for about 77 minutes. During the third EVA, biomedical data from EMU 3 behaved erratically for several minutes then dropped out completely. Additional biomedical data dropouts were seen during the fourth EVA from EMUs 3 and 4. The biomedical data dropouts are most likely due to one of the sternal harness pads separating from the crewman's chest. This was the first flight of the sternal harness with the disposable electrodes. The disposable

electrodes are peel-and-stick similar to a Band-Aid. The anomalous data were similar to disconnected electrodes with the old system. This condition did not impact the EVAs.

During preparations for the third EVA, anomalous indications were seen on EMU 1 and it was discovered that water had leaked into the primary life support system (PLSS). The investigation into the source of the water revealed that a voltage spike from the power supply and battery charger resulted in the feedwater shutoff valve inadvertently opening (Flight Problem STS-109-V-07). As a result of the leak, the hard upper torso (HUT) for EMU 3 was re-sized for the extravehicular (EV) 1 crewman so the planned EVA could proceed. Also as a result, the EVA was initiated approximately 2 hours late at 065:08:28 G.m.t. (04:21:06 MET). The third extravehicular activity ended at 065:15:16 G.m.t. (05:03:54 MET) and had a duration of 6 hours 48 minutes. The primary activity for the crew during this EVA was the replacement of the power control unit (PCU), and this was completed satisfactorily.

Review of the data for the OMS crossfeed lines indicated an off-nominal response from the temperature sensors in heater zones 1 and 2. The heaters in zones 3 and 4 strongly influenced the response of the temperature sensors in zones 1 and 2, respectively. The most likely cause is that the zone 1 and 2 sensors are in a location that does not provide the optimum indication for zone 1 and 2 thermal performance. Closeout photographs indicate that the temperature sensor for zone 2 is not in the desired location. A photograph could not provide validation of the location of temperature sensor for zone 1, and based on the flight data, it is suspected that its location is also undesirable. A postflight inspection will be performed, and if needed, the sensors and or thermostats will be relocated to more desirable locations.

The fourth EVA for the HST was initiated at 066:09:00 G.m.t. (05:21:38 MET) and progressed nominally during the 7-hour and 30-minute EVA. The primary objectives of the EVA were the replacement of the Faint Object Camera (FOC) with the new Advanced Camera for Surveys (ACS), installation of an Electronics Support Module (ESM) and performance of some remaining Power Control Unit (PCU) cleanup tasks. The fourth EVA was completed at 66:16:30 G.m.t. (06:06:05 MET).

The fifth EVA for the HST was initiated at 067:08:46 G.m.t. (06:21:24 MET) and ended after 7 hours 21 minutes with all planned activities completed. The primary objectives to install the Near-Infrared Camera and Multi-Object Spectrometer (NICMOS) Cryogenic Cooler and NICMOS Cooling System Radiator were completed successfully. With the completion of the fifth EVA, a total of 35 hours 56 minutes were spent during the mission in EVA activities, and the total man-hours in space for this mission was 71 hours 56 minutes.

To support troubleshooting of the BITE annunciation observed during the direct-drive test portion of the RMS checkout on FD 2, the RMS was positioned in the extended park position to perform a single-drive test. A sequence of ten positive and negative single drive commands of the wrist yaw joint were executed to obtain engineering data on the performance of the single/direct-drive switch. The anomaly noted earlier in the mission did not recur.

The HST reboost session was started at 067:17:18:04 G.m.t (07:05:56:02 MET) when primary reaction control subsystem (RCS) thrusters F5L, F5R, L5D, and R5D were fired. The session lasted nearly 36 minutes. There was no predefined duty cycle and the thrusters were turned off as necessary to maintain attitude within the 5-degree deadband. The reboost delivered a ΔV of 11.8 ft/sec, resulting in an overall average

altitude increase of 3.6 nmi for a final orbit of 314.7 by 310.6 nmi. The RCS performed satisfactorily throughout the maneuver.

The RMS grappled the HST at 068:07:08 G.m.t. (07:19:46 MET) in preparation for deploying the HST. During grapple, the digital readout of the RMS wrist camera horizontal field of view (HFOV) was drifting approximately 3.5 degrees in both directions. The downlink of the camera video also indicated that the zoom telemetry appeared to be drifting. The crew power-cycled the camera but the problem did not clear. Although the HST grapple was successful, the inability to determine the actual HFOV impacted the grapple accuracy.

The HST was unberthed from the Orbiter at 068:08:34 G.m.t. (07:21:12 MET) and released at 068:10:04 G.m.t. (07:22:42 MET).

Following the release of the HST, two RCS separation maneuvers were performed. The RCS performed satisfactorily, and the orbit after the two maneuvers was 309.4 by 314.6 nmi. Parameters for the two maneuvers are presented in the maneuver table shown on page 4 of this report.

The OMS dual-engine orbit-adjust maneuver was performed at 068:12:01:02 G.m.t. (08:00:39:46 MET). The maneuver was 45.4 seconds in duration, and the ΔV delivered was 74.8 ft/sec. The vehicle was placed in an orbit of 266.4 by 312.3 nmi. The OMS performed satisfactorily throughout the maneuver.

At approximately 069:02:37 G.m.t. (008:15:15 MET), the flash evaporator system (FES) accumulator/high-load feedline B (starboard) heater system 2 failed (Flight Problem STS-109-V-05). The thermostat is located on the accumulator line and the temperature sensor, also on the accumulator line, had been indicating the heater turning on at approximately 66 °F. When the accumulator line temperature dropped to 50 °F, the crew switched to heater system 1, which performed nominally for the remainder of the mission. A postflight checkout and repair of the heater will be performed during the turnaround activities.

The flight control subsystem (FCS) checkout was performed using auxiliary power unit (APU) 1 to support the checkout with an APU start time of 070:07:13 G.m.t. (09:19:51 MET). The run time was 5 minutes, 34 seconds, and 16 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. The hot-fire began at 070:08:14:35 G.m.t. (09:20:52:33 MET) and ended at 070:08:22:03 G.m.t. (09:21:00:01 MET). During the RCS hot-fire, primary RCS thruster R3R failed off when first commanded to fire and was auto-deselected by the RCS redundancy management (RM) (Flight Problem STS-109-V-06 MET). The reaction jet driver (RJD) output was nominal, however, the chamber pressure reached only 11 psia prior to the thruster being deselected. The thruster did not leak propellant following the failure. The thruster-injector temperatures and chamber pressure suggest a problem with a thruster pilot-operated valve. The thruster remained deselected for the duration of the flight, and no flight impact occurred. Each of the remaining primary thruster firings was satisfactory.

An orbit-adjust maneuver that used the -X primary RCS thrusters was performed at 070:10:07:32.3 G.m.t. (09:22:45:30.3). The maneuver was 48.3 seconds in duration, and

the ΔV delivered was 11.6 ft/sec. The vehicle was placed in an orbit of 259 by 312.5 nmi.

The payload bay doors were closed and latched for the first KSC landing opportunity at 071:05:54 G.m.t. (10:18:32 MET). All payload bay door close and latch operations occurred in dual motor time.

During deorbit preparations when the right vent door 3 was closed at 071:07:57:38 G.m.t. (010:20:35:36 MET), the close 1 microswitch initially indicated closed. Approximately 4.5 seconds later, the microswitch transferred off where it remained for 4 minutes and 43 seconds. Following that period, the microswitch transferred back on and remained in that position. The data indicate that the door closed nominally in dual motor time. The door close 1 indication was also momentarily lost during door-closure after landing. Similar behavior occurred on the previous flight of this vehicle (STS-93).

The deorbit maneuver for the first KSC landing opportunity, a two-engine straight-feed firing, was performed on orbit 165 at 071:08:22:39.365 G.m.t. (10:21:04:42.344 MET). The maneuver was 244.80 seconds in duration with a ΔV of 418.3 ft/sec.

Entry interface occurred at 071:09:00:52 G.m.t. (10:21:38:50 MET), and entry was completed satisfactorily. Main landing gear touchdown occurred on KSC concrete runway 33 at 071:09:31:53 G.m.t. (10:22:09:51 MET) on March 12, 2002. The drag chute was deployed at 071:09:31:55 G.m.t. The nose gear touchdown occurred at approximately 071:09:32:04 G.m.t. The drag chute was jettisoned at 071:09:32:37 G.m.t. Wheels stop occurred at 071:09:33:05 G.m.t. The rollout was normal in all respects. The flight duration was 10 days 22 hours 09 minutes 51 seconds. The APUs were shut down approximately 20 minutes after landing.

PAYLOADS

HUBBLE SPACE TELESCOPE

Summary

The STS-109 mission was the fourth servicing mission to the Hubble Space Telescope (HST). A successful rendezvous was completed on flight day 3 as planned. All mission objectives were accomplished during the performance of the five extravehicular activities (EVAs).

Mission Operations

On the first EVA, the Solar Array 2 was replaced with a Solar Array 3, and the Diode Box Controller was also replaced. On EVA 2, the other Solar Array and Diode Box Controller were replaced, as well as replacement of one new outer blanket layer. On EVA 3, the Power Control Unit was replaced, and this task represented one of the most difficult tasks ever performed during an EVA. On EVA 4, the European Space Agency (ESA) Faint Object Camera was replaced with the Advanced Camera for Surveys. On EVA 5, the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) Cryogenic Cooler System were installed.

After the Orbiter completed a reboost of the HST that raised the orbital parameters 3.6 nautical miles, the HST was released and is in an orbit of 314.7 by 310.6 nmi. The latest report received on the HST status at the time of this writing was that the HST checkout is progressing nominally with no significant problems noted.

VEHICLE PERFORMANCE

SOLID ROCKET BOOSTERS

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

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

Both SRBs were recovered and returned to KSC for inspection, disassembly and refurbishment. The inspection revealed that both SRBs were in excellent condition. No anomalous SRB conditions were noted during the postflight operations. The right-hand SRB top/left position forward booster separation motor (BSM) cover was missing. Preliminary examination of the fracture plane revealed no sooting effects, thus indicating that the damage most probably occurred at water impact.

There were failed resistors in the Orbiter and SRB signal conditioning hardware that are from a suspect lot. Testing showed that the failures were an isolated event.

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. No in-flight anomalies have been identified from the data evaluation. The prelaunch countdown was normal and no RSRM LCC or OMRSD violations occurred.

All RSRM temperatures were maintained within acceptable limits throughout the countdown. The maximum in-flight trace shape variation of pressure versus time during the 62- to 80-second time frame was calculated to be 0.919 percent at 76.0 seconds and 1.305 percent at 67.5 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 52 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 66 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 18 hours 14 minutes during the final launch countdown and 22 hours 30 minutes during the three launch countdowns. Power was applied to the heating elements 93 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 nine times during the time of recorded data and lasted for a total of 32 hours and 49 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 78 °F to 85 °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 64 °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 0.3675 and 0.3683 in/sec for the left and right motors, respectively.

MOTOR PERFORMANCE PARAMETERS

Parameter	CEI Specification Limit (60 °F)	Left Motor Delivered	Right Motor Delivered
Web time, seconds	105.4 – 116.7	111.1	110.8
Action time, seconds	115.2 – 131.2	123.5	123.1
Head end pressure, psia	847.9 – 965.7	902.3	907.6
Maximum sea level thrust, Mlbf	2.88 – 3.26	3.06	3.08
Web time average pressure, psia	629.9 – 700.5	664.3	668.7
Web time average vacuum thrust, Mlbf	2.46 – 2.74	2.60	2.62
Web time total impulse, Mlbf sec	285.8 – 291.6	289.0	290.0
Action time impulse, Mlbf seconds	293.7 – 299.7	297.0	297.7
ISP average delivered, lbf sec/lbm	266.5 – 270.3	268.8	269.4
Loaded propellant weight, lbm	>1103750	1105730	1105494

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

EXTERNAL TANK

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

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

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

ET separation was confirmed. The postflight analysis of the impact point showed the ET impact to be 78 nautical miles uprange from the preflight predicted impact point.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 74 °F		Right motor, 74 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10 ⁶ lbf-sec	64.25	64.48	64.03	64.87
I-60, 10 ⁶ lbf-sec	172.55	173.60	172.06	174.57
I-AT, 10 ⁶ lbf-sec	296.84	297.21	296.78	297.91
Vacuum Isp, lbf-sec/lbm	268.5	268.8	268.5	269.5
Burn rate, in/sec @ 60 °F At 625 psia	0.3667	0.3675	0.3660	0.3683
Event times, seconds ^a				
Ignition interval	0.232	N/A	0.232	N/A
Web time ^b	111.0	110.7	111.3	110.3
50 psia cue time	121.2	120.7	121.5	120.4
Action time ^b	123.4	123.0	123.8	122.6
Separation command	126.0	-	126.0	-
PMBT, °F	64	64	64	64
Maximum ignition rise rate, psia/10 ms	90.8	N/A	90.8	N/A
Decay time, seconds (59.4 psia to 85 K)	3.2	3.3	3.21	3.1
Tailoff Imbalance Impulse Differential	Predicted N/A		Actual 802.9	

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

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

^bReferenced to liftoff time (ignition interval).

SPACE SHUTTLE MAIN ENGINES

Prelaunch operations of the Space Shuttle main engines (SSMEs) were smooth with no LCC or OMSRD violations noted. The ignition confirm limits and mainstage redline margins were satisfactory. All Interface Control Document (ICD) start and shutdown transient requirements were met. Engine performance during start, mainstage, and shutdown was nominal and as predicted. Engine cutoff times were 509.85, 509.95, and 510.08 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 453.3 seconds, which was 1.4 seconds higher than predicted. 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) throttle-down was a two-step throttle-down to 72 percent.

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 System

The main propulsion subsystem (MPS) performed satisfactorily. No LCC violations were noted during the loading, and one in-flight anomaly was identified from the analysis of the data. 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.

During the prelaunch External Tank (ET) LH₂ pre-pressurization operation, the Space Shuttle main engine (SSME) 1 LH₂ ullage pressure transducer data exhibited unusual behavior by not tracking the pre-pressurization pulses during significant portions of the pre-pressurization time frame. The SSME 1, 2 and 3 liquid hydrogen (LH₂) ullage pressure transducers typically track each other as the pre-pressurization pulses maintain the LH₂ tank pressure within the control band. The SSME 1 transducer data were flat-lined for approximately 7 seconds at T-90 seconds and again for approximately 36 seconds starting at T-1 minute. At approximately T-24 seconds, the transducer output recovered and closely tracked the other two transducers throughout ascent. This condition has been noted previously, is acceptable, and is fully explained by the transducer design and the lower-than-typical flow rate on the mobile launch platform 2 (MLP 2). The flow rate on MLP 2 is noticeably lower than the other two MLPs, but still within specification. This condition has been tracked and accepted by the ground support equipment (GSE) and MPS communities prior to STS-109. The lower flow-rate results in a smaller than typical rise in the ET ullage pressure when the pulse is applied. The transducer is made up of a coil with a wiper mechanism that moves along the coils as the ullage pressure rises or falls. This design results in the transducer having discrete bit toggles that will vary slightly depending on the number of wire coils in the coil. The lower-than-normal ullage pressure rise resulted in the ullage pressure not rising enough to trigger the SSME 1 transducer to its next bit toggle during the pre-pressurization pulse. This condition had no mission effect and is not considered a discrepant condition by the ET Project or the Integration community.

Review of valve-timing data determined that the MPS LH₂ 4-inch recirculation-line disconnection failed to close when commanded at MECO (Flight Problem STS-109-V-03). The requirement is a maximum of 2.8 seconds from signal-to-switch (close power on to close indication on). The actual signal-to-switch time for the disconnection was 13.79 seconds. The disconnect-open indication was lost approximately 0.5 second after the loss of open power indicating partial movement of the disconnection hardware. The close-indication on coincided with the ET/Orbiter umbilical retract implying a back-up mechanical closure after stalling at some intermediate point between open and closed. The LH₂ umbilical 16mm film was reviewed to check the post-separation condition of the ET half. The ET LH₂ umbilical was in the vehicle's shadow, but it was apparent that the ET half of the 4-inch recirculation disconnect had closed completely, and that there was no sign of venting or excessive ice build-up on the ET/Orbiter interface. Inspections and troubleshooting of the portion of the disconnect hardware that remains with the Orbiter will be performed. This condition had no effect on the mission operations.

The LH₂ engine 1 prevalve (PV) 4 open-position indicator A failed off at 160:11:46:52 G.m.t. (00:00:24:50 MET), and remained off for 2 hours and 40 minutes. The indication then recovered to the expected on-state at 060:14:29:33 G.m.t. (00:03:07:31 MET), approximately 14 minutes after the liquid hydrogen (LH₂) prevalves were opened for the LH₂ dump. The PV4 closed indication and open indicator B were in their proper state during the entire time period. The prevalves remained in the open position for the remainder of the mission and this failure did not affect main propulsion system (MPS) on-orbit or entry operations. The suspect measurement is an LCC critical measurement with 1 of 2 LH₂ pre valve open indications (A and B) on required for SSME start. However, this indication is not critical for a failure to the off state or for the remainder of the mission. Postflight troubleshooting will check out the position switch circuit to determine if any indication exists that could lead to the loss of the position indication.

STS-109 was the first official flight that used the new hazardous gas detection system (HGDS) Haz Gas 2000. The maximum hydrogen concentration level in the Orbiter aft compartment, with the normally elevated system backpressure used for the fast-fill operations, was 242 parts per million (ppm). This compares favorably with previous data from this vehicle.

The LH₂ 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 LH₂ load at the end of replenish was 231,669 lbm. This assessment shows that the loading was well within the MPS loading accuracy requirements.

Based on the analysis of the oxygen load at the end of replenish 1,383,130 lbm. This assessment showed that the loading was well within the required MPS loading accuracy

At the start of loading, the background Helium concentration in the aft compartment was higher than normal for this vehicle. The concentration started at approximately 8900 ppm and continued upward to over 11,600 ppm. The concentration remained high for approximately 30 minutes and then decreased to approximately 7,226 ppm.

Starting at about T-3 hours, the hydrogen umbilical mass spectrometer (HUMS) indicated higher than normal helium concentrations in the midbody (normally no helium is detected). After discussions and analysis, a decision was made that the quick-disconnect (QD) for the midbody sample line was probably leaking and pulling helium from the T-0 umbilical purge.

The overall gaseous hydrogen (GH₂) system performance during the ascent phase was nominal. All three flow-control valves (FCVs) performed nominally.

The gaseous oxygen (GO₂) fixed orifice pressurization system performed as predicted. Reconstructed data from engine and MPS parameters closely matched the actual ET ullage pressure measurements. Helium system performance for the SSMEs and pneumatic Helium systems was also nominal. Entry Helium usage was 58.4 lbm, which is well within the allowable requirements.

Preliminary data indicate that the LO₂ and LH₂ pressurization systems performed as planned. Engine inlet net suction pressure was met throughout the flight.

Reaction Control Subsystem

The reaction control subsystem (RCS) performed acceptably throughout the mission. A total of 16 maneuvers, which included one 36-minute reboost period that raised the altitude of the HST approximately 3.6 nautical miles (nmi.), were completed satisfactorily. One in-flight anomaly was identified during the mission and it is discussed later in this section of the report. This anomaly did not impact the successful completion of the planned mission.

A total of 4735.5 lbm of RCS propellants (2930.3 lbm - oxidizer, 1805.2 lbm - fuel) were consumed during the mission. No orbital maneuvering subsystem (OMS) propellants were used by the RCS during the mission. The primary RCS thrusters had 2708 firings and a total firing time of approximately 1087.70 seconds. The vernier RCS thrusters had 17,306 firings and a total firing time of 18,506.4 seconds.

The RCS window protect maneuver was initiated at 060:11:24:06.4 G.m.t. (00:00:02:04 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.

The HST reboost session was started at 067:17:18:03.8 G.m.t (07:05:56:01.8 MET) when primary RCS thrusters F5L, F5R, L5D, and R5D were fired. The session lasted nearly 36 minutes. There was no predefined duty cycle and the thrusters were turned off as necessary to maintain attitude within the 5-degree deadband. The reboost delivered a differential velocity (ΔV) of 11.8 ft/sec, resulting in an overall average altitude increase of 3.6 nmi. for a final orbit of 314.7 by 310.6 nmi. The RCS performed satisfactorily throughout the maneuver.

During the RCS hot-fire, primary RCS thruster R3R failed off when first commanded to fire and the RCS redundancy management (RM) deselected the thruster (Flight Problem STS-109-V-06). The reaction jet driver output was nominal, however, the chamber pressure reached only 11 psia prior to the thruster being deselected. The thruster did not lead propellant following the fail-off. The thruster injector temperatures and chamber pressure suggest a problem with a thruster pilot-operated valve. The thruster remained deselected for the remainder of the flight. All thrusters on this manifold will be removed and sent to White Sands Test Facility (WSTF) for valve-response tests.

The table on the following page shows all of the significant RCS maneuvers and the pertinent data for each maneuver.

RCS RENDEZVOUS AND SEPARATION MANEUVERS

Maneuver	Time, G.m.t./MET	ΔV , ft/sec	Firing time, sec	Orbit, nmi.
ET Photography	060:11:30:55.5 000:00:08:53.5	N/A	10.2	N/A
NC2 (-X RCS)	061:05:12:52.6 000:17:50:50.5	4.5	19.7	112.1 by 310.4
NC3 (Multi-axis RCS)	061:14:17:34 01:02:55:32	3.1	12.6	113.7 by 310.4
NC4 (Multi-axis RCS)	062:05:09:03 01:17:47:01	4.8	20.4	302.4 BY 309.3
NCC (Multi-axis RCS)	062:06:00:59 01:18:38:57	1.3	5.5	302.3 by 309.2
MC-1 (Multi-axis RCS)	062:07:21:06 01:19:59:04	0.8	3.2	303.6 by 313.5
Out of Plane Null (Multi-axis RCS)	062:07:33:51 01:20:11:49	N/A	0	No change
MC-2 (Multi-axis RCS)	062:07:56:29 01:20:34:27	0.4	1.79	303.4 by 313.5
MC-3 (+X RCS)	062:08:13:28 01:20:51:26	1.9	8.1	303.4 by 313.8
MC-4 (Multi-Axis RCS)	062:08:23:29 01:21:01:28	1.9	8.1	303.4 by 314.8
HST Capture	062:09:31:21 001:21:09:19	N/A	N/A	N/A
HST Reboost	067:17:18:03 007:05:56:01	Discussed	In a previous	Paragraph
HST Separation (RCS)	068:10:05:08 07:22:43:06	1.2	Ten 0.48-second Pulses (4.8 sec)	N/A
HST Separation (RCS)	068:10:37:16 07:23:15:14	2.5	10.24	309.4 by 314.6
Orbit Adjust -2	070:10:07:32 009:23:45:30	11.6	48.3	N/A

Orbital Maneuvering Subsystem

The OMS performed satisfactorily throughout the mission. A total of seven maneuvers were performed during the mission. Two problems of concern are discussed in later paragraphs.

A total of 23,204 lbm (14,476 lbm - oxidizer and 8728 lbm - fuel) of OMS propellants were consumed during the mission. No interconnect operations were made with the RCS.

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

OMS MANEUVERS

Maneuver	Time, G.m.t./MET	ΔV , ft/sec	Firing time, sec	Orbit, nmi.
OMS 2 (Dual engine)	060:12:05:59 000:00:43:57	134.0	87.6	310.4 by 105.2
NC1A (OMS 3) (Right engine)	060:16:43:49 00:05:21:47	10.3	13.8	110.9 by 310.6
NH (OMS 4) (Dual engine)	062:04:07:30 01:16:45:28	326.6	207	302.9 by 312.2
TI (OMS 5) (Left engine)	062:07:01:05 01:19: 39:03	8.4	10.8	303.5 BY 313.5
OMS 6 (Dual engine)	068:12:01:02 008:00:39:00	74.8	45.4	259.0 by 312..5
Deorbit (Dual engine)	071:08:22:39 010:21:00:37	418.3	244.8	

Following the NC-3 maneuver, the left OMS quantity gages began exhibiting abnormal behavior, eventually failing to zero. The left OMS fuel and oxidizer total and aft quantity indications experienced a sudden downward shift at approximately 061:14:35:19 G.m.t. (01:03:13:17 MET) followed approximately 99 seconds later by another downward shift. About 5 minutes and 40 seconds after the latter occurrence, the fuel and oxidizer total and aft quantity indications failed off-scale low. Analysis of the failure signature indicates a probable failure in the power-supply circuitry of the OMS quantity totalizer. The OMS gaging function is criticality 3/3 and the failure did not impact the mission.

Review of the data for the OMS crossfeed lines indicated an off-nominal response from the temperature sensors in heater zones 1 and 2. The heaters in zones 3 and 4 strongly influenced the response of the temperature sensors in zones 1 and 2, respectively. Examination of the drawings revealed that the temperature sensors within the "doghouse" were mounted 1-inch \pm 1.5 inches from the flange, as opposed to as far away from the flange as possible. Also with the removal of the 2.5-inch crossfeed line and its replacement with a 1.5-inch crossfeed line this past Orbiter Maintenance Down Period (OMDP) flow, the heater system was removed and reinstalled. When the heater was reinstalled, the change to the crossfeed line diameter resulted in the OV-102 vehicle having a greater density of heater wire at the end of the crossfeed line (where the line exits the aft fuselage and enters the doghouse). This diameter difference resulted in this vehicle having 33 percent more heater wire than the rest of the fleet. In addition, a review of preflight photographs indicated that the sensor was not located in accordance with the drawing (sensor to be 0.25 inch from the thermostat). There had been a requirement on the drawing that had been deleted. Engineering will re-engineer this heater and sensor installation, and KSC will perform the re-installation.

Power Reactant Storage and Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem performance was nominal throughout the STS-109 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 2659 lbm of oxygen and 335 lbm of hydrogen for the production of 3858 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 14.7 kW. A 76-hour mission extension was possible at the average power level with the reactants remaining at landing, and at extension day power level of 12.1 kW, a 92-hour mission extension was possible.

PRSD tanks 4 and 5 were depleted to residual quantities during the mission. The Orbiter landed with 1079 lbm of oxygen and 118 pounds of hydrogen remaining.

A 28-ppm oxygen indication, which is above-the-allowable baseline, was detected by the hazardous gas detection system (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 similar indication has been observed on previous HST missions.

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 14.7 kW and 481 amperes. The fuel cells produced 2994 lbm of potable water and 3858 kWh of electrical energy while using 2659 lbm of oxygen and 335 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 0.1 V above the predicted for fuel cell 1, 0.15V above predicted for fuel cell 2, and 0.2 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, 0.9 V for fuel cell 2, and 1.1 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 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.

The fuel cell 3 alternate product-water line temperatures indicate a slight leak past the check valve. As a precaution, the supply water system was reconfigured to preclude water from the alternate line being used for the EMU recharges. Tanks C and D were isolated from tanks A and B. Tank B, used for EMU recharges, was dumped and then refilled with water from tank A, which did not contain hydrogen.

At 066:10:29 G.m.t. (05:23:07 MET), a 6-second 32-ampere spike, was observed on fuel cell 3. Orbiter data were reviewed and no current spikes were observed, indicating that the current draw was on the payload side of the interface.

Auxiliary Power Unit Subsystem

The auxiliary power unit (APU) subsystem performed nominally during the mission with no in-flight anomalies or significant problems identified.

At approximately 061:03:22 G.m.t. (00:16:00 MET), the auxiliary power unit (APU) 3 fuel-pump seal-cavity drain line pressure began to slowly decay (approximately 1.1 psi/day). It was determined that helium was left in the drain line following a preflight leak check. It is believed that the helium was permeating the Teflon in the flex-hose, thus accounting for the pressure decay. There was no mission impact. A revision of ground procedures to ensure a nitrogen purge is performed following the helium leak check is in work.

The flight control subsystem (FCS) checkout was performed using APU 1 to support the checkout with an APU start time of 070:07:13 G.m.t. (09:19:51 MET). The run time was 5 minutes, 34 seconds, and 16 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.

During entry at approximately 071:09:09 G.m.t. (10:21:47 MET), the APU 2 exhaust gas temperature sensor (EGT) 1 temperature sensor became erratic. The temperature sensor will be replaced.

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

APU RUN TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (S/N 405) (a) (b)		APU 2 (S/N 303) (a)		APU 3 (S/N 409) (a)	
	Time, Min:sec	Fuel consumption, lb	Time, Min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	20:31	46	29:32	50	20:34	49
FCS checkout	5:34	16				
Entry ^a	63:21	122	94:08	181	63:24	123
Total	89:26	184	123:40	231	83:58	172

^a APUs were shut down 16 minutes 24 seconds after landing.

^b APU 1 was used for the FCS checkout.

Hydraulics/Water Spray Boiler Subsystems

The hydraulics/water spray boiler (WSB) subsystem performed satisfactorily throughout the mission. STS-109 was the first flight of the OV-102 vehicle with the water additive, Propylene Glycol Monomethyl Ether (PGME), added to all three WSBs.

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.

During preparations for the third EVA, anomalous indications were seen on EMU 1 and it was discovered that water had leaked into the primary life support system (PLSS). The hard upper torso (HUT) for EMU 3 was re-sized for the extravehicular (EV) 1 crewman so the planned EVA could proceed. The investigation into the source of the water revealed that a voltage spike from the power supply and battery charger resulted in the feedwater shutoff valve inadvertently opening (Flight Problem STS-109-V-07).

A 32-ampere spike of 6 seconds duration was observed on fuel cell 3 at 066:10:29:00 G.m.t. (05:23:06:58 MET). Data plots of this time period revealed no current spikes. This indicates that the current draw was to the payload bus, or a crew cabin panel or to the cryogenics system. The payload community has agreed that the HST drew the current.

Atmospheric Revitalization Subsystem Pressure Control Subsystem

The atmospheric revitalization pressure control subsystem (ARPCS) performed normally throughout the duration of the flight.

To minimize the use of consumables, the 14.7-psia cabin pressure regulators remained isolated after the launch and ascent, and the cabin pressure was allowed to bleed down below 14.7 psia prior to the 10.2 psia depressurization. The 10.2 psia cabin depressurization was performed at 00:06:51 G.m.t. (00:19:13. MET).

Cabin pressure was maintained at 10.2 psia to support the five extravehicular activities (EVAs). Manual operation of pressure control system (PCS) 1 and direct input of oxygen was used to maintain cabin pressure between 10.2 psia and 10.4 psia, and partial pressure of carbon dioxide (ppCO₂) greater than 2.7 psia. While PCS was not configured to system 2, some internal leakage of the system 2 nitrogen/ oxygen (N₂/O₂) flow controller valve was observed. This leakage was determined to be less than allowable leakage and therefore required no action.

After the fifth EVA was completed and the Hubble Space Telescope was released, the cabin was repressurized to 14.7 psia at 068:14:20 G.m.t. (08:02:58 MET). Normal pressure control was used for the remainder of the mission. The PCS was configured to system 2 after the repressurization to 14.7 psia and a full switchover of the N₂/O₂ controller valve was observed. The following day, the PCS was configured to system 1 and full switchover was observed on that system.

Atmospheric Revitalization Subsystem

The atmospheric revitalization subsystem (ARS) performed nominally throughout the duration of the flight with the following highlights.

The 72 °F cabin air temperature at launch was 2 degrees warmer than the predicted preflight temperature which was determined through the STS-109 ECLSS/Payload Thermal Compatibility Verification Analysis. However, the 72 °F was below the flight rule limit of a 75 °F air temperature during the launch phase. During the mission, the cabin

air temperature peaked at an indicated sensor value of 79.1 °F. This occurred while the cabin was at 10.2-psia and during the group B power up for rendezvous and capture of the Hubble Space Telescope (HST).

Based on the lithium hydroxide (LiOH) change-out schedule, a total of 35 LiOH canisters were expended during the flight.

At approximately 066:30:00 G.m.t. (06:18:38 MET), the crew performed the cabin temperature controller reconfiguration by unpinning the linkage from controller 1 and pinning the linkage to controller 2. During this time, the cabin temperature selector is positioned to 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 for crewman to remove and install the linkage pip pin. The flight continued flawlessly on the secondary controller for the remainder of the flight. The water coolant loop 1 bypass valve functional checkout was successfully performed at 071:02:30 G.m.t. (10:17:08 MET).

During the launch phase, the crew compartment temperature was 71.9 °F and climbed to 74.1 °F 1 hour and 53 minutes into the flight. The temperature continued to rise and it stabilized at 75.5 °F at 060:13:55:56 G.m.t. (00:02:33:54 MET). Cabin humidity peaked to 39.2 percent 4 minutes and 49 seconds after launch. The heat exchanger outlet air temperature peaked to 75.78 °F approximately 3 minutes 35 seconds into the flight.

During the on-orbit phase of the mission, the cabin temperature averaged 74 °F. While the cabin was at 10.2-psia, the cabin temperature peaked to 79.15 °F, which is below the preflight prediction of 80 °F. The ppCO₂ peaked at an indicated 5.9 mmHg while the cabin pressure was at 10.2 psia. Based on the contractor's ppCO₂ equivalent value at 14.7 psia, this is equal to 9.15 mmHg of ppCO₂.

Cabin Humidity averaged 32.5 percent for the flight, and peaked at 43 percent during the crew deorbit preparation period on flight day 12.

During the landing phase of the flight, the heat exchanger outlet temperature peaked at 55.7 °F 8 minutes and 39 seconds after wheel stop. The cabin air temperature peaked to 70.9 °F 22 minutes and 30 seconds after wheel stop. The temperature at landing was 69.5 °F, which is below the 75 °F cabin-air temperature limit. The cabin humidity peaked near 46 percent approximately 11 minutes after wheel stop.

Active Thermal Control Subsystem

Three occurrences highlight the active thermal control subsystem (ATCS) performance for STS-109. Two events were anomalous.

The first anomalous event occurred about 6 seconds after MECO. At about 060:11:30:34 G.m.t. (00:00:08:32 MET), the aft-coldplate flow-rate on Freon coolant loop (FCL) 1 dropped from 304 lb/hr to 226 Lb/hr (Flight Problem STS-109-V-01). The flow-rate drop was about a 30-percent decrease. After the radiators were placed in the flow position, the FCL 1 aft coldplate flow rate further decreased to 195 to 200 lb/hr. The FCL1 interchanger flow and payload heat exchanger flow increased at the same time, which confirmed a restriction existed and was causing the reduction in flow in the aft coldplate. Evaluation of the flight data showed that a blockage existed in the FCL 1 aft coldplate line. A concern was raised on whether the Freon coolant loops could provide sufficient cooling for the aft coldplates during the deorbit/entry phase when most avionics

in the aft fuselage would be powered. Enough cooling was being provided in the FCL 2 side for the aft coldplates, thus resulting in no changes to the nominal mission on-orbit timeline. A system analysis performed on the flow rates for the coldplate for different phases of the mission showed that the mission could proceed nominally in the event of the loss of FCL 2 and that the Orbiter could land at the next PLS should FCL 2 fail. The reduced FCL 1 aft coldplate on-orbit flow rate remained constant throughout the mission and returned to the 220 lb/hr range when the radiators were bypassed on deorbit day. Postflight X-rays of the line revealed a 0.5-inch object near the orifice upstream of the aft cold-plate.

In the event that FCL 2 had failed, a contingency procedure had been developed and verified in the Shuttle Avionics Integration Laboratory (SAIL) that would have enabled entry operations with some equipment powered off. However, this procedure was not invoked as FCL 2 operated properly throughout the mission.

No pre-evaporative cooling was observed during the ascent phase. The flash evaporation system (FES) performed nominally for the duration of the flight.

The second anomalous event occurred at about 069:03:01 G.m.t. (08:15:49 MET) when heater string 2 on the FES accumulator line and high-load-line zones of the system B feedline failed off resulting in the accumulator line temperature dropping to approximately 50 °F (Flight Problem STS-109-V-05). The thermostat is located on the accumulator line and the temperature sensor on the accumulator line was indicating that the heater turning on at 68 °F. The accumulator line was cycling between 67 and 90 °F and the high-load line was cycling between 90 and 135 °F. At 069:07:39 G.m.t. (08:20:17 MET), the crew was requested to switch feedline B to heater string 1, and nominal cycling of the accumulator line and high-load line on feedline B resumed. The feedline B was kept on heater string 1 for the rest of the flight. The vendor will assist in postflight checkout and repair of the heater on the FES.

The third observation was a difference in temperature readings between the FCL 1 and FCL 2 FES outlet sensors. The two sensors should read similarly drifting no more than one telemetry bit apart (0.4 °F). Throughout the mission, it was observed that the two sensors would read as much as 1.7 °F apart especially after a FES water dump was initiated. The difference was evident while the outlet temperatures were in the control band of the primary and secondary controllers. It was also observed during transients. This had no impact on the mission. All other ATCS parameters performed nominally.

For postlanding, the ammonia boiler subsystem (ABS) B was enabled on primary and performed for about 54 minutes before blowdown occurred. After system B operation, the system A was enabled on the primary controller, and the ABS performed for about 4.5 minutes before it was deactivated for ground cooling initiation.

Supply and Wastewater Subsystem

The supply water and waste-water subsystems performed nominally throughout the mission and all of the scheduled in-flight checkout requirements were satisfied. Supply water was managed through the use of the FES and the overboard nozzle dump system. Three supply-water dumps through the nozzle were performed at a nominal dump rate of 1.5 percent per minute (2.47 lb/min). The line heater maintained the supply water dump line temperature between 77 °F and 107°F throughout the mission.

Four wastewater dumps through the nozzle were made at an average rate of 1.86 percent per minute (3.07 lb/min). The wastewater dump line temperature was maintained between 57.5 °F and 74.8 °F throughout the mission.

The fuel cell 3 alternate-product-water line-temperature indicated a minimal amount of leakage through a check valve. Due to this condition, the supply water system was reconfigured to preclude tank B water from entering the alternate line. The alternate line contained hydrogen that could have been introduced to Tank B, which was used for extravehicular mobility unit (EMU) servicing. Tank B was isolated from tanks C and D by closing the crossover valve. Tank B was dumped to less than 5 percent and ganged with tank A for iodine mixing.

The vacuum vent line temperature was maintained between 59.6 °F and 74.6°F.

Waste Collection Subsystem

The waste management subsystem performed satisfactorily throughout the mission.

Airlock Support System

The airlock support system performed satisfactorily through out the mission. The airlock depressurization valve was used to lower the cabin from 14.7 psia to 10.2 psia and the airlock from 10.2 psia to a vacuum to support the five scheduled EVAs to service the Hubble Space Telescope.

The active system monitor parameters indicated normal output during all 5 EVA airlock depress/repress operations and throughout the rest of the flight.

Smoke Detection and Fire Suppression Subsystem

The smoke detection system showed no indications of smoke generation during the entire duration of the flight. Use of the fire suppression system was not required.

Flight Data Subsystem

The flight data subsystem performed satisfactorily except for the problem discussed in the following paragraph.

At 062:06:09 G.m.t. (01:18:47 MET), the crew reported what they called a multifunction electronic display system (MEDS) anomaly. While performing the RMS power-up, three expected messages were annunciated. When the crew pressed the aft keyboard message-reset key, the text portion of the message line cleared, but the time tag associated with the message did not clear. Pressing the message-reset key a second time cleared the time tag. A note in the Level A software requirements explains that this can occur due to software timing in certain situations.

Flight Software

The flight software performed satisfactorily throughout the mission with no problems or anomalies noted in the data review.

Flight Control Subsystem

Flight control subsystem performance was nominal with the exception of the anomaly discussed in the following paragraph.

At 061:05:12:59 G.m.t (00:17:50:57 MET), channel C on the forward translational hand controller (THC) turned off earlier than channels A and B during the -X NC₂ firing and was deselected by the redundancy management (RM) system (Flight Problem STS-109-V-04) The channel was reselected manually, and the problem did not repeat in subsequent -X pulses. The switch inside the THC is a snap-action rotary device using magnets and Hall-effect sensors to ensure simultaneous activation and deactivation of all three discrete channels. According to the manufacturer, it is impossible for one sensor to turn off by itself without a fault in the sensor or the signal path from the sensor to the multiplexer/demultiplexer (MDM), or momentary loss of power to the THC. There was no mission impact. Data evaluation is continuing. Evaluation of the data for the data display unit (DDU) indicates no BITE flags on any channel and the new DDU require a minimum of a 1-second flag to ensure it is recorded. The THC has a criticality of 1R2 for ET separation (down-firing thrusters), and 1R3 for on-orbit operations.

The FCS checkout was performed using auxiliary power unit (APU) 1 to support the checkout with an APU start time of 070:07:13 G.m.t (09:19:51 MET). FCS, APU and hydraulics performance was nominal.

Displays and Controls Subsystem

The displays and controls subsystem performed satisfactorily throughout the STS-109 mission. No in-flight anomalies or significant problems were noted during the mission.

Communications and Tracking Subsystems

The communications and tracking subsystems performed satisfactorily throughout the mission. No in-flight anomalies or significant problems were noted in this subsystem.

The S-band system experienced more frequent than expected dropouts on the forward and return links throughout the mission. The problem was seen on multiple antennas as well as Tracking and Data Relay Satellites (TDRS). As is typical, the mission was started on string 2. Evaluations of these lists determined that the events do not have a single failure point. At approximately 062:16:07 G.m.t. (02:02:45 MET), the S-band system was switched to string 1. Dropouts were also observed on string 1.

Data review indicates that the S-band dropouts have a variety of causes. These include Mission Control Center (MCC)/network data errors (not Orbiter S-band related), Orbiter antenna look-angles to the TDRS, false lock, radio frequency (RF) "multipath" regions, known interruption-potential during antenna switching, short occasional radio frequency interference (RFI), and HST-rendezvous RFI (seen on other HST missions). No apparent on-board S-band system failure was identified.

Post-mission S-band evaluations and discussions have concluded no current onboard S-band system failures have been identified and this problem has thus been closed.

Operational Instrumentation/Modular Auxiliary Data System

The operational instrumentation/modular auxiliary data subsystems performed satisfactorily throughout the mission. No in-flight anomalies or significant problems were noted in this subsystem.

On FD 3, it was reported that when payload interrogator (PI) 1 was not locked on to radio frequency (RF) telemetry from the HST, output signals (noise) from the PI affected the Ku-band signal processor assembly and the HST laptop caused loss of data. Subsequently, the PI 1 will be turned off when the HST transmitter is off. This feature of PI operation without telemetry lock has been noted in previous missions, and is to be expected. This problem concerns procedures that are in existence because of this same performance was experienced during the STS-85 and STS-95 missions.

Structures and Mechanical Subsystems

The structures and mechanical subsystems met all requirements of the mission; however, one in-flight anomaly and two other problems were noted and are discussed in the following paragraphs.

On flight day (FD) 1, when the crew attempted to open the internal airlock hatch, or "A" hatch, they reported that it was difficult to move the hatch actuator-locking tab out of the locked position, and therefore the hatch could not be unlatched (Flight Problem STS-109-V-02). While "jiggling" the actuator handle, they were able to move it axially, or away from the actuator. When they pressed it back against the actuator, they were able to move the locking lever and unlatch the hatch. While this actuator handle is designed to be removable, it is to be fully seated for both the hatch latching and unlatching operations and should not have the looseness that was reported. For the duration of the flight, the crew left the "A" hatch actuator unlocked. The hatch latch actuator uses a no-back clutch to ensure that it is not latching or unlatching. A closeout technician had noted a similar condition prior to launch. In addition, whenever the airlock was depressurized, the differential pressure across the hatch prevented an inadvertent opening.

The crew reported at 069:02:30 G.m.t. (08:15:07 MET) that middeck locker MF43C/E had shifted and resulted in MF43C/E being difficult to close and, in turn, prevented MF43G from closing. A pry bar was used to close the lockers for entry. Significant bowing of the locker frame was noted, and other middeck lockers were also difficult to close.

During deorbit preparations when the right vent door 3 was closed at 071:07:57:38 G.m.t. (010:20:35:36 MET), the close 1 microswitch initially indicated closed. The microswitch transferred to off approximately 4.5 seconds later, and it remained in that condition for 4 minutes and 43 seconds. Following that period, the microswitch transferred back on and remained in that position. The data indicate that the door closed nominally in dual motor time. The vent door 3 close 1 indication was also momentarily lost during door-closure after landing. Similar behavior occurred on STS-93. Similar behavior was observed on STS-93, and postflight testing did not duplicate the problem. Troubleshooting will again be performed.

Main landing gear touchdown occurred on KSC concrete runway 33 at 071:09:31:53 G.m.t. (10:22:09:51 MET) on March 12, 2002. The drag chute was deployed at 071:09:31:55 G.m.t. The nose gear touchdown occurred at approximately

071:09:32:04 G.m.t. The drag chute was jettisoned at 071:09:32:37 G.m.t. Wheels stop occurred at 071:09:33:05 G.m.t. The rollout was normal in all respects. The postflight inspection of the tires showed the tires to be in good condition.

The following table presents the pertinent landing parameters for the STSs-109 mission.

LANDING PARAMETERS

Parameter	From Threshold, ft	Speed, Keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	3519.5	185.8	-2.59	N/A
Nose gear touchdown	6285.7	149.2	N/A	-4.86
Brake initiation speed		6605 keas		
Brake-on time		42.71 seconds		
Rollout distance		10114.9 feet		
Rollout time		72.28 seconds		
Runway		33 (Concrete) KSC		
Orbiter weight at landing		222,139.7 lb		
Brake sensor Location	Peak Pressure, Psia	Brake assembly	Gross energy, million ft-lb	
Left-hand inboard 1	1225.5	Left-hand inboard	11.89	
Left-hand inboard 3	1225.5			
Left-hand outboard 2	970.6	Left-hand outboard	10.73	
Left-hand outboard 4	970.6			
Right-hand inboard 1	921.6	Right-hand inboard	5.17	
Right-hand inboard 3	921.6			
Right-hand outboard 2	902.0	Right-hand outboard	6.99	
Right-hand outboard 4	902.9			

The External Tank/Orbiter separation devices EO-1, EO-2, and EO-3 functioned normally. No fragments were found on the runway beneath the umbilicals. The EO-2 and EO-3 fitting retainer springs appeared to be the nominal configuration.

The postlanding walkdown of runway 33 was performed immediately after landing. All components of the drag chute were recovered and appeared to have functioned properly.

Integrated Aerodynamics, Heating and Thermal Interfaces

The prelaunch thermal interface purges were normal with no problems noted. Likewise, the ascent aerodynamic heating and plume heating were nominal with no problems noted. The entry aerodynamic heating on the SSME nozzles was also normal with no bluing of the metal noted during the postflight inspection.

Thermal Control Subsystem

The thermal control subsystem performed nominally throughout the mission in maintaining all temperatures within nominal limits. The beta angle at orbital insertion was -7 degrees and ranged between that angle and +25 degrees during the course of the mission. Two table maintenance block updates (TMBUs) were made during the mission

to prevent nuisance alarms to the crew. The OMS crossfeed lower limit temperature was changed from 50 °F to 45 °F, and the FES feedline upper-limit measurements were raised from 145 °F to 150 °F.

The FES accumulator/high-load feedline system B (starboard) string 2 heater failed off late in the mission. The heaters were switched to string 1 with no impact to the mission. This failure is discussed in the Active Thermal Control Subsystem section of this report.

Aerothermodynamics

Structural thermocouple temperature data, aileron deflection data, and yaw thruster firings all indicated a 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 normal entry heating.

Local heating was also normal with the exception of the gap filler between the nose cap and the chin panel had two locations where the outer fabric was breached.

Thermal Protection Subsystem and Windows

The thermal protection subsystem (TPS) performed satisfactorily. The postlanding inspection of the Orbiter TPS identified a total of 98 damage sites of which 18 had a major dimension of 1-inch or larger. The distribution of these impacts on the vehicle is shown in the following table. This total does not include the numerous damage sites on

TPS DAMAGE SITES

Orbiter Surfaces	Hits > 1 Inch	Total Hits
Lower Surface	14	63
Upper Surface	0	1
Window Area	4	29
Right Side	0	4
Left Side	0	1
Right OMS Pod	0	0
Left OMS Pod	0	0
Total	18	98

the base heat shield that are attributed to the flame arrestment sparkler system, SSME vibration/acoustics and exhaust plume recirculation.

The Orbiter lower surface sustained 63 damage sites of which 14 had a major dimension of 1-inch or larger. The majority of the hits (34 damage sites with 7 larger than 1-inch in length) were located in the area between the nose landing gear and the main landing gear wheel wells. Film analysis will be used to determine the source of the debris.

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 -101	STS -92	STS -97	STS -98	STS -102	STS -100	STS -104	STS -105	STS -108	STS -109
Lower surface, total hits	70	86	78	73	44	42	108	144	95	63
Lower surface, hits > 1 in.	19	14	10	8	10	4	4	25	22	14
Longest damage site, in.	8.0	2.0	3.0	3.0	1.0	2.5	4.5	5	8.0	3.5
Deepest damage site, in.	0.75	0.75	0.5	0.5	0.12	0.12	0.25	0.06	0.37	0.12

Approximately 13 of the total lower surface hits were around the LH₂ and LO₂ umbilical areas. 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 on the left-hand chine area and measured 3.5-inches long by 2 inches wide by 1/8-inch deep.

Gap filler material was found protruding from in between tiles at two locations on the lower surface; the left-hand wing near the elevon and the left-hand outboard elevon.

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 29 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 slightly greater 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. The potential identification of debris damage sources for this mission will be based on laboratory analysis of the Orbiter postlanding microchemical samples, inspection of the recovered SRB components, film analysis and aerodynamic debris particle trajectory analysis. The results will be published in the STS-109 Debris/Ice/TPS Assessment and Integrated Photographic Analysis report.

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 Bottle 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 OPERATIONS

All five of the extravehicular activities (EVAs) were completed satisfactorily. A total of 35 hours 56 minutes of EVA was accumulated during this mission, with the man-hours of EVA being 71 hours 52 minutes. One in-flight anomaly was recorded during the mission; also some minor problems did occur and the anomaly and all of the problems are discussed in the following paragraphs.

Extravehicular mobility unit (EMU) checkout was performed satisfactorily. The secondary oxygen package (SOP) pressure on EMU 4 was 5807 psia when 6200 psia was expected. Evaluation showed that as long as that pressure was above 5489 psia, it would provide the 30-minute emergency oxygen supply if required. The EMU was declared satisfactory for use during the EVA operations

EXTRAVEHICULAR ACTIVITY 1

The first extravehicular activity (EVA) was initiated at 063:06:37 G.m.t. (02:19:15 MET) to begin servicing of the HST. EMU 1 did not send EMU data scans through the real-time data system (RTDS) at the expected 2-minute intervals. These data are typically sent by interrupting the EMU biomedical signal every two minutes. As a result, the EV1 crewmember provided Mission Control with verbal data from the EMU every hour.

Tasks completed during the first EVA included the replacement of the existing solar array and the installation of the -V2 Solar Array 3 (SA3) and the replacement and installation of the diode box controller. Installation of the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) cryogenic cooler began with the installation of the Multi-Layer Installation electrical power system tent for the NICMOS cooling system (NCS) power feed.

The EVA ended at 063:13:38 G.m.t. (03:02:16 MET) for a total EVA time of 7 hours and 1 minute. All planned tasks were completed. The EVA lasted about 30 minutes longer than planned; however, this delay in completing the EVA had no impact on the mission. After the completion of the EVA, the RTDS power was cycled and satisfactory data were obtained from the EMU.

EXTRAVEHICULAR ACTIVITY 2

The second EVA began at 064:06:40 G.m.t. (03:19:18 MET) and was completed 7 hours and 16 minutes later. The crew completed all of their scheduled tasks plus several get-ahead tasks. The major tasks were the change-out of the +V2 solar array and the replacement of the reaction wheel assembly. In addition, three get-ahead tasks were performed. These were installation of a new outer layer blanket on bay 6, the installation of two doorstop extensions (one of the +V2 side and one on the -V2 side) and the installation of an aft shroud latch repair kit on one of the +V2 door bolts, as well as another bolt being checked and lubricated.

During the second EVA, the biomedical data from EMU 2 was lost for about 77 minutes. During the third EVA, biomedical data from EMU 3 behaved erratically for several minutes then dropped out completely. Additional biomedical data dropouts were seen during the fourth EVA from EMUs 3 and 4. The biomedical data dropouts are most likely due to one of the sternal harness pads separating from the crewman's chest. This condition did not impact the EVAs.

This was the first flight of the sternal harness with the disposable electrodes. The disposable electrodes are peel-and-stick similar to a Band-Aid. It has been confirmed that the anomalous data were similar to disconnected electrodes with the old system. A consideration will be given to returning to the previous system for upcoming missions.

EXTRAVEHICULAR ACTIVITY 3

The third EVA began at 065:08:28 G.m.t. (04:21:06) and was completed in 6 hours and 48 minutes. During preparations for the third EVA, anomalous indications were seen on EMU 1 and a large puddle of water was discovered near the battery (Flight Problem STS-109-V-07). Other suit conditions indicated that the feedwater shutoff solenoid valve was open. Investigation into this occurrence revealed that during STS-77 preflight ground testing, a voltage spike from the dual power supply and battery charger resulted in the feedwater shutoff solenoid valve inadvertently opening. The voltage spike from the power supply was a result of fluctuations in the battery charge current because the EMU fan was operating in the flow-control mode. This condition is unique to specific power supply/EMU combinations. The power supply used in the previous occurrence was downgraded to an engineering unit. A recurrence of the voltage spike is suspected to be the cause of the valve being open. A modification was incorporated in the power supply to preclude this voltage spike from occurring, but the power supplies with this modification have not yet been incorporated into the vehicles. Approval was recently given to incorporate the modified power supplies into the vehicles, beginning with the STS-110 mission. This condition resulted in the hard upper torso (HUT) for EMU 3 being re-sized for the extravehicular (EV) 1 crewman so the planned EVA could proceed. As a result, the EVA was initiated approximately 1 hour later than planned.

The primary activity for the crew during this EVA was the replacement of the power control unit (PCU), which now has passed all aliveness and functional testing. Subsequent power-up of the observatory was nominal, and with the completion of this EVA, the HST was in the normal servicing-mission configuration. The EVA was completed in 6 hours 48 minutes.

EXTRAVEHICULAR ACTIVITY 4

The fourth EVA for the HST was initiated at 066:09:00 G.m.t. (05:21:38 MET) and progressed nominally during the 7-hour and 30-minute EVA. The primary objectives of the EVA were the replacement of the Faint Object Camera (FOC), an original piece of HST science equipment, with the new Advanced Camera for Surveys (ACS). The ACS has completed and passed all aliveness and functional testing. The Electronics Support Module (ESM), a part of the NICMOS, was also successfully installed. The ESM also has successfully completed the aliveness and functional testing. All PCU cleanup tasks were also completed. The fourth EVA was successfully completed at 66:16:30 G.m.t. (06:05:08 MET).

EXTRAVEHICULAR ACTIVITY 5

The fifth EVA for the HST was initiated at 067:08:46 G.m.t. (06:21:24 MET) and was completed nominally. The time of the EVA was 7 hours 21 minutes, and all of the objectives were accomplished. The primary objectives to install the NICMOS cryogenic cooler and NICMOS cooling system radiator were completed successfully. The new hardware passed all aliveness and functional testing. In addition to completing the NICMOS installation, the new outer blanket layers were installed on bay 6. The EVA was

completed at 067:16:07 G.m.t. The Hubble Space Telescope was now ready to be released to continue its mission.

REMOTE MANIPULATOR SYSTEM

The remote manipulator system (RMS) performed satisfactorily. No in-flight anomalies were recorded during the operation of the RMS. However, The built-in test equipment (BITE) discussed in the following paragraph occurred, but did not impact the flight. The RMS retrieved the Hubble Space Telescope (HST) as well as deploying the HST. The RMS moved the crewmembers to various positions during the five extravehicular activities that were made to update the HST.

During RMS checkout on flight day (FD) 2, when the crew commanded the wrist yaw joint during the direct-drive (DD) test; a DD BITE was annunciated on the five non-driven joints. This BITE was a nuisance alarm that was caused by a timing issue when DD switch contacts are opened/closed, that is, when the switch is actuated. In some conditions, if the switch status contact is open when the enable and command contacts are closed, the DD BITE will be annunciated. DD is a contingency mode of operation, thus, there was no impact to nominal RMS operations. A second direct-drive demonstration was performed on-orbit to gather additional data with no recurrence of the BITE. The panel was removed for troubleshooting during the turnaround operations.

The RMS was powered and uncradled at 062:06:08 G.m.t. (01:17:46 MET), and the HST was captured at 062:09:13:34 G.m.t. (01:21:51:32 MET). The HST was successfully berthed in the flight support structure (FSS) at 062:10:31 G.m.t. (01:23:10 MET). The RMS was then used to perform a video survey of the HST using the wrist camera.

The RMS grappled the HST at 068:07:08 G.m.t. (07:19:46 MET) in preparation for deploying the HST. During grapple, the digital readout of the RMS wrist camera horizontal field of view (HFOV) was drifting approximately 3.5 degrees in both directions. The downlink of the camera video also indicated that the zoom telemetry appeared to be drifting. The crew power-cycled the camera but the problem did not clear. Although the HST grapple was successful, the inability to determine the actual HFOV impacted the grapple accuracy.

Following the final EVA, to support troubleshooting of the built-in test equipment (BITE) annunciation observed during the direct-drive test portion of the RMS checkout on flight day 2, the RMS was positioned in the extended-park position to perform a single-drive test. A sequence of ten positive and negative single-drive commands of the wrist yaw joint was executed to obtain engineering data on the performance of the single/direct-drive switch. The anomaly noted earlier in the mission did not recur.

The HST was unberthed from the Orbiter at 068:08:34 G.m.t. (07:21:12 MET) and released at 068:10:04 G.m.t. (07:22:42 MET).

GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

Overall, the Government furnished equipment/flight crew equipment performed satisfactorily. Problems were noted and are discussed in the following paragraphs.

The crew reported that when switching between the remote manipulator system (RMS) wrist and elbow cameras on FD 3, the newly powered camera would come up with the video scene present, instead of with the iris closed as expected. The RMS camera problem was better characterized after receiving answers to questions sent to the crew. It was initially thought that when switching between the RMS wrist and elbow cameras, the newly powered camera would come up with the video scene present, instead of with the iris closed as expected. It was determined that when switching from the wrist to the elbow camera, the elbow camera performed nominally. However, when switching from the elbow to the wrist camera, the wrist camera came up with its iris open. The iris in the wrist camera did not close when the camera power was off. The problem occurred each time the wrist camera was selected. The crew was instructed to manually close the iris prior to powering the wrist camera down. The wrist camera was removed from the vehicle, bench-tested and sent to the vendor for repair.

The Hubble Space Telescope (HST) was grappled by the RMS for release at 068:07:08 G.m.t. (07:19:46 MET). During the grapple, the digital readout of the RMS wrist camera horizontal field-of-view (HFOV) was drifting approximately 3.5 degrees in both directions. The downlink of the camera also indicated that the zoom telemetry appeared to be drifting. The crew power-cycled the camera, but the problem did not clear. Although the HST grapple was successful, the inability to determine the actual HFOV impacted the grapple accuracy.

POSTLAUNCH LAUNCH COMPLEX INSPECTION

The postlaunch inspection of the mobile launch platform (MLP) -2, Launch Pad A flight service structure (FSS), north flame trench, and the Launch Pad A apron was conducted from Launch + 1.5 to 3.5 hours. No flight hardware was found.

Orbiter lift-off lateral acceleration data that are used to predict stud hang-ups showed a value of 0.08g, which indicated that no SRB holddown stud hang-up had occurred. Evaluation of the MLP 0-level was performed and the south holddown studs were visually assessed as having no indication of hang-up. Erosion was typical for both the north and south posts. North holddown post blast covers and the T-0 umbilical exhibited nominal exhaust plume damage. Both SRB aft-skirt GN₂ purge lines were intact; however, the protective tape layering was partially eroded on both the RH and LH sides.

The LO₂ and LH₂ tail service masts (TSMs) appeared undamaged with both bonnets closed properly. The MLP deck was generally in good shape. All MLP deck communication connector caps were found intact and secured.

The GH₂ vent line latched on the eighth of eight teeth on the latching mechanism. The restraint-catch cable that had paint applied for an indication of the first contact point was in contact with the retracted line and a witness mark could not be identified. The ground umbilical carrier plate (GUCP) 7-inch quick-disconnect probe was accessible for inspection and appeared to be undamaged with the sealing surface in good shape. The deceleration cable was in its nominal configuration, and the vent-line blanket was sooted and torn. Film review should provide additional data for the assessment of the vent-line retraction position.

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

The gaseous oxygen (GO₂) vent arm, ducts and structure appeared to be in nominal shape with the only damage being a broken ground strap at the GO₂ vent arm console. The GO₂ vent seals were inspected and found to be in good shape.

Debris findings included:

- A. The FSS 115-foot level had one or two water lines broken (rotating service structure [(RSS) side]);
- B. The FSS 175-foot level Regulator knob fell off of the GN₂/GHE crossover panel 5.

Overall damage to the pad appeared to be normal.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DEVELOPMENT TEST OBJECTIVES

DTO 700-14 - Single String Global Positioning System with Miniature Air-to-Ground Receiver - All objectives of this DTO were completed successfully. The call-down of status information periodically by the crew confirmed proper payload and ground support computer (PGSC) data recording. In addition to recording the special engineering data blocks on the PGSC, the miniature air-to-ground receiver (MAGR) operational objectives were also completely successful. The operational objectives included power cycling of the MAGR, initialization, filter restart command and commanded self-test.

The final objective was the Lower-Preamplifier-Off test. This test gathered data to help determine the upper Global Positioning System (GPS) antenna characteristics on the OV-102 vehicle. A similar test was performed during STS-103 (OV-103 vehicle). The thermal protection covering the upper antenna is slightly different on OV-102, when compared to the other vehicles in the fleet. Postflight data reduction will determine any difference in upper antenna characteristics between OV-102 and the other vehicles in the fleet.

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

DETAILED SUPPLEMENTARY OBJECTIVES

DSO 490 - Bioavailability and Performance Effects of Promethazine During Space Flight - Detailed Supplementary Objective (DSO) 490 was conducted as planned with no anomalies. The results will be reported in other documentation when the postflight analysis is complete.

DSO 493 - Monitoring Latent Virus Reactivation and Shedding in Astronauts - This DSO was conducted each day during the flight. Based on the lack of crew reports, it was as planned during the flight. Based on the lack of crew reports, it was completely successful. The results will be reported in other documentation when the postflight analysis is complete.

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 503S - Test of Midodrine as a Countermeasure Against Postflight Orthostatic Hypertension - 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.

DTO 634 – Sleep-Wake Actigraphy and Light Exposure during Space Flight - This DSO was performed during the flight and was completely successful. The results will be reported in other documentation when the postflight analysis is complete.

DSO 635 - Spatial Reorientation Following 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.

DSO 802 - Education Activities, Objective 3 – All activities required by this DSO were completed successfully. The results will be reported in other documentation when the postflight analysis is complete.

PHOTOGRAPHY AND VIDEO ANALYSIS

The launch videos and films were reviewed and evaluated following the STS-109 launch. A total of 24 launch videos and 20 launch films were reviewed and no anomalous events or conditions were noted.

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

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

TABLE I. - STS-109 SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
APU Activation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	060:11:17:15.851 060:11:17:19.117 060:11:17:22.811
SRB HPU Activation ^a	LH HPU System A start command LH HPU System B start command RH HPU System A start command RH HPU System B start command	060:11:21:33.971 060:11:21:34.131 060:11:21:34.291 060:11:21:34.451
Main Propulsion System Start ^a	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	060:11:21:55.464 060:11:21:55.593 060:11:21:55.703
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	060:11:22:02.021
Throttle up to 104.5 Percent Thrust ^a	ME-2 Command accepted ME-1 Command accepted ME-3 Command accepted	060:11:22:06.093 060:11:22:06.102 060:11:22:06.104
Throttle down to 101 Percent Thrust ^a	ME-2 Command accepted ME-1 Command accepted ME-3 Command accepted	060:11:22:20.493 060:11:22:20.503 060:11:22:20.504
Throttle down to 72 Percent Thrust ^a	ME-2 Command accepted ME-1 Command accepted ME-3 Command accepted	060:11:22:42.093 060:11:22:52.103 060:11:22:42.104
Maximum Dynamic Pressure (q)	Derived ascent dynamic pressure	060:11:22:54
Throttle up to 104.5 Percent Thrust ^a	ME-2 Command accepted ME-1 Command accepted ME-3 Command accepted	060:11:22:56.013 060:11:22:56.023 060:11:22:56.024
Both RSRM's Chamber Pressure at 50 psi ^a	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	060:11:24:02.101 060:11:24:02.461
End RSRM ^a Action ^a Time	RH SRM chamber pressure mid-range select LRH SRM chamber pressure mid-range select	060:11:24:04.821 060:11:24:05.043
SRB Separation Command	SRB separation command flag	060:11:24:07
SRB Physical Separation ^a	LH rate APU turbine speed - LOS	060:11:24:07.341
Throttle Down for 3g Acceleration ^a	ME-2 command accepted ME-3 command accepted ME-1 command accepted	060:11:29:24.339 060:11:29:24.348 060:11:29:24.350
3g Acceleration	Total load factor	060:11:30:08.4
Throttle Down to 67 Percent Thrust ^a	ME-2 command accepted ME-3 command accepted ME-1 command accepted	060:11:30:19.060 060:11:30:19.068 060:11:30:19.071
SSME Shutdown ^a	ME-2 command accepted ME-3 command accepted ME-1 command accepted	060:11:30:25.540 060:11:30:25.548 060:11:30:25.551

^aMSFC supplied data

**TABLE I. - STS-109 SEQUENCE OF EVENTS
(Continued)**

Event	Description	Actual time, G.m.t.
MECO	MECO command flag	060:11:30:26
	MECO confirm flag	060:11:30:27
ET Separation	ET separation command flag	060:11:30:47
APU Deactivation	APU-1 GG chamber pressure	060:11:37:44.304
	APU 2 GG chamber pressure	060:11:37:48.776
	APU 3 GG chamber pressure	060:11:37:53.990
OMS-1 Ignition	Left engine bi-prop valve position	Not performed - direct insertion trajectory flown
	Right engine bi-prop valve position	
OMS-1 Cutoff	Left engine bi-prop valve position	Not performed
	Right engine bi-prop valve position	
OMS-2 Ignition	Left engine bi-prop valve position	060:12:05:59.0
	Right engine bi-prop valve position	060:12:05:59.0
OMS-2 Cutoff	Right engine bi-prop valve position	060:12:07:27.0
	Left engine bi-prop valve position	060:12:07:27.0
Payload Bay Doors (PLBDs) Open	PLBD right open 1	060:13:17:12
	PLBD left open 1	060:13:21:20
OMS-3 Ignition	Left engine bi-prop valve position	N/A
	Right engine bi-prop valve position	060:16:43:49.6
OMS-3 Cutoff	Right engine bi-prop valve position	N/A
	Left engine bi-prop valve position	060:16:44:03.6
Cabin Depressurization Ended	Cabin pressure	061:07:10:50
OMS-4 Ignition	Left engine bi-prop valve position	062:04:07:30.0
	Right engine bi-prop valve position	062:04:07:30.1
OMS-4 Cutoff	Left engine bi-prop valve position	062:04:10:57.2
	Right engine bi-prop valve position	062:04:10:57.3
OMS-5 Ignition	Left engine bi-prop valve position	062:07:01:05.3
	Right engine bi-prop valve position	N/A
OMS-5 Cutoff	Left engine bi-prop valve position	062:20:53:29.7
	Right engine bi-prop valve position	N/A
Hubble Space Telescope (HST) -Grapple	As reported	062:09:31:34
HST Ungrapple	As reported	062:10:49:41
Airlock Depressurization (End)	Airlock differential pressure no. 1	063:06:32:02
Begin First Extravehicular Activity (EVA)	As reported	063:06:37
Modified Foot Restraint (MFR) Grapple	As reported	063:07:01:41
Airlock Repressurization (start)	Airlock differential pressure no. 1	063:13:37:58
End First Extravehicular Activity	As reported	063:13:38
Airlock Depressurization (End)	Airlock differential pressure no. 1	064:06:36:44
Begin Second EVA	As reported	064:06:40
Airlock Repressurization (start)	Airlock differential pressure no. 1	064:13:56:38
End Second EVA	As reported	064:13:56
Airlock Depressurization (End)	Airlock differential pressure no. 1	065:08:26:45
Begin Third EVA	As reported	065:08:28
Airlock Repressurization (start)	Airlock differential pressure no. 1	065:15:16:10
End third EVA	As reported	065:15:16
Airlock Depressurization (End)	Airlock differential pressure no. 1	066:08:57:29

**TABLE I. - STS-109 SEQUENCE OF EVENTS
(Concluded)**

Event	Description	Actual time, G.m.t.
Begin Fourth EVA	As reported	066:09:00
Airlock Repressurization (start)	Airlock differential pressure no. 1	066:16:30:14
End Fourth EVA	As reported	066:16:30
Airlock Depressurization (End)	Airlock differential pressure no. 1	067:08:42:39
Begin Fifth EVA	As reported	067:08:46
Airlock Repressurization (start)	Airlock differential pressure no. 1	067:16:07:41
End Fifth EVA	As reported	067:16:07
MFR Ungrapple	As reported	067:15:12:49
HST Reboost	As reported	067:17:18:04
HST Grapple	As reported	068:07:07:55
HST Ungrapple - Release	As reported	068:10:04:16
OMS 6 Ignition (Orbit Adjust Maneuver)	L engine bi-propellant valve position R engine bi-propellant valve position	068:12:01:02.3 068:12:01:02.3
OMS 6 Cutoff	L engine bi-propellant valve position R engine bi-propellant valve position	068:12:01:47.9 068:12:01:47.9
Cabin Repressurization (start)	Cabin pressure	068:13:53:19
Flight Control System Checkout		
APU Start	APU 3 GG chamber pressure	070:07:12:58.192
APU Stop	APU 3 GG chamber pressure	070:07:18:29.822
Payload Bay Doors Close	PLBD left close 1 PLBD right close 1	071:05:50:34 071:05:52:38
APU Activation for Entry	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	071:08:17:40.208 071:08:48:24.956 071:08:48:28.137
Deorbit Burn Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	071:08:22:39.2 071:08:22:39.4
Deorbit Burn Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	071:08:26:44.4 071:08:26:44.4
Entry Interface (400K feet)	Current orbital altitude above	071:09:00:52
Blackout end	Data locked (high sample rate)	No blackout
Terminal Area Energy Management	Major mode change (305)	071:09:25:38
Main Landing Gear Contact	LH main landing gear tire pressure 1 RH main landing gear tire pressure 2	071:09:31:52.8 071:09:31:52.9
Main Landing Gear Weight on Wheels	LH MLG weight on wheels RH MLG weight on wheels	071:09:31:52.8 071:09:31:52.8
Drag Chute Deployment	Drag chute jettison 1 CP Volts	071:09:31:54.9
Nose Landing Gear Contact	NLG LH tire pressure 1	071:09:32:01
Nose Landing Gear Weight On Wheels	NLG weight on wheels 1	071:09:32:02
Drag Chute Jettison	Drag chute jettison 1 CP Volts	071:09:32:36.5
Wheel Stop	Velocity with respect to runway	071:09:33:05
APU Deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	071:09:51:43.342 071:09:51:46.956 071:09:51:50.060

TABLE II- STS-100 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-109-V-01	Freon Coolant Loop 1 Degraded Aft Cold Plate Flow	060:11:31 G.m.t. 00:00:08 MET IPR 107V-0001 SPR 109RF01	<p>Several seconds after MECO, the Freon Coolant Loop (FCL) 1 aft coldplate flow rate decreased from 304 lb/hr to 226 lb/hr. The FCL 1 interchanger flow and payload heat exchanger flow increased at the same time, and this confirmed a restriction was causing the reduction of flow in the aft coldplate branch. The flow rate remained stable for the remainder of the mission. The Flight Rules state that the minimum flow rate in the aft coldplate branch is 211 lb/hr actual, 236 lb/hr when allowing for measurement at uncertainty, for a one-FCL entry. The analysis and assumptions used to determine this limit were reviewed and it was determined that despite the degraded flow, FCL 1 was able to provide adequate cooling during entry in the event of a failure of FCL 2. As a result, the Mission Management Team decided that the mission should continue as planned. Postflight X-rays revealed a 0.5-inch object near the orifice upstream of the coldplate. KSC: Repair was performed.</p>
STS-109-V-02	Airlock A Hatch Locking Device Difficult to Actuate	060:15:57 G.m.t. 00:04:34 MET IPR 107V-0003 SPR 109RF05	<p>On flight day 1, when the crew attempted to open the internal airlock hatch, or A hatch, they reported difficulty moving the actuator-locking tab out of the locked position, and therefore could not unlatch the hatch. While jiggling the actuator handle, they were able to move it axially, or away from the actuator. When the crew pressed it back against the actuator, they were able to move the locking tab and unlatch the hatch. While this actuator handle is designed to be removable, it is supposed to be fully seated for hatch latch latching and unlatching operations and should not have the kind of looseness reported. It was recommended that for the duration of the flight, the crew leave the A hatch actuator unlocked. The hatch latch actuator uses a no-back clutch to ensure it is not back-driven by loads from the latches. In addition, whenever the airlock is depressurized, the differential pressure across the hatch will prevent any internal opening. KSC: Postflight troubleshooting and repair was required.</p>

TABLE II- STS-100 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-109-V-03	MPS LH ₂ 4-Inch Recirculation Disconnect Slow-to-Close	060:11:31 G.m.t. 00:00:08 MET IPR 107V-0005 SPR 109RF03	<p>Review of the valve timing data determined that the MPS LH₂ 4-inch recirculation-disconnect was slow to close when commanded at MECO. The requirement is 2.8 seconds maximum from signal-to-switch (close power to close indication on). The signal-to-switch time for the disconnect to operate was 13.79 seconds. The disconnect-open indication was lost approximately 0.5 second after the loss of open power indicating partial movement of the disconnect. The close indication coincided with the ET/Orbiter umbilical retract implying a back-up mechanical closure. The 4-inch recirculation disconnect is not operated after closure at MECO and this slow response did not impact the mission.</p> <p>KSC: A troubleshooting plan was developed.</p>
STS-109-V-04	Forward THC -X Contact Lost During One Firing.	061:05:13 G.m.t. 00:17:50 MET IPR 107V-0010 SPR 109RF07	<p>At 061:05:12:58 G.m.t. (00:17:50 MET), channel C on the forward translational hand controller (THC) turned off earlier than expected during the -X NC-2 maneuver. The problem did not repeat on subsequent -X pulses. The switch inside the THC is a snap-action rotary device using magnets and Hall-effect sensors to ensure simultaneous activation and deactivation of all three discrete channels. According to the manufacturer it is impossible for one sensor to turn off itself without a fault in the sensor or signal path from the sensor to the Multiplexer/Demultiplexer (MDM), or momentary loss of electrical power to the THC. There was no mission impact. Data evaluation is ongoing. Evaluation of the telemetry data for the Data Display Unit (DDU) indicates no Built In Test Equipment (BITE) flags on any channel, and the new DDU provides a minimum of 1-second flag to ensure it is recorded. The THC is 1R2 for ET separation (down thrusters), 1R3 for on-orbit operations.</p> <p>KSC: A postflight inspection of the THC will be performed.</p>
STS-109-V-05	FES Accumulator/High Load Feedline B Heater System 2 Failure	069:02:37 G.m.t. 08:15:15 MET IPR 107V-0011 SPR 109RF08	<p>At approximately 069:02:37 G.m.t. (08:15:15 MET), the FES accumulator/high load feedline B (starboard) heater system 2 failed off. The thermostat is located on the accumulator line and the temperature sensor on the accumulator line had been indicating the heater turning on at approximately 68 °F. When the accumulator line temperature dropped to 50 °F, the crew switched to heater system 1, which is performing nominally.</p> <p>KSC: Troubleshooting and repair will be performed.</p>

TABLE II- STS-100 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-109-V-06	Primary RCS Thruster R3R Failed Off	070:08:19 G.m.t. 09:20:57 MET PR RP05-16-0454 SPR 109RF04	<p>During the RCS hot-fire, primary RCS thruster R3R failed off when first commanded to fire and was automatically deselected by the RCS redundancy management (RM). The reaction jet driver (RJD) output was nominal; however, the chamber pressure reached only 11 psia prior to the thruster being deselected. The thruster did not leak propellant following the fail-off. The thruster injector temperatures and chamber pressure suggest a problem with a thruster pilot-operated valve. The thruster remained deselected for the remainder of the flight.</p> <p>KSC: Postflight, all thrusters on the R3R manifold will be removed and sent to the White Sands Test Facility (WSTF) for gaseous nitrogen and water valve - response testing.</p>
STS-109-V-07	Suspect Dual Power Supply and Battery Charger Voltage Spike	065:05:34 G.m.t. 04:18:11 MET SPR 109RF10	<p>During EVA preparations, the crew reported that the back of EV portable life support system (PLSS) had a large puddle of water near the extravehicular mobility unit (EMU) battery. Other suit conditions indicated that the feedwater shutoff solenoid valve was open. Investigation into this occurrence revealed that during STS-77 preflight ground testing, a voltage spike from the dual power supply and battery charger resulted in the feedwater shutoff solenoid valve inadvertently opening. The voltage spike from the power supply is a result of fluctuations in the battery charge current because the EMU fan is operating in the flow-control mode, and is unique to specific power supply/EMU combinations. The power supply used in the previous occurrence was downgraded to an engineering unit. A recurrence of this voltage spike is suspected to be the cause of this valve opening. A modification was incorporated in the power supply to preclude this voltage spike from occurring, but the power supplies with the modification have not been incorporated into the vehicles. Approval was recently made to incorporate the modified (-0004) power supplies into the vehicles, starting with STS-110.</p>

DOCUMENT SOURCES

In an attempt to define the official as well as the unofficial sources of data for the STS-109 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-109 Summary of Significant Events
17. Contractor Reports of Subsystem Operation

ACRONYMS AND ABBREVIATIONS

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

ABS	ammonia boiler subsystem
ACS	Advanced Camera for Surveys
APU	auxiliary power unit
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
ATCS	active thermal control system
BITE	built-in test equipment
BSM	Booster Separation Motor
CEI	contract end item
DD	direct-drive
DDU	data display unit
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
ΔV	differential velocity
ECLSS	environmental control and life support system
e.d.t.	Eastern daylight time
EGT	exhaust gas temperature
EMU	extravehicular mobility unit
EPDC	electrical power distribution and control
ESA	European Space Agency
ESM	electronics support module
ET	External Tank
E/O	External Tank/Orbiter
ET/Orb	External Tank/Orbiter
EV	extravehicular (crew member)
EVA	extravehicular activity
FBMBT	flexible bearing mean bulk temperature
FCL	Freon coolant loop
FCMS	fuel cell monitoring system
FCP	fuel cell powerplant
FCS	flight control system/subsystem
FCV	flow control valve
FD	flight day
FES	flash evaporator system
FOC	Faint Object Camera
FOD	foreign object damage
FSS	Fixed Service Structure
ft/sec	feet per second
GFE	Government furnished equipment
GH ₂	gaseous hydrogen
G.m.t.	Greenwich mean time
GN ₂	gaseous nitrogen
GO ₂	gaseous oxygen
GSE	Ground Support Equipment

GUCP	ground umbilical carrier plate
HFOV	horizontal field of view
HGDS	hazardous gas detection system
HST	Hubble Space Telescope
HUMS	hydrogen umbilical mass spectrometer
HUT	hard upper torso (suit)
ICD	Interface Control Document
I_{sp}	specific impulse
JSC	Johnson Space Center
keas	knots estimated air speed
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt/hour
lbf	pound force
lb/hr	pound per hour
lbm	pound mass
lb/min	pound per minute
LCC	Launch Commit Criteria
LH ₂	liquid hydrogen
LiOH	lithium hydroxide
LMSO	Lockheed Martin Space Operations
LO ₂	liquid oxygen
MADS	Modular Auxiliary Data System
MAGR	Miniature Air to Ground Receiver
Max $q\alpha$	maximum dynamic pressure
MC	midcourse correction (rendezvous maneuver)
MCC	Mission Control Center
MDM	multiplexer/demultiplexer
MECO	main engine cutoff
MEDS	multifunction electronics display systems
MET	mission elapsed time
MLP	Mobile Launch Platform
Mlbf	million pounds force
mmHg	millimeter mercury
MPS	main propulsion system
MSFC	Marshall Space Flight Center
MV	millivolt
N ₂	nitrogen
NASA	National Aeronautics and Space Administration
NC1, NC2	circularization maneuvers (rendezvous maneuver)
NC3, NC4	circularization maneuvers (rendezvous maneuver)
NCS	NICMOS cooling system
NICMOS	Near Infrared Camera and Multi-Object Spectrometer
nmi.	nautical mile
O ₂	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

OV	Orbiter Vehicle
PCS	pressure control system
PCU	power control unit
PGME	Propylene Glycol Monomethyl Ether
PGSC	payload and general support computer
PI	payload interrogator
PLSS	portable life support system
PMBT	propellant mean bulk temperature
ppCO ₂	partial pressure carbon dioxide
ppm	parts per million
PRSD	power reactant storage and distribution/Prototype Synchrotron Radiation Detector
psia	pound per square inch absolute
psid	pound per square inch differential
PV	prevalve
QD	quick disconnect
RCS	reaction control subsystem
RF	radio frequency
RFI	radio frequency interference
RJD	reaction jet driver
RM	redundancy management
RMS	Remote Manipulator System
RSRM	Reusable Solid Rocket Motor
RTDS	real time data system
S&A	safe and arm
SAIL	Shuttle Avionics Integration Laboratory
SLWT	super lightweight tank
S/N	serial number
SOP	secondary oxygen package
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSME	Space Shuttle main engine
STS	Space Transportation System
SWAR	Sea water activated release
T	time of launch
TDRS	Tracking and Data Relay Satellite
THC	translation hand controller
TMBU	table maintenance block update
TPS	thermal protection system/subsystem
TSM	tail service mast
V	Volts
WSB	water spray boiler
WSTF	White Sands Test Facility