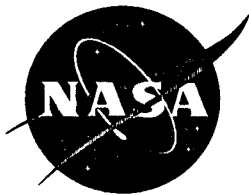


STS-100 SPACE SHUTTLE MISSION REPORT

June 2001



**National Aeronautics and
Space Administration**

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

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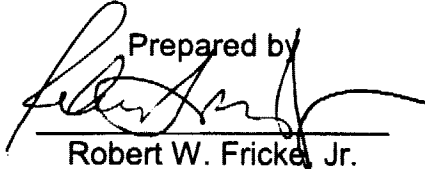
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STS-100

SPACE SHUTTLE

MISSION REPORT

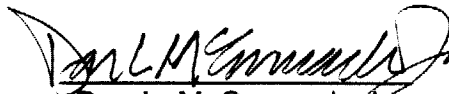
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INTRODUCTION

The Space Transportation System (STS)-100 Space Shuttle Program Mission Report presents a discussion of the Orbiter subsystem operation and the in-flight anomalies that were identified during the mission. The STS-100 flight was the ninth mission to the International Space Station (ISS), and it performed hardware delivery, maintenance and logistics tasks.

The STS-100 report summarizes the activities of the mission, as well as presenting a summary of the External Tank (ET), Solid Rocket Booster (SRB), Reusable Solid Rocket Motor (RSRM), and Space Shuttle main engine (SSME) performance during this one-hundred and fourth mission of the Space Shuttle Program. STS-100 was the seventy-ninth flight since the return to flight, and the sixteenth flight of the OV-105 (Endeavor) vehicle. This flight delivered the Space Station Remote Manipulator System (SSRMS) (Canadarm2) and the Multi Purpose Logistics Module (Raffaello) to the ISS.

The flight vehicle consisted of the OV (Orbiter vehicle) -105 Orbiter; an ET, which was the eleventh Super Lightweight Tank (SLWT), and it was designated ET-108; three Block IIA SSMEs that were designated as S/Ns 2054, 2043, and 2049 in positions 1, 2, and 3, respectively; and two SRBs that were designated B1107. The two RSRMs were designated RSRM-79 with one installed in each SRB. The individual RSRMs serial numbers were 360L079A for the left SRB and 360L079B for the right SRB.

The primary objective of the STS-100 mission was to deliver and integrate the 6A launch package (LP) in to the orbiting ISS Stage 5A.1. The LP consisted of the Spacelab Logistics Pallet/Launch Deployment Assembly (SLP/LDA), the Multi-Purpose Logistics Module (MPLM), Utilization Experiments and the Direct Current Switching Unit (DCSU), which is a critical spare. The SLP/LDA carried the SSRMS and the Ultrahigh Frequency (UHF) Antenna, both of which were attached/installed on the ISS during the two scheduled extravehicular activities (EVAs). The MPLM is a pressurized module which was outfitted with Resupply/Return Stowage Platforms (RSP's) and Resupply Stowage Racks (RSR's) to transport Russian/U. S. logistics and other critical spares to the ISS. Powered and unpowered Utilization Experiments were carried in the Orbiter middeck and were transferred to the ISS. The DCSU was transferred from the cargo bay and installed on the ISS External Stowage Platform (ESP) during an EVA. The secondary objective of the STS-100 mission was to perform IMAX Cargo Bay Camera-3 Dimension (ICBC-3D) operations.

The STS-100 flight was planned as a 11 day plus 1 day, plus 2-contingency-day flight, of which six days were planned to be spent docked to the ISS. The capability for an additional day was provided for one fully operational backup day for an unscheduled EVA (an additional docked day) or a flight day 4 rendezvous, which protected an any-day launch capability. 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-person crew of the STS-100 flight consisted of Kent V. Rominger, Capt., U. S. Navy, Commander; Jeffrey S. Ashby, Capt., U. S. Navy, Pilot; Chris A. Hadfield, Col. Canadian Air Force, Canadian Space Agency Astronaut, Mission Specialist 1; John L. Phillips, Ph. D.,

Civilian, Mission Specialist 2; Scott. E. Parazynski, M. D., Civilian, Mission Specialist 3; Umberto Guidoni, Ph. D., Civilian, European Space Agency Astronaut, Mission Specialist 4; and Yuri V. Lonchakov, Lt. Col., Russian Air Force Cosmonaut, Mission Specialist 5.

STS-100 was the fifth space flight for the Commander, the fourth space flight for Mission Specialist 3, the second space flight for the Pilot, Mission Specialist 1 and Mission Specialist 4, and the first space flight for the Mission Specialist 2 and Mission Specialist 5.

MISSION SUMMARY

The STS-100 mission was launched as planned with no unscheduled holds during the flawless countdown. The time of launch was 109:18:40:41.988 G.m.t. (2:41 p.m. e.s.t. on April 19, 2001). All Orbiter subsystems performed satisfactorily during ascent.

Structural flexing was observed on the left orbital maneuvering subsystem (OMS) pod during the Space Shuttle main engine (SSME) start sequence. The flexing was characterized as first and second harmonic motion over an area of about 1.5 by 2.5 feet just forward of the reaction control subsystem (RCS) stinger. The flexing damped out quickly (0.6 second) and no damage was observed and no tiles were lost. There was no mission impact and inspection of this area was performed during the postflight turnaround activities, and no damage was found.

The OMS assist maneuver was performed at 109:18:42:55.6 G.m.t. [(00:00:02:13.7 (Mission Elapsed Time (MET))] following Solid Rocket Booster (SRB) separation. The maneuver was 102.5 seconds in duration, and the OMS performed satisfactorily.

The main propulsion system (MPS) SSME 1B 750-psia regulator outlet pressure was 729 psia for about 2 minutes during ascent, from 109:18:42 to 109:18:44 G.m.t. (00:00:02 to 00:00:04 MET) (Flight Problem STS-100-V-02). The regulator recovered to within the Operational Maintenance Requirements and Specifications Document (OMRSD) File IX requirement of 730 to 790 psia as the gaseous helium bottle pressure dropped and the ambient pressure decreased. There was no mission impact.

The OMS 2 maneuver was performed at 109:19:24:24.37 G.m.t. (00:00:43:42.3 MET) and was 53.8 seconds in duration. The differential velocity (ΔV) delivered was 81.9 ft/sec, and the orbit was 85.6 by 178.7 nautical miles (nmi.) following the maneuver. The OMS performed satisfactorily throughout the maneuver.

The payload bay doors were opened at 109:20:18:25 G.m.t. (00:01:37:43 MET). All voltages were nominal and the motors opened the doors in nominal dual-motor time.

During flight day 1, between approximately 8 and 17 hours MET, dropouts were observed over the S-band system. The dropouts were coincident with the selection of the lower left antenna path and had little or no correlation with the forward/aft beam selection. The data indicate that the reflected power was minimal with minor fluctuations during the period. There were also minor fluctuations in the forward (up) link automatic gain control (AGC) during the period. Postflight testing of the S-band lower left and lower right antennas, cables and connectors will be performed.

The flash evaporator system (FES) starboard feedline zone 3 heater system 1 temperature dropped to 53 °F at 110:08:11 G.m.t. (00:13:30 MET). The heater set point is 68.9 °F and the heater had not cycled since launch, indicating that the heater had probably failed (Flight Problem STS-100-V-01). Switching to the system-2 heater was planned before the temperature reached 43 °F. The system 2 heater was enabled at 110:12:01 G.m.t. (00:17:20 MET) and cycled normally for the remainder of the mission. No mission impact occurred as a result of this problem.

During the end effector (EE) portion of the remote manipulator system (RMS) checkout at 110:14:42 G.m.t. (00:20:01 MET), the rotational hand controller (RHC) capture/release switch appeared to stick when the EE snares were commanded closed in the manual EE mode. This resulted in an extended stall period for the EE motor. The crew cycled the RHC capture/release

switch and the condition cleared. The switch and the EE were subsequently retested and operated nominally. The crew noted that the switch did have a sticky feel. Only the EE automatic mode is normally used. Thermal analyses showed that the temperature increase in the motor windings was not sufficient to impact EE operations for this mission. The problem did not recur.

On several occasions during the rendezvous tools checkout, the trajectory control sensor (TCS) command and display system (CADS) application displayed error messages regarding the failure of the TCS to execute a legal command in its entirety and return a completion status to the payload and general support computer (PGSC). The problem appeared to be directly related to communications between the TCS CADS in the PGSC and the TCS unit. Analysis of the flight data confirmed that the TCS unit was correctly receiving and implementing commands and sending completion acknowledgements. However, some of the acknowledgements to the PGSC were not received and this resulted in the error messages. Exchanging the prime (STS-3) with the backup (STS-5) PGSC did not change the condition. The backup cable is the pre-routed cable to the Orbiter space vision system (OSVS). Due to timeline and system impacts, it was not utilized. Ground personnel monitored TCS operations and the possibility of this condition recurring was not ruled out. The TCS performed nominally during rendezvous and docking operations, but failed to automatically execute shutdown commands. Manual execution of the commands was successful and was the recommended workaround.

Troubleshooting with ground hardware duplicated the problem and confirmed that acknowledgements were not being received from the TCS unit prior to the software timing-window closing. The problem was eliminated when the master control interface unit (MCIU) 422 card was replaced with a Quatech card and the PGSC was taken off the network. The manual workaround continued to be used on this mission. Corrective action recommendations for future flights have been developed.

The main propulsion system (MPS) SSME 1B 750-psia regulator outlet pressure was 729 psia for about 2 minutes during ascent, from 109:18:42 to 109:18:44 G.m.t. (00:00:02 to 00:00:04 MET) (Flight Problem STS-100-V-02). The regulator recovered to within the Operational Maintenance Requirements and Specifications Document (OMRSD) File IX requirement of 730 to 790 psia as the gaseous helium bottle pressure dropped and the ambient pressure decreased. There was no mission impact.

The Orbiter docking system (ODS) ring extension was performed at 110:22:05 G.m.t. (01:03:24 MET). System performance was normal and power-on time was approximately 15 minutes. The ring was driven to its initial position; however, the power-off steps were initiated too quickly and the system did not mode the slip clutch to 'slip', which is required for docking. The ground controllers noted the condition, and the crew performed the steps required to correct the condition. This event has occurred once before on STS-92. The recovery steps used were appropriate, and there were no hardware issues.

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

The ISS capture of the Orbiter occurred at 111:13:58:49 G.m.t. (01:19:18:07 MET). A successful ring-in and hard mating was subsequently performed. During the drive-in of the ring, alignment was temporarily lost, because the high-energy dampers (HEDs) at petals 1 and 2 failed to disengage. The drive-in was temporarily stopped and the ring realigned without further action. This phenomenon has been observed in past missions; however, this is the first time that two HEDs remained engaged during retraction.

RENDEZVOUS MANEUVERS

Maneuver	Time, G.m.t./MET	ΔV , ft/sec	Firing time, sec	Orbit, nmi.
OMS 3 (NC1) Dual engine	109:22:23:18 00:03:42:36	80.3	52.5	130.8 by 178.3
OMS 4 (NC2) Right engine	110:10:42:37 00:16:01:55	7.8	10.4	133.4 by 189.2
OMS 5 (NC3) Dual engine	110:20:52:12 01:02:11:30	120.3	77.4	177.8 by 204.2
OMS 6 (NC4) Dual engine	111:09:44:53 01:15:04:11	42.2	27.4	202.7 by 204.1
NCC (RCS)	111:10:19:42 00:15:39:01	1.3	6.0	202.0 by 203.7
OMS 7 (TI) Left engine	111:11:17:25 01:16:36:43	10.2	12.8	204.1 by 208.8
MC-1 (RCS)	111:11:37:24 01:16:56:42	1.6	5.0	203.7 by 208.1
MC-2 (RCS)	111:12:14:18 01:17:33:36	2.0	9.0	204.4 by 209.0
MC-3 (RCS)	111:12:31:18 01:16:41:12	0.8	3.0	204.3 by 209.3
MC-4 (RCS)	111:12:41:18 01:18:00:36	0.3	1.0	199.1 by 206.1

The first extravehicular activity (EVA) was successfully completed and both extravehicular mobility units (EMUs) performed nominally during the 7 hour 10 minute EVA.

In support of the first EVA, the RMS was powered up and uncradled at 112:08:10 G.m.t. (02:13:29:18 MET). The arm grappled the Spacelab Pallet (SLP) and unberthed the hardware from the Orbiter. The SLP was installed on the Laboratory Cradle Assembly (LCA) at 112:10:48 G.m.t. (02:16:07:18 MET), and the RMS released the SLP. During the EVA, the RMS supported the installation of the ultrahigh frequency (UHF) antenna on the ISS U. S. Laboratory and the assembly and deployment of the Space Station RMS (SSRMS). Following the unfolding and bolting of the SSRMS booms, the RMS was placed in a position where the raising of the SSRMS boom could be viewed. The arm was cradled and powered down at 112:20:05 G.m.t. (03:01:24:18 MET).

The Space-to-Space Communication System (SSCS) supported the first EVA and nominal communications were maintained throughout the EVA. With the installation of the new UHF antenna on the ISS during the EVA, the Space-to-Space Station Radio (SSSR) was cleared for on-orbit use. The antenna was successfully tested at the end of the EVA. The plan for the second EVA was to power the SSSR prior to EVA crewmember egress and leave it on for the entire EVA. This provided an opportunity to monitor the link quality between the radios as the EVA crewmembers translated up and down the ISS.

The downlinked video from payload bay camera B appeared jittery at 112:18:13 G.m.t. (02:23:32 MET). The camera was commanded into different modes with no change to the jitter condition. The camera was subsequently power cycled and the jitter condition was cleared. The problem did not recur.

The ISS hatch opening and crew ingress into the ISS occurred at approximately 113:09:20 G.m.t. (03:14:40 MET).

The water spray boilers (WSBs) were configured to the B controllers at 110:17:21 G.m.t. (00:22:40 MET). After that time, the WSB 3 core, water tank, and gaseous nitrogen (GN₂) tank temperatures sharply increased (six degrees in three hours). Initially, it was believed that the boiler core and water tank heaters, which turn on and off together as a function of the boiler temperature feedback to the WSB controller, had failed on. Further data evaluation indicated that the GN₂ shutoff valve or the hydraulic bypass valve may have been continuously powered while on the B controller and could have caused the response. At 113:22:18 G.m.t. (04:03:37 MET), the WSB 3 A controller was selected and system temperatures returned to nominal values.

A plan was developed for the management of the system for the remainder of the mission. WSB 3 remained on the A controller (there was no constraint to continuous operation of the WSB feedline heater) for the remainder of the mission. Also, since a failure of the GN₂ shutoff valve or hydraulic bypass valve could not be ruled out, APU 3 was started late during entry [(at terminal area energy management (TAEM) interface)].

At 113:09:06 G.m.t. (03:14:25 MET), the crew reported a problem with the video setup for the ISS ingress operations. While video appeared normal in the camcorder viewfinder, there was no video at the Orbiter monitor. The audio function, however, was nominal. Crew troubleshooting identified that the pre-routed 42 ft. battery-powered speaker microphone unit (BPSMU) cable was the cause of the problem. A spare BPSMU cable restored normal operations.

The supply water tank A quantity transducer exhibited a dropout at 113:09:59 G.m.t. (03:15:18 MET). The sensor output went to zero percent when the tank quantity reached approximately 72.3 percent. The dropout only lasted for a few seconds and was followed by a return to normal data. This problem is believed to be associated with minor contamination of the quantity gage potentiometer, and does not impact supply-water-tank usage.

The Orbiter RMS was powered up and uncradled at 113:08:56 G.m.t. (03:14:15 MET). The arm was moved to the SSRMS walk-off viewing position, and supported the viewing of the SSRMS walk-off and checkout. After the successful checkout of the SSRMS, the Orbiter RMS was then used to grapple the multi-purpose logistics module (MPLM) in the payload bay. The Orbiter RMS maneuvered the MPLM to the pre-installation position over the Node 1 nadir common berthing module (CBM), and installation of the MPLM followed at 113:16:06 G.m.t. (03:21:25 MET). The Orbiter RMS then ungrappled from the MPLM and was cradled and powered down.

The first ISS reboost maneuver was started at 113:19:50:54 G.m.t. (04:01:09:54 MET) when RCS thrusters L3A and R3A were fired. The maneuver had a duration of 59 minutes and 36.4 seconds. The primary RCS thruster pulse widths were 160 ms, and the firing period was 11.6 seconds from start of one pulse firing until the next firing. Breaks in the thruster operation for attitude maintenance limited the maneuver to 243 pulses. Attitude maintenance was performed with the vernier thrusters. The aft down-firing vernier thrusters had a typical duty cycle of 8.08 seconds on and 3.56 seconds off. The resulting orbit was 205.5 by 212.2 nmi., and the ΔV was 7.41 ft/sec. The orbit was raised 2.1 nmi.

The second EVA was successfully completed and both EMUs performed nominally during the 7 hour 39 minute event. After completion of several tasks, EV2 returned to the airlock and connected to the servicing and cooling umbilical (SCU) for 1 hour and 2 minutes while EV1 performed tasks that required only one crewmember. This allowed EV2 to conserve battery power for the task of stowing the direct current switching unit (DCSU) on the pallet.

The Orbiter RMS was powered up and uncradled at 114:11:32 G.m.t. (04:16:51 MET). The arm was then used for EVA support to reconfigure the Laboratory J4000 panel connectors to route power and data to the Laboratory power and data grapple fixture (PDGF). At 114:16:57 G.m.t. (04:22:16 MET), the arm was maneuvered to the SLP uninstalled-viewing position to provide camera views of the SSRMS as it unberthed the SLP. Following the SLP unberthing, the SSRMS was maneuvered to the DCSU transfer position at 114:18:37 G.m.t. (04:23:56 MET).

During RMS berthing at 114:20:00 G.m.t. (05:01:19 MET), the forward manipulator positioning motor (MPM) pedestal manipulator retention latch (MRL) 1 latch microswitch failed to indicate on during latching. The associated latch motor 1 ran 19.4 seconds, while motor 2 ran for the nominal dual motor drive time of 5.7 seconds. The crew was requested to drive the latch closed for another 2 seconds (actual drive time was 4 seconds) with no change in the microswitch indication. Almost 2 hours later, upon coming out of a loss of signal (LOS) period, the microswitch indicated on. The power down of the arm occurred at 114:20:04 G.m.t. (05:01:23 MET).

At 114:23:46 G.m.t. (05:05:05 MET), the crew reported that use of the P4-to-Camcorder audio/video cable produced intermittent video. The crew was able to regain function through the use of a spare. At the same time, the crew reported that use of the 44 ft. BPSMU cable produced bad video with good audio. Again the crew was able to regain the video function through the use of a spare.

The Orbiter RMS was powered up and uncradled at 115:10:14 G.m.t. (05:15:33 MET). The arm was maneuvered from the pre-cradle position to the SLP uninstalled-viewing position in preparation for the SSRMS loaded tests, however, the SSRMS activities were cancelled because of ISS commanding issues.

At 115:22:40 G.m.t. (06:03:59 MET), the RMS was maneuvered from the SLP uninstalled-viewing position to the arm's pre-cradle position to begin power down. The MRL were commanded closed at 115:22:52 G.m.t. (06:04:11 MET). Again latched indications were obtained for all latches except the forward motor 1 latch microswitch, which had exhibited similar behavior during RMS operations earlier in the mission. The microswitch indicated on three minutes later, and as before, the behavior had no impact on RMS operations. The RMS was powered down at 115:23:11 G.m.t. (06:04:30 MET).

The second ISS reboost maneuver scheduled for flight day 7 was delayed because of the ISS command and control (C&C) computer problems. Other Orbiter maneuvers, which similarly required the Orbiter to take over attitude control of the mated stack, such as those required to achieve Orbiter water dump attitudes, were also delayed because the ISS commanding issue made the return of attitude control to ISS after the maneuvers problematic. Ultimately, the mission was extended one day as a result of the ISS C&C computer problems.

Owing to progress with the ISS computer problems, mission activities that had been delayed from the previous day were pursued on flight day 8. At 117:08:31 G.m.t. (07:13:51 MET) the Orbiter assumed attitude control of the mated stack and maneuvered to a water-dump attitude. A simultaneous supply and waste-water dump was initiated at approximately 117:09:06 G.m.t. (07:14:26 MET) and the dump was successfully completed.

After installing a contingency water container (CWC) for condensate collection at 116:10:32 G.m.t. (06:15:51 MET), the crew reported the presence of about 2 oz. of water at the humidity separator B air-outlet screen. The water was cleaned up, and no additional water was observed during a subsequent check a few hours later on the same flight day. During a check conducted on the next flight day (FD) at 117:10:28 G.m.t. (07:15:47 MET), the crew reported

that about the same quantity of water had again accumulated at the outlet screen. This indicates a possible humidity separator B water carryover problem. In response to this possibility, the humidity separator system was switched from B to A. The crew reported there was no free water at the air outlet screen following the switchover to the A separator.

The second ISS reboost maneuver was initiated at 117:11:20:42 G.m.t. (07:16:40:00 MET) when RCS thrusters F5R, F5L, L5D and R5D were fired. The maneuver ended after 1 hour as planned. There was no predefined thruster duty cycle, and the thrusters were turned off as necessary to maintain attitude within the 5-degree dead-band. The ΔV was 15.9 ft/sec. The resulting orbit was raised 4 nmi. to 219 by 206 nmi.

At 117:17:31:15 G.m.t (07:22:50:33 MET), the ground observed a remote power controller (RPC) trip on mid power control assembly (PCA) main bus B. The crew was asked to verify the state of the payload bay floodlights and they confirmed that the mid port floodlight was out. This floodlight was considered failed for the remainder of the flight. The loss of this light did not impact normal payload bay operations.

The Orbiter RMS was powered up and uncradled at 117:17:34 G.m.t. (07:22:53 MET) in preparation for retrieval of the MPLM from the Node 1 nadir CBM. After the MPLM was berthed in the Orbiter payload bay, the arm was cradled and powered down at 117:21:24 G.m.t (08:02:43 MET). Delayed transition of the forward MPM MRL 1 latch microswitch, which had been noted during the two previous RMS cradling operations, was not observed this time.

The Orbiter RMS was powered up and uncradled at 118:10:27 G.m.t. (08:15:46 MET). After the SSRMS had placed the SLP into a handoff position, the Orbiter RMS grappled the SLP at 118:20:43 G.m.t. (09:02:02 MET). The SSRMS then ungrappled and was maneuvered away from the SLP. The RMS berthed the SLP in the Orbiter payload bay at 118:22:50 G.m.t. (09:04:09 MET), and was then cradled and powered down. The forward MPM MRL 1 latch microswitch operated nominally.

In preparation for undocking, the Orbiter assumed attitude control of the mated stack with the digital autopilot (DAP) configured to AUTO at 119:16:48:55 G.m.t. (09:22:07:55 MET). Forward RCS thrusters F1U, F2U, and F3U were reselected. Low chamber pressure (P_c) of approximately 50 psi was observed during firings using RCS vernier thruster R5D beginning at 119:16:50 G.m.t. (09:22:09 MET) (Flight Problem STS-100-V-04). The low P_c continued throughout the fly-around, separation and continued to be present during each firing of that thruster. The redundancy management (RM) did not deselect the thruster since the low-level limit for RM deselection is 26 psia. During longer-duration firings, the chamber pressure gradually increased to the nominal range, but returned to the off-nominal signature when fired again. The observed P_c signature is indicative of combustion byproducts blocking the P_c sense tube, a condition that has been seen in past missions. To avoid a possible fail-off of the thruster that would result in waking the crew during their sleep period, the Orbiter was configured for attitude control using the primary thrusters. A return to vernier operations was performed at the start of flight control subsystem (FCS) checkout. This thruster continued to perform in the manner discussed for the remainder of the mission.

Successful undocking from the ISS was completed at 119:17:34 G.m.t. (09:22:53 MET). The initial separation from the ISS was performed with a +Z pulse at 119:17:34 G.m.t. (09:22:53 MET). Final separation was accomplished with a 12.16 second -X pulse of thrusters F1F and F2F. The resulting ΔV was 3.0 ft/sec with a resulting orbit of 218 by 206 nmi.

The Ku-Band radar acquired the ISS at 119:17:47 G.m.t. (09:23:06 MET) at a range of 240 ft. The radar tracked the ISS during the fly-around and final separation until the system was placed

back in the communication mode at 119:18:43 G.m.t. (10:00:02 MET) at a range of 3300 feet from the ISS. The separation rate was approximately 5.0 ft/sec.

During the rendezvous tools checkout, undocking, and fly-around activities, the TCS performed nominally. The crew did acknowledge some expected messages and issued some manual commands during the TCS operations because of the communication problems discussed earlier in the Mission Summary.

The first use of the Space-to-Space Orbiter Radio (SSOR) and SSSR during the undocking/separation maneuvers was successfully performed. During the fly-around activity, the communications link was very satisfactory and no anomalous performance was noted.

The FCS checkout was performed with no problems identified. Auxiliary power unit (APU) 3 was used to support the checkout with a start time of 10:09:41:08 G.m.t. (10:15:00:26 MET). The run time was 3 minutes 44 seconds, and 12 pounds of fuel were used during the APU 3 operation. APU 3 performance was nominal. The total run time was too short to require the WSB to provide spray cooling.

Following FCS checkout, the RCS hot-fire was performed nominally. The hot-fire began at 120:10:42 G.m.t. (10:16:02 MET) and ended at 120:10:50 G.m.t. (10:16:10 MET). A review of thruster chamber-pressure data confirmed that all of the firings were satisfactory, with each thruster performing at least two pulses of 320-millisecond duration.

With closed-circuit television (CCTV) camera A pointed at a light background, the camera's video revealed a thread-like piece of debris which moved along with the camera view when the camera was panned or tilted. Camera D was used to examine camera A, but the debris could not be seen. The debris image could not be made sharper by adjusting the camera A focus.

The first landing opportunity at the KSC Shuttle Landing Facility (SLF) was waived because of unacceptable weather conditions. The payload bay doors were closed and latched for the second KSC landing opportunity at 121:10:56:34 G.m.t. (11:16:15:52 MET). All voltages were nominal and the motors closed the doors in nominal dual-motor time.

The second landing opportunity at the KSC SLF was also waived because of unacceptable weather conditions. Due to an unfavorable weather forecast at KSC throughout the week, the decision was made to land at Edwards Air Force Base (EAFB), CA.

The deorbit maneuver for the first EAFB landing opportunity, a two-engine straight-feed firing, was performed on orbit 186 at 121:15:02:47.173 G.m.t. (11:20:22:04.184 MET). The maneuver was 213.8 seconds in duration with a ΔV of 365.8 ft/sec.

Entry interface occurred at 121:15:39:17 G.m.t. (11:20:58:35 MET), and entry was completed satisfactorily. Main landing gear touchdown occurred on EAFB concrete runway 22 at 121:16:10:43 G.m.t. (11:21:30:01 MET) on May 1, 2001. The nose gear touchdown occurred at 121:16:10:53 G.m.t. The drag chute was deployed at 121:16:10:45 G.m.t. The drag chute was jettisoned at 121:16:11:16 G.m.t. Wheels stop occurred at 121:16:11:33 G.m.t. The rollout was normal in all respects. The flight duration was 11 days 21 hours 30 minutes 1 second. The APU's were shut down 18 minutes 20 seconds after landing.

PAYLOADS AND EXPERIMENTS

The International Space Station (ISS) –6A mission was the ninth U. S. logistics and supply mission to the ISS. A successful rendezvous and docking to the ISS Stage 5A.1 occurred as planned on April 21, 2001. During the eight docked days, two extravehicular activities (EVAs) were performed to install the Space Station Remote Manipulator System (SSRMS), the ultra high frequency (UHF) antenna, and the direct current switching unit (DCSU) critical spare in addition to the removal of the early communications system antenna. On non-EVA days, activities such as middeck hardware transfer, utilization experiment transfers, water transfer, and unloading of the Multi Purpose Logistics Module (MPLM) were performed. The preflight planned 11-day mission duration was extended to 12 days to allow an additional docked day to resolve ISS computer problems.

Specific scenes of the Orbiter approach as well as the undocking, ISS assembly tasks, and EVA activities were documented using the IMAX three-dimension (IMAX3D) in-cabin camera and the IMAX cargo bay camera-3 dimension (ICBC-3D).

Two ISS reboost maneuvers were successfully completed using the Orbiter reaction control subsystem (RCS) to increase the ISS altitude to 219 by 206 nautical miles.

Following the successful completion of all major mission objectives, the Orbiter was undocked on April 30, 2001.

ISS OPERATIONS AND TASK PERFORMANCE

All of the ISS major mission objectives were accomplished during the STS-100 mission. A total of 27 tasks were completed with 10 tasks added during the mission. Eleven tasks were performed in support of subsequent flights. Two of the planned tasks were deleted and six planned tasks were deferred or not completed. Three major ISS hardware anomalies impacted the accomplishment of the ISS-6A mission tasks.

Nominal Tasks Completed

The flight priority tasks that were completed during the mission are as follows;

1. Berth the Spacelab Logistics Pallet (SLP) cargo element to the U. S. Laboratory module-to-truss structure attachment system (MTSAS) on the Laboratory Cradle Assembly (LCA), and apply SSRMS keep-alive power, which required connection of the flight support equipment grapple fixture (FSEGF) umbilicals;
2. Deployed, activated and completed the checkout of the SSRMS [required reconfiguration of the power data grapple fixture rigid umbilical (PDGF RU) to the U. S. Laboratory umbilicals and grapple of the Laboratory PDGF]
3. Performed water transfer [10 contingency water containers (CWCs) required – real-time assessment resulted in 14 CWCs being transferred];
4. Berth MPLM to Node 1 Nadir using the Shuttle RMS and activating and performing a checkout of the MPLM;
5. Transferred the following from MPLM and stowed in the ISS:
 - a. Assembly-related critical systems;
 - b. Critical maintenance and crew-related cargo; and
 - c. Category 1 of the priority transfer list.
6. Returned the MPLM to the payload bay using the Shuttle RMS;

7. Transferred the following from the Orbiter middeck and stowed in the ISS:
 - a. Assembly-related critical systems;
 - b. Critical maintenance and crew-related cargo; and
 - c. Middeck group 1 of the priority transfer list.
8. Returned the SLP/Launch Deployment Assembly (LDA) to the payload bay, and this required the disconnection and stowage of the FSEGF umbilicals on the SLP;
9. Removed the UHF antenna from the SLP and installed the antenna on the U. S. Laboratory;
10. Removed the starboard early communications (ECOMM) antenna and stowed the antenna for return with the Orbiter;
11. Transferred the DCSU from the payload bay and stowed the unit on the External Stowage Platform (ESP);
12. Removed the PDGF contingency fiber optics cable from the tool stowage assembly (TSA) and stowed the cable in the ISS;
13. Activated and performed a checkout of the UHF communications system;
14. Transferred the following from the MPLM to the U. S. Laboratory;
 - a. EXPRESS Rack 1;
 - b. EXPRESS Rack 2; and
 - c. Equipment required to install and checkout EXPRESS Rack 1.
15. Installed, activated and performed a checkout of EXPRESS Rack 1;
16. Transferred the EXPRESS active payloads and equipment required for installation;
17. Installed EXPRESS active payloads in EXPRESS Rack 1 and applied power within the 30 minutes constraint from deactivation to activation;
18. Transferred the following from the middeck and MPLM and stow in the ISS;
 - a. Remaining cargo;
 - b. EXPRESS equipment and utilization equipment; and
 - c. MPLM and middeck category 2 and 3 items on priority transfer list.
19. Transferred the return cargo from the ISS to the MPLM in accordance with the priority transfer list;
20. Performed an exchange of all the dosimeters throughout the ISS;
21. Performed Development Test Objective (DTO) 700-22, Crew Return Vehicle (CRV) Space Integrated Global Positioning System, Navigation System (SIGI);
22. Dismantled the Komparus unit for return to earth in the MPLM;
23. Recorded ISS 6A assembly-related mission scenes with the ICBC3D camera and recorded internal scenes in accordance with the Increment Definition Requirements Document (IDRD) Annex 3 requirements;
24. Installed the nitrogen (N₂)/oxygen (O₂) lines between pressurized mating adapter (PMA) 2 and the U. S. Laboratory;
25. Performed photogrammetry portion of DTO 261, ISS On-orbit Loads Validation;
26. Performed ISS reboost using the Orbiter reaction control subsystem; and
27. Performed a fly-around maneuver of the ISS after undocking.

Real-Time Task Additions

The following tasks were real-time additions to the task-performance requirements:

1. Installed Node 1 Nadir hatch cover and closed the flap. Performed an inspection of the window as well as photographing the window;
2. Verified the SLP SSRMS super-bolt return configuration during EVA 2;
3. Removed old ISS resistive exercise device (IRED) canisters;
4. Installed new IRED canisters and cables;
5. Installed treadmill vibration isolation system (TVIS) slats;

6. Removed and replaced the failed remote power control module (RPCM) V and return failed unit;
7. Sampled the two internal control systems (ITCSs);
8. Removed and replaced the failed command and control multiplexer/demultiplexer (C&C MDM) 1 and returned the failed unit;
9. Removed utility outlet panel (UOP); and
10. Performed a checkout of the medium rate communications outage records (MCOR)..

Tasks Performed in Support of Subsequent Flights

The following tasks were performed in support of subsequent flights:

1. Delivered the DCSU (Launch on need on STS-104/7A);
2. Removed starboard ECOMM antenna and related equipment;
3. Installed and performed a checkout of the UHF antenna;
4. Returned five airlock valves for precision cleaning and reflight on STS-104;
5. Installed N₂/O₂ lines between the PMA-2 and the U. S. Laboratory;
6. Delivered airlock spares, some of which are mandatory for airlock EVAs;
7. Delivered EXPRESS Racks 1 and 2;
8. Installed and performed a checkout of the SSRMS;
9. Removed and replaced the failed C&C MDM 1 and returned the removed MDM to the ground;
10. Returned the DTO 1214 flex hose assembly, flown on the ISS/2A mission, for precision cleaning; and
11. Delivered the Optical Time Domain Reflectometer (OTDR) and PDGF fiber optic contingency cable.

Mission 6A Tasks Deleted

The following two tasks were deleted:

1. Document the EXPRESS Rack transfers on video tape; and
2. Perform Beta Gimbal Assembly (BGA) latch operations during EVA 2.

Tasks Not Completed or Deferred

The following tasks were either not completed or deferred to a following flight:

1. One mandatory on-orbit checkout requirement (OCR) – SSRMS 7A airlock trajectory dry run;
2. Removal of the video signal conditioner (VSC) from the SLP FSEGF and stowage in the ISS;
3. Payload operations for Human Research Facility (HRF) bonner ball assembly/deployment, phantom torso, and dosimeter mapping instrument (DOSMAP);
4. Perform DTO 264, which is entitled SSRMS dynamic Model validation;
5. Perform three chemical archive samples of the U. S. Laboratory condensate; and
6. Some IMAX scenes that were lost because of poor lighting or timeline changes.

ISS ANOMALIES

Five ISS anomalies occurred during the STS-100 flight that affected Orbiter and crew operations. The following paragraphs discuss these anomalies. More detailed information may be obtained from the ISS Program Office or the ISS Mission Evaluation Room.

During the EVA task to remove the starboard ECOMM antenna, a wing nut connector fell apart. The wing nut debris (wing nut and three screws) was lost under the common berthing mechanism (CBM) thermal cover. The crew was unsuccessful in recovering the debris after opening the CBM petals and shroud access panels. A concern exists for the next mission in that the loose debris may damage the CBM and impact airlock installation.

The VSC failed to release from the SLP during EVA 2 and could not be transferred to the ISS as a prepositioned spare. A spare VSC will be flown on a later flight.

The redundant power string of the SSRMS would not power up through the PDGF during the second EVA. The P6/P8 connector (mated via EVA on STS-98) was removed by the EVA crew, inspected, and retorqued. Subsequent power up of the PDGF was successful and no future impacts are expected. This troubleshooting and repair required approximately two hours of EVA time.

The ISS Ku-band antenna experienced temperatures below the lower set points, thus requiring the antenna to be parked intermittently during planned operations. As a result, video coverage of powered payload activation in EXPRESS Rack 1 was reduced. Later in the mission, the lower set point temperature limit was reduced to allow more optimized Ku-band operation. The ISS will continue to assess the temperature limits and workaround to determine the implications to future ISS operations.

The C&C MDM 1, 2 and 3 began experiencing anomalies on flight day 7. There were no significant impacts to the planned mission activities, and the mission was extended a day to support the resolution of the MDM problems. Nominal SSRMS loaded checkout and nominal SLP handover were prevented because the robotics workstations were unable to download required files from the Mass Storage Device (MSD) in the C&C MDM. The SLP handover to the Shuttle RMS was performed via the single-joint mode and the MPLM reberth was performed once redundant C&C MDM capability was restored. The C&C MDM 1 was removed and replaced with a spare MDM. The C&C MDM was returned for postflight inspections and anomaly resolution. The SSRMS checkout activities that could not be performed during STS-100 are planned during normal operations to prepare for the airlock installation on STS-104/ISS 7A.

MULTI-PURPOSE LOGISTICS MODULE

The MPLM systems performed nominally. The configuration of the MPLM for this mission consisted of four Resupply/Return Stowage Platforms (RSPs), four Resupply stowage racks (RSRs), and two EXPRESS Racks (1 and 2).

TRANSFER OPERATIONS

The transfer operations were completed very successfully and the weight of the transfers from the MPLM and to the MPLM are as shown in the following table.

Description	Weights, lb	Percentage completion
MPLM Stowage to ISS		
Total Cargo	6346	100
EXPRESS Racks	2457	100
Stowage Items in RSR's and RSP's	3889	100
ISS Stowage Items to MPLM	1608	119

IMAX THREE-DIMENSION CAMERA OPERATIONS

The objective of the IMAX3D in-cabin camera and the ICBC-3D payload bay camera was to document specific scenes of the Orbiter approach as well as the Orbiter undocking, ISS assembly tasks, and EVA activities. Timeline constraints and ISS anomalies impacted the accomplishment of several specific scenes; however, the IMAX team expressed their appreciation for the perseverance and commitment of the Shuttle crew, ISS Expedition 2 crew, and the ground teams in performing the IMAX filming on STS-100/6A.

The IMAX3D camera is prepositioned on the ISS while the film and support hardware were stowed in the middeck and MPLM to support IMAX3D scene requirements. A total of seven rolls of exposed IMAX3D film were returned on STS-100, and one roll of exposed film from onboard the ISS. Based on the number of available rolls of film, the total number of potential scenes was 31. One interior roll of film was accidentally exposed to light, causing the loss of three potential scenes. The total number of scenes actually shot during this mission was 28 scenes. However, two of these scenes are in place of two planned scenes of the SLP Unberth/maneuvers that were missed. A total of 26 scenes from the pre-mission planned scene list were captured. Based on the exposure of 26 planned scenes out of the total potential scenes, the payload mission success was 84 percent.

The ICBC3D filming captured a total of 14 scenes, which were based on the planned list of available scenes. However, one scene is expected to be unusable because of an incorrect focus setting. Based on 13 usable scenes out of a potential 14 scenes, the payload mission success was 93 percent.

VEHICLE PERFORMANCE

SOLID ROCKET BOOSTERS

Analysis of the Solid Rocket Booster (SRB) systems data indicated nominal performance of all SRB subsystems including the new C-Band Controller system, which was flown for the first time in the Space Shuttle Program. One in-flight anomaly was identified from the evaluation of the data.

The prelaunch countdown was normal and no SRB Launch Commit Criteria (LCC) or Operations and Maintenance Requirements And Specifications Document (OMRSD) violations occurred.

At liftoff, there were no stud hang-ups based on Orbiter accelerometer data. Both SRB's were successfully separated from the vehicle at approximately T+125 seconds.

Visual tracking indicated a normal descent and splash down. All 48 sea-water-activated release (SWAR) links (8 links per parachute) fired satisfactorily.

The C-band controller was flown for the first time on this flight and its performance was nominal.

Both SRB's were recovered and returned to KSC for inspection, disassembly and refurbishment. The inspection revealed that both SRBs were in excellent condition except for one area discussed in the following paragraph.

The postflight inspection revealed 6 to 8 pounds of unburned propellant in the booster separation motor (BSM) located in the lower right position of the forward BSM cluster on the right SRB (Flight Problem STS-100-B-01). An anomaly investigation team was formed. The most likely cause of the condition was moisture intrusion; however, the investigation was ongoing at the writing this report.

REUSABLE SOLID ROCKET MOTORS

All Reusable Solid Rocket Motor (RSRM) systems performed satisfactorily during the countdown and the ascent phase of the mission. No LCC or OMRSD violations occurred during the countdown phase. No in-flight anomalies were identified during the review of the data. However, numerous (55) voids were observed in the left-hand nozzle joint 3 room temperature vulcanizing (RTV) material. This is the highest number of voids seen in this joint thus far in the Space Shuttle Program. No heat effects to the RTV or phenolics were observed in any of the voids during the postflight inspection.

All RSRM temperatures were maintained within acceptable limits throughout the countdown. The motor performance parameters were all within contract end item (CEI) specification limits.

The field joint heaters operated for 13 hours 33 minutes during the final launch countdown. Power was applied to the heating elements an average amount of time (51 percent) during the LCC time frame. All field joint heaters operated as expected.

Reconstructed propulsion performance parameters at the 68 °F propellant mean bulk temperature (PMBT) are shown in the table on the following page.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 68 °F		Right motor, 68 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10 ⁶ lbf-sec	65.51	65.41	65.72	65.79
I-60, 10 ⁶ lbf-sec	175.35	175.45	175.84	176.13
I-AT, 10 ⁶ lbf-sec	296.96	296.62	297.09	297.26
Vacuum Isp, lbf-sec/lbm	268.5	268.2	268.5	268.7
Burn rate, in/sec @ 60 °F at 625 psia	0.3700	0.3703	0.3706	0.3709
Event times, seconds ^a				
Ignition interval	0.232	N/A	0.232	N/A
Web time ^b	109.0	109.0	108.7	109.0
50 psia cue time	119.0	118.9	118.7	118.0
Action time ^b	121.2	121.6	120.9	120.6
Separation command	123.4	-	123.4	-
PMBT, °F	68	68	68	68
Maximum ignition rise rate, psia/10 ms	90.8	N/A	90.8	N/A
Decay time, seconds (59.4 psia to 85 K)	3.1	3.6	3.1	3.6
Tailoff imbalance impulse	Predicted		Actual	
differential, Klbf-sec	N/A		561.0	

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).

The igniter joint heaters operated for 18 hours 27 minutes during the final launch countdown. Power was applied to the heating elements 68 percent of the time during the LCC time frame of the final launch countdown to keep the igniter joints in their normal operating range.

It was necessary to activate the aft skirt purge to maintain the nozzle/case joint temperatures above the minimum LCC temperature. The purge was also necessary to thermally condition the flex bearing. During the LCC time frame, the nozzle/case joint sensor temperatures ranged from 78 to 83 °F on both motors. The final flexible bearing mean bulk temperature was determined to be 79 °F.

Data indicate that the flight performance of both RSRM's was within the allowable performance envelopes, and was typical of the performance observed on previous flights. The predicted PMBT was 68 °F.

Delivered burn rates were 0.3700 and 0.3706 inch/second for the left and right motors, respectively. The maximum trace shape variation of pressure versus time during the 62 to 80 second time frame was calculated to be 0.332 percent at 64.5 seconds (left motor) and 0.337 percent at 63.5 seconds (right motor). These values were well within the 3.2 percent allowable limits.

The launch pad environment showed ambient temperatures between 41 °F and 50 °F during the LCC time frame of the countdown. Field joint heaters operated for 13 hours 41 minutes during the final launch countdown.

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

EXTERNAL TANK

All External Tank (ET) objectives and requirements associated with propellant loading and flight operations were met. 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 monitored and performed properly. No ET LCC or OMRSD violations occurred during the countdown.

The observed thermal protection system (TPS) cracks were acceptable. No unexpected ice/frost formations were observed during the countdown. There was no observed ice or frost on the acreage areas of the ET. Normal quantities of ice or frost were present on the liquid oxygen (LO₂) and liquid hydrogen (LH₂) feedlines.

The pressurization systems functioned properly throughout engine start and flight. The minimum LO₂ ullage pressure experienced during the ullage pressure slump was 13.6 psid.

The 35mm umbilical well camera film showed the ET separation bolt in the External Tank/Orbiter (EO) -3 (aft) fitting, on the LO₂ side of the ET, was not fully retracted into the shaft of the ET ball joint. Determining the motion of the bolt by comparing successive frames was made. The EO-3 bolt appeared similar to the protruded EO-3 bolt seen on the STS-106 umbilical well camera film. Further analysis will be conducted to ascertain whether or not the bolt did have lateral motion and if no motion is detected, measurements of how much the bolt is protruding out of the fitting will be conducted.

ET separation was performed and since it occurred within expected tolerances, entry and break-up occurred within the expected footprint approximately 63 nmi. downrange from the preflight predicted impact point.

SPACE SHUTTLE MAIN ENGINES

The prelaunch operation for the Space Shuttle main engines (SSME's) was satisfactory. The SSME's performed satisfactorily throughout ascent with no in-flight anomalies identified from the data. The flight-derived specific impulse (I_{sp}) was approximately 0.8 second higher than predicted. The Block IIA engines, which were on this vehicle, have typically delivered approximately 0.8 second higher I_{sp} than predicted from ground testing.

The main propulsion system (MPS) Space Shuttle main engine (SSME) 1B 750-psia regulator outlet pressure was 729 psia for about 2 minutes during ascent, from 109:18:42 to 109:18:44 G.m.t. (00:00:02 to 00:00:04 MET) (Flight Problem STS-100-V-02). The regulator recovered to within the OMRSD File IX requirement of 730 to 790 psia as the gaseous helium bottle pressure dropped and the ambient pressure decreased. There was no mission impact. This problem is discussed in greater detail in Main Propulsion Subsystem section of this report.

Main engine cutoff (MECO) occurred 504.9 seconds after SRB ignition. The commanded maximum dynamic pressure (Max Q α) throttle-down was in a single throttle step 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.

The right SRB SRSS system A and B signal strengths went below the range safety minimum requirement of -85 dBm approximately 109 seconds after liftoff. The lowest observed signal strengths were -91 dBm and -85.3 dBm, respectively for the A and B systems. This condition was not a problem as the low signal-strength condition is expected on high-inclination flights. The cause is plume attenuation and right SRB shading.

ORBITER SUBSYSTEMS PERFORMANCE

Main Propulsion Subsystem

The main propulsion system (MPS) operated satisfactorily, and no LCC or OMRSD violations occurred during the launch countdown and flight. The overall prelaunch and ascent system performance was nominal.

No significant hazardous gas concentrations were detected prior to liftoff. The maximum hydrogen concentration level in the Orbiter aft compartment, with the normally elevated system backpressure used for fast-fill, was 177 ppm (corrected for mass spectrometer drift). This compares favorably with previous data for this vehicle.

The MPS Space Shuttle main engine (SSME) 1B 750-psia regulator outlet pressure failed to remain in its control band when the pressure fell to 729 psia for about 2 minutes during ascent, from 109:18:42 to 109:18:44 G.m.t. (00:00:01:18 to 00:00:03:16 MET) (Flight Problem STS-100-V-02). The regulator recovered to within the OMRSD File IX requirement of 730 to 790 psia as the gaseous helium bottle pressure dropped and the ambient pressure decreased. There was no mission impact.

The performance of the same regulator over the last 5 flights (STS-89, STS-88, STS-99, STS-97 and STS-100) was reviewed. This period corresponds to the time since the last Orbiter major modification (OMM) period when the pressure transducer used to measure the outlet pressure was last calibrated. In that time, the outlet pressure reading of the regulator at the same point in the ascent profile has been dropping. The overall profile of the regulator doesn't change noticeably, that is, the shift in pressure occurs at all flow rates and ambient pressures. From these data, it was not possible to rule out drift of either the transducer output or the regulator performance. Postflight troubleshooting of the regulator and pressure transducer was performed. The problem was isolated to a shift in the pressure transducer and it was replaced.

Data indicate that the LO_2 and LH_2 pressurization systems performed as planned. Engine inlet net positive suction pressure (NPSP) requirements were met throughout the flight. All three flow-control valves performed nominally, and all pneumatic valve cycles were within the timing requirements. The gaseous oxygen (GO_2) fixed-orifice pressurization system performed as predicted. The data from the engines and MPS closely matched the actual ET ullage pressure measurements. Helium system performance for the SSME and pneumatic helium systems was nominal. Entry helium usage was 61.36 lbm, which is within the requirements.

Reaction Control Subsystem

The reaction control subsystem (RCS) performed satisfactorily throughout the mission. One in-flight anomaly was noted in the evaluation of the data, and it is discussed in a later paragraph.

During ascent at SRB separation, the RCS window protect maneuver was performed at 109:18:42:44.5 (00:00:02:03.5 MET) and was terminated 2.08 seconds later. Initial indications were that the windows were clearer than what has been seen on previous flights.

The RCS was used to perform five translation firings in support of the rendezvous with the ISS, two RCS reboost maneuvers and a final separation maneuver from the ISS. The overall altitude increase delivered during the two separate reboost maneuvers was approximately 6.1 nmi. The following table reflects the major RCS maneuvers performed during the mission.

RCS MANEUVERS

Maneuver	Time, G.m.t./MET	ΔV , ft/sec	Firing time, sec	Orbit, nmi.
NCC (RCS)	111:10:19:42 00:15:39:01	1.3	6.0	202.0 by 203.7
MC-1 (RCS)	111:11:37:24 01:16:56:42	1.6	5.0	203.7 by 208.1
MC-2 (RCS)	111:12:14:18 01:17:33:36	2.0	9.0	204.4 by 209.0
MC-3 (RCS)	111:12:31:18 01:16:41:12	0.8	3.0	204.3 by 209.3
MC-4 (RCS)	111:12:41:18 01:18:00:36	0.3	1.0	199.1 by 206.1
First Reboost Maneuver	113:19:50:54 04:01:09:54	7.41	59 minutes 36.4 seconds	205.5 by 212.2
Second Reboost Maneuver	117:11:20:43 07:16:40:01	15.9	60 minutes	206 by 219
Final Separation	119:18:27:26.1 09:23:46:44.1	3.0	12.16	206 by 218

A total of 3896.8 lbm propellants (2404.1 lbm - oxidizer, 1492.7 lbm - fuel) were used from the RCS during the rendezvous mission with the International Space Station. In addition, a total of 1664.7 lbm of the orbital maneuvering subsystem (OMS) propellants were used by the RCS during interconnect operations. The primary RCS thrusters had 4098 firings and a total firing time of approximately 961.78 seconds. The vernier RCS thrusters had 6833 firings and a total firing time of 29679.64 seconds.

The first ISS reboost maneuver used RCS thrusters L3A and R3A, and the primary RCS thruster pulse widths were 160 msec, and the firing period was 11.6 seconds from start of one pulse firing until the next firing. Breaks for attitude maintenance limited the maneuver to 243 pulses. Attitude maintenance was performed with the vernier thrusters. The aft down-firing vernier thrusters had a typical duty cycle of 8.08 seconds on and 3.56 seconds off.

The second ISS reboost maneuver scheduled for flight day 7 was delayed because of the ISS command and control (C&C) computer problems. Other Orbiter maneuvers which similarly require the Orbiter to take over attitude control of the mated stack, such as those required to achieve Orbiter water dump attitudes, were also delayed because the ISS commanding issue

made the return of attitude control to ISS after the maneuvers problematic. Ultimately, the mission was extended one day as a result of the ISS C&C computer problems.

The second ISS reboost maneuver used RCS thrusters F5R, F5L, L5D and R5D. There was no predefined thruster duty cycle, and the thrusters were turned off as necessary to maintain attitude within the 5-degree dead-band.

In preparation for undocking, the Orbiter assumed attitude control of the mated stack with the digital autopilot (DAP) configured to automatic at 119:16:48:55 G.m.t. (09:22:07:55 MET). Forward RCS thrusters F1U, F2U, and F3U were reselected. Low chamber pressure (Pc) of approximately 50 psi was observed during three pulses using RCS vernier thruster R5D beginning at 120:16:50 G.m.t. (09:22:09 MET) (Flight Problem STS-100-V-04). The low Pc continued throughout the fly-around, separation and continued to be present during each firing of that thruster. The redundancy management (RM) did not deselect the thruster since the low-level limit for RM deselection is 26 psia. A thorough data review revealed low Pc during firings of R5D earlier in the mission. During longer-duration firings, the chamber pressure gradually increased to the nominal range. The observed Pc signature was indicative of combustion byproducts blocking the Pc sense tube, a condition that has been seen in past missions. To avoid a possible fail-off of the thruster that would result in waking the crew, the Orbiter was configured for attitude control using the primary thrusters during crew sleep. A return to vernier operations was performed at the start of FCS checkout. This thruster continued to perform in the manner discussed for the remainder of the mission. Following the mission, the decision was made to remove and replace the thruster.

Successful undocking from the ISS was completed at 119:17:34 G.m.t. (09:22:53 MET). The initial separation from the ISS was performed with a +Z pulse at 119:17:34 G.m.t. (09:22:53 MET). Final separation was accomplished with a 12.16 second -X pulse of thrusters F1F and F2F. The resulting ΔV was 3.0 ft/sec with a resulting orbit of 218 by 206 nmi.

Following flight control subsystem (FCS) checkout, the RCS hot-fire was performed nominally. The hot-fire began at 120:10:42 G.m.t. (10:16:02 MET) and ended at 120:10:50 G.m.t. (10:16:10 MET). A review of thruster chamber pressure data confirmed that all of the firings were satisfactory, with each thruster performing at least two pulses of 320-millisecond duration.

Orbital Maneuvering Subsystem

The OMS performed satisfactorily throughout the mission. No in-flight anomalies were identified from the evaluation of the data. The OMS inlet pressures, chamber pressures and regeneration jacket temperatures for both engines were as predicted, verifying nominal engine performance. All eight OMS maneuvers were performed accurately, and OMS operation was nominal during all the maneuvers. The table on the following page lists the OMS maneuvers performed during the flight.

A total of 22435 lbm (14,049 lbm - oxidizer and 8386 lbm - fuel) of OMS propellants were consumed during the mission. Of this total, the OMS provided 1664.7 lbm of propellants to the RCS during interconnect operations.

The OMS assist maneuver was performed following SRB separation. The OMS 2 maneuver was performed at 109:19:24:24.37 G.m.t. (00:00:43:42.3 MET). The deorbit maneuver for the first Edwards Air Force Base (EAFB) landing opportunity was performed on orbit 186.

OMS MANEUVERS

Maneuver	Time, G.m.t./MET	ΔV , ft/sec	Firing time, sec	Orbit, nmi.
OMS Assist Dual engine	109:18:42:55.6 00:00:02:13.7	-	102.3	-
OMS 2 Dual engine	109:19:24:24.37 00:00:43:42.3	81.9	53.8	85.6 by 178.7
OMS 3 (NC1) Dual engine	109:22:23:19 00:03:42:37	80.3	52.5	130.8 by 178.3
OMS 4 (NC2) Right engine	110:10:42:38 00:16:01:56	7.8	10.4	133.4 by 189.2
OMS 5 (NC3) Dual engine	110:20:52:12 01:02:11:30	120.3	77.4	177.8 by 204.2
OMS 6 (NC4) Dual engine	111:09:44:53 01:15:04:11	42.2	27.4	202.7 by 204.1
OMS 7 (TI) Left engine	111:11:17:25 01:16:36:43	10.2	12.8	204.1 by 208.8
Deorbit Dual engine	121:15:02:47.17 11:20:22:04.18	365.8	212.5	-

Power Reactant Storage and Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem performance was nominal throughout the STS-100 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. The PRSD subsystem supplied the fuel cells with 2627 lbm of oxygen and 331 lbm of hydrogen for the production of 3847 kW of electrical energy. In addition, the environmental control and life support system (ECLSS) was supplied 179 lbm of oxygen for life support.

PRSD tanks 4 and 5 were depleted to residual quantities during the mission. The Orbiter landed with 1119 lbm of oxygen and 126 lbm of hydrogen remaining in the PRSD subsystem. A 88-hour mission extension capability existed at landing, based on the PRSD oxygen (limiting reactant) tank landing quantities and an average power level of 13.5 kW. At an extension-day power level of 12.9 kW, a 92-hour mission extension capability was available.

After the first cabin depressurization, when the high oxygen flow rate was stopped, both oxygen manifold pressures increased above the nominal operating pressure. The oxygen manifold 1 pressure increased to 974 psia and manifold 2 increased to 964 psia. Neither reached the 975 psia cracking pressure of the manifold relief valve. Oxygen manifold pressure increases like what occurred in this instance are common after cabin depressurizations or repressurizations when the cryogenic oxygen tank quantity is high. The oxygen tank quantity was 84 percent when this instance occurred.

Fuel Cell Powerplant Subsystem

The overall performance of the fuel cell powerplant (FCP) subsystem was nominal during the mission. There were no OMRSD or LCC violations, nor were any in-flight anomalies found during the analysis of the data. The average power level and load was 13.5 kW and 437 amperes. The fuel cells produced 2958 lbm of potable water and 3847 kWh of electrical energy while using 2627 lbm of oxygen and 331 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 0.05 V above the predicted for fuel cell 1, 0.10 V above predicted for fuel cell 2, and 0.30 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 1.1 V for fuel cell 1, 1.2 V for fuel cell 2, and 0.9 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 5.7 days of the mission. The B system was selected at that time and it operated for the remainder of the mission.

STS-100 was the first flight of fuel cells incorporating cells manufactured using the drip-fill process. This new process drips the electrolyte solution into the cell-unitized electrode assembly, replacing the previous immersion process. This new development minimizes the initial electrolyte contact with the cell fiberglass/epoxy frame material, which helps to reduce the formation of corrosion products that contaminate the electrolyte and reduce cell voltage. This new development also mitigates electrolyte migration from the plate seals to the power section exterior and manifold area. This minimizes formation of potassium carbonate solids that may cause port plugging. All newly manufactured power sections incorporate this newly developed process.

Auxiliary Power Unit Subsystem

The auxiliary power unit (APU) subsystem performed nominally during the mission with no in-flight anomalies or significant problems identified. One minor problem was identified and it is discussed in a following paragraph. The APU run times and fuel consumption for the mission are shown in the following table.

APU RUN TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (S/N 405)		APU 2 (S/N 303)		APU 3 (S/N 409)	
	(a) (b) Time, Min:sec	Fuel consumption, lb	(a) Time, Min:sec	Fuel consumption, lb	(a) Time, min:sec	Fuel consumption, lb
Ascent	21:34	49	21:55	55	22:06	53
FCS checkout					03:44	12
Entry ^a	63:53	125	92:41	193	26:32	62
Total	85:27	174	114:36	248	52:22	127

^a APUs were shut down 18 minutes 20 seconds after landing.

The FCS checkout was performed with no problems identified. APU 3 was used to support the checkout with a start time of 120:09:41:08 G.m.t. (10:15:00:26 MET). The run time was 3 minutes 44 seconds, and 12 pounds of fuel were used during the APU 3 operation. APU 3 performance was nominal. The total run time was too short to require spray cooling from the WSB.

The APU 2 exhaust gas temperature (EGT) 2 indication was slightly erratic during ascent and more erratic during entry. The sensor was slightly erratic during the entry of STS-97 and STS-99. The EGT 1 sensor was also slightly erratic during entry as well as during entry of the STS-97 mission. This signature is a common occurrence for this sensor, which is located in a

high-vibration, high-temperature environment. The replacement of both EGT sensors is planned.

Hydraulics/Water Spray Boiler Subsystem

The hydraulics/WSB subsystem performed satisfactorily throughout the mission. One in-flight anomaly was identified from the analysis of the data and it is discussed in a following paragraph.

STS-100 was the seventh flight in which the new WSB water additive [Propylene Glycol Monomethyl Ether (PGME)] was used to preclude ascent freeze-ups. The STS-100 mission was the second flight in which the additive was loaded into all three WSB system cores during the turnaround flow at KSC to preclude ascent under-cooling conditions from occurring.

Hydraulic performance during ascent, FCS checkout and entry was nominal. There were no unexpected decreases in reservoir quantities, indicating no gross leaks in the systems. Priority valve cracks at APU activation were all within the 1-second specification limit, and reseats on all three systems at APU shutdown were also within the specification limit (>2675 psia).

The water spray boilers (WSBs) were configured to the B controllers at 110:17:21 G.m.t. (00:22:40 MET). After that time, the WSB 3 core, water tank, and gaseous nitrogen (GN₂) tank temperatures increased sharply from 72 to 78 °F within three hours after switching to controller B. The GN₂ tank temperature subsequently increased to 84 °F following 76.6 hours of operation on controller B (Flight Problem STS-100-V-03). It was suspected that the most likely cause of the GN₂ tank temperature rise was a failure in the B controller circuitry, which either powered the GN₂ valve solenoid continuously or partially powered the WSB 3 boiler heaters. At 113:22:18 G.m.t. (04:03:37 MET), the WSB 3 A controller was selected and system temperatures returned to nominal values for the remainder of the mission.

A plan was developed for the management of the system for the remainder of the mission. WSB 3 remained on the A controller (there was no constraint to continuous operation of the WSB feedline heater) for the remainder of the mission. Also, since a failure of the GN₂ shutoff valve or hydraulic bypass valve could not be ruled out, APU 3 was started late during entry (at terminal area energy management (TAEM) interface). In the event of an additional APU/hydraulic system failure, APU 3 could have been started as early as Mach 18 with a failed closed GN₂ shutoff valve. Nominal WSB 3 spray cooling began after landing.

If the controller B failure involved control of the boiler heaters, it is postulated that the failure was limited to powering only one of the heaters in a failed-on condition. The electrical schematics show that one of the three 11.5-watt boiler core heater patches can be solely affected by the failure of a single controller driver. This particular boiler heater patch is located approximately 150 degrees around the circumference of the boiler core from the core temperature sensor. The core temperature sensor monitors the core heater operation and provides feedback to the core and tank heater control logic.

A KSC troubleshooting plan was developed. It consisted of instrumenting WSB components with temperature sensors and powering the B controller. The B controller (likely source of failure) will be replaced. The GN₂ shutoff valve, the hydraulic bypass valve, water tank heaters and core heaters were instrumented and monitored to determine the source of the heat. It was determined that the source of the heat was power being supplied continuously to the GN₂ valve solenoid. Inspection/testing of the water spray valve that is heated by the feedline heater when on the A controller, is also being planned. The A controller was powered for the ferry flight to KSC.

Electrical Power Distribution and Control Subsystem

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

Orbiter Docking System

The Orbiter Docking System (ODS) performed satisfactorily throughout the mission.

The ODS valves were used during the docked operation and for extravehicular activities (EVAs). The Orbiter was docked with the ISS pressurized mating adapter 2 (PMA 2), the vestibule was pressurized from the ISS, and post-docking vestibule leak check was performed, all with nominal results.

The vestibule depressurization valves were used to depressurize the vestibule to vacuum before undocking and the pre-undocking vestibule leak check was performed with nominal results. The external airlock waterline heater reconfiguration from string A heaters to string B heaters was performed as part of the in-flight checkout. String C heaters were not required. The active system monitor parameters indicated normal outputs throughout the duration of the flight.

The ODS ring extension was performed at 110:22:05 G.m.t. (01:03:24 MET). System performance was normal and power-on time was approximately 15 minutes. The ring was driven to its initial position; however, the power-off steps were initiated too quickly and the system did not mode the slip clutch to 'slip', which is required for docking. The ground controllers noted the condition, and the crew performed the steps required to correct the condition. This event occurred once before on STS-92. The recovery steps used were appropriate, and there were no hardware issues.

The first physical contact of the Orbiter with the ISS occurred at 111:13:58:47.947 G.m.t. (01:19:18:05.959 MET) and was indicated by ballscrew 3 linear advance. Capture occurred at 111:13:58:48.053 G.m.t. (01:19:18:06.065 MET). The ring was out of alignment for 14 seconds after capture occurred. The high and low energy brakes activated 5 seconds after capture occurred. However, as the first ring retraction progressed, the ring went out of alignment and exceeded the 4 percent linear advance difference allowed by the flight rules. Because of that, ring retraction was stopped after 38 seconds. Analysis of linear advance difference data has shown that petals 1 and 2 were lagging petal 3. Based on previous experience, it appears that the high-energy dampers (HEDs) of petals 1 and 2 became mechanically stuck and caused the misalignment. In previous flights, instances occurred where one HED mechanically stuck. This is the first occurrence of two HEDs becoming mechanically stuck. During the 3 minute 8 second waiting period before starting ring retraction, the system returned to alignment. The crew initiated the second ring retraction at 111:14:05:24.071 G.m.t. (01:19:24:45.083 MET), and the successful operation of the system retraction stopped aft 2 minutes 47 seconds.

Successful undocking from the ISS was completed at 119:17:34 G.m.t. (09:22:53 MET).

Atmospheric Revitalization Pressure Control Subsystem

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

Cabin pressure at the beginning of the mission was allowed to bleed down. The first cabin depressurization was performed at 110:17:37 G.m.t. (00:22:57 MET). The Shuttle was docked to the ISS, the docking interface leak check was performed and then, the Orbiter pressure was equalized with the pressurized mating adapter (PMA). The equipment transfer to the PMA was completed, and cabin pressure was maintained at 10.2 psia to support the first EVA. The external airlock-to-vestibule hatch was closed and after crew egress for the first EVA, the cabin pressure was raised to 14.7 psia. Pressure was maintained at 14.7 psia during ISS ingress at 113:09:24 G.m.t. (03:14:44 MET). The hatch at the top of the external airlock was again closed in preparation for the second EVA. The cabin was depressurized to 10.2 psia at 113:20:00 G.m.t. (04:01:20 MET). After crew egress for the second EVA, the cabin was repressurized to 14.7 psia.

The ARPCS was configured to system 1 for the first half of the mission and to system 2 for the remainder of the mission. A complete in-flight checkout of PCS 2 was performed with satisfactory results. The active system monitor parameters indicated normal outputs throughout the duration of the flight.

Atmospheric Revitalization Subsystem

The atmospheric revitalization subsystem (ARS) performed nominally throughout the duration of the flight, with the exception of the B fan water separator problem that is discussed in a later paragraph.

During the launch phase, the crew compartment temperature was 76.6 °F and climbed to 77.4 °F three minutes into the flight where it remained constant throughout the remainder of ascent. The cabin humidity peaked to 41.6 percent at 5 minutes and 2 seconds after launch. The heat exchanger outlet air temperature peaked to 77.37 °F at approximately 10 minutes 26 seconds into the flight.

The partial pressure oxygen (ppCO₂) peaked to 5.89 mmHg when cabin pressure was at 14.7 psia. During 10.2-psia cabin pressure operations, the ppCO₂ was maintained below the flight rule limit for acceptable CO₂ concentration.

Cabin humidity averaged 33.0 percent for the flight, peaking to 46 percent during the pre-sleep period of flight day 11.

During the landing phase of the flight, the heat exchanger outlet temperature peaked to 59.3 °F 11 minutes after wheel stop, with the cabin air temperature peaking to 74.1 °F 16 minutes after wheel stop. The cabin humidity peaked near 48 percent approximately 13 minutes after wheel stop.

After installing a contingency water container (CWC) for condensate collection at 116:10:32 G.m.t. (06:15:51 MET), the crew reported the presence of about 2 oz. of water at the humidity separator B air-outlet screen. The water was cleaned up, and no additional water was observed during a subsequent check a few hours later on the same flight day. However, during a check conducted on the next flight day at 117:10:28 G.m.t. (07:15:47 MET), the crew reported that about the same quantity of water had again accumulated at the outlet screen. This indicated a possible humidity separator B water-carryover problem. In response to this possibility, the humidity separator system was switched from B to A. The crew reported that there was no free water at the air outlet screen following the switchover to the A separator. This was the fifth flight of this water separator assembly, which was installed prior to STS-89 following the last OMM period. Flight data indicated that the water separator interfacing systems were operating within their normal ranges when the water carryover occurred. It is

systems were operating within their normal ranges when the water carryover occurred. It is believed that the internal components of the fan separator assembly may be contaminated with debris causing the water to carryover. The hardware will be replaced with a refurbished unit.

The Orbiter condensate separation (OCS) hardware was partially manifested on STS-100. Approximately 2 weeks prior to launch, the water dispense valve assembly (WDVA) was removed from the mission manifest because the hardware was considered not necessary since the solid urine pretreat assembly (SUPA) would not be flown. However, during the mission, the ISS lost the capability of maneuvering and the Orbiter was not able to be oriented to the dump attitude, therefore making it necessary to collect condensate or offload wastewater from the waste tank. Use of components borrowed from the contingency water kit made it possible to collect condensate in a CWC. Condensate collection was performed for approximately 4 hours and 45 minutes after it was terminated. The same condensate CWC was used to offload wastewater from the waste tank.

Active Thermal Control Subsystem

The active thermal control subsystem (ATCS) performed satisfactorily during the mission with the exception of one in-flight anomaly that is discussed in a following paragraph.

The flash evaporator subsystem (FES) performed nominally during the ascent. No pre-evaporative cooling was observed prior to the FES being activated by the general purpose computer (GPC) about 2 minutes 15 seconds after liftoff. No FES outlet temperature oscillations were observed. About 16 minutes into the flight, the FES controller was configured from primary A GPC to primary A command. At 109:20:04 (00:01:24 MET), the radiator flow control valves of both Freon coolant loops (FCLs) were configured to radiator flow. A few seconds later, the FES control was changed from primary A command to primary B command in preparation for accumulating water in tanks A and B for water transfer to the ISS.

At 110:09:01 G.m.t. (00:14:21 MET), it was noted that the FES feedline B zone 3 temperature had dropped down to 53 °F. The zone was heated at that time by the string 1 heater, which has a thermostat set point of 68.9 °F (Flight Problem STS-100-V-01). Normally, the heater causes the sensor to cycle on between 67 and 70 °F. A further evaluation of the measurement showed that the heater might not have cycled after launch. The data indicate that the string 1 heater for zone 3 had failed off and that environmental and feed-water temperatures were the only factors affecting the line temperature. Switching to the system-2 heater was planned before the temperature reached 43 °F. At 110:12:02 G.m.t. (00:17:21 MET), the crew configured the feedline B heaters from string 1 to string 2. No anomalous behavior was observed after the switch to string 2. No mission impact occurred as a result of this problem. Postflight, the problem was isolated to a broken wire at a ground point.

At 117:13:42 G.m.t. (07:19:02 MET), the FES primary A controller was deactivated so that the duct heaters could be powered off to maximize cryogenic consumables. The duct heaters were deactivated 30 minutes later. The duct heaters were powered back on at 118:11:11 G.m.t. (08:14:31 MET) in preparation for the second FES water dump.

Two FES water dumps were performed. The first was conducted from 112:11:12 G.m.t. (02:16:32 MET) through 112:16:44 G.m.t. (02:22:02 MET) using the primary B controller. The second was conducted from 118:11:04 G.m.t. (08:16:24 MET) through 118:23:53 G.m.t. (09:05:13 MET) using the primary A controller. The second FES water dump of the mission was terminated by having the crew switch the radiator controller from high setpoint to normal setpoint without powering off the FES primary A controller. The FES water dump had been running for almost 13 hours. At the end of the water dump, the radiators were easily able to

were relatively cold. About 1 minute later, the FES outlet temperatures began to drop below 38 °F. The FES outlet temperatures remained under 37 °F for about 30 seconds and bottomed out at 35 °F at approximately 118:23:55:32 G.m.t. (09:05:14:50 MET). The crew was instructed to perform this FES water dump termination using the described method with concurrence from the Mission Evaluation Room (MER). The method was a deviation from nominal procedures. This under-temperature shutdown was confirmed later when the FES failed to come out of standby. The cause of the shutdown was the FES controller could not adjust quickly enough to the cooling transient from the radiators, thus resulting in an under-temperature condition. The reason this procedure was adopted was because the Mission Control Center (MCC) was trying to minimize crew interaction during the pre-sleep period. The FES water dump termination was one of the last MCC commands voiced to the crew before voice blackout for the sleep period. The standard procedure would have involved a crewmember standing by the L1 panel for a short period of time being prepared to restart the FES so that the FES could remain active during the sleep period. It was understood by MCC and also the MER expressed that the probability that an under-temperature shutdown could occur, but that the impact of it was considered to be minimal for this period in the mission. Because the attitude enabled the radiators to cool adequately for most of the next 12 hours, it was believed that a restart could be put off until the crew awakened the next day. At 119:07:53 G.m.t. (09:18:13 MET), the FES primary A controller was restarted while the radiators were in control. Because the attitude allowed good radiator cooling, the FES did not come out of standby until 119:13:49 G.m.t. (09:19:09 G.m.t.). The FES performed nominally for the rest of the mission.

The radiator coldsoak was initiated at 121:08:08 G.m.t. (11:13:28 MET). The radiator bypass/FES checkout was completed at 121:10:46 G.m.t. (11:16:06 MET). The checkout was performed later, and resulted in a 2 hour 30 minute coldsoak because of the one revolution waive-off of the first KSC landing opportunity and the eventual plan to land at Edwards AFB.

At 121:14:48 G.m.t. (11:20:08 MET), the FES shut down under primary B GPC controller because the crew accidentally closed the feedline B isolation valve thereby cutting off the water supply to the FES. After the MCC called, the crew opened the feedline B isolation valve and then successfully restarted the FES in primary B GPC control.

At 121:15:59 G.m.t. (11:21:19 MET), about 11 minutes before nose landing gear touchdown, the radiators were placed in radiator-flow mode under the automatic system B controllers so that the radiator coldsoak could be used. The radiators were placed in high setpoint control at in preparation for ammonia boiler subsystem (ABS) activation. Ten minutes after wheels stop, the ABS was activated using the system A primary controller. At 121:16:59 G.m.t., the ABS was deactivated and the ground support equipment (GSE) cooling was started.

Supply and Waste Water Subsystem

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

Supply water was managed through the use of the flash evaporator system, water transfer to the ISS and the overboard nozzle-dump system. One supply water nozzle-dump was performed at a nominal dump rate of 1.6 percent/minute (2.64 lb/min). The line heater maintained the supply water dump-line temperature between 75 and 95 °F throughout the mission.

Six wastewater nozzle dumps at an average rate of 1.94 percent/minute (3.18 lb/min) were performed. As a result of not being able to maneuver to the dump attitude, condensate separation was initiated to minimize filling of the waste-tank, thereby delaying the need for a waste dump. After about 5 hours of condensate separation, it was decided to offload waste-

water from the waste tank and stow the CWC in the Multi-Purpose Logistics Module (MPLM) before access to the MPLM was lost because of hatch closure. Condensate separation was terminated, and the same CWC used for condensate collection was used to offload about 87 lb of wastewater, after which the CWC was stowed in the MPLM. The ISS was concerned about the wastewater contaminating the solar arrays during a waste dump. As a result, the first two wastewater nozzle dumps were video taped and monitored to confirm that the dump spray pattern did not contaminate the ISS solar arrays. The wastewater dump line temperature was maintained between 54 °F and 75 °F throughout the mission. Vacuum vent line temperature was maintained between 58 °F and 80 °F.

Fourteen CWCs were filled with 1373 lb of supply water and transferred to the ISS. Eight of the CWCs transferred were potable water and six were technical water. The calculated average fill rate was 104 lb/hr. Four of the fourteen CWCs were filled to offload supply water and create ullage because of the ISS attitude-control problem prevented attaining the required water dump attitude.

The supply water tank A quantity transducer exhibited a dropout at 113:09:59 G.m.t. (03:15:18 MET). The sensor output went to zero percent in three seconds when the tank quantity reached approximately 72.3 percent. The dropout lasted for several seconds and was followed by a return to normal data. This problem is believed to be caused by minor contamination on the quantity gage potentiometer that causes an intermittent break in continuity, and does not impact supply water tank usage. This problem will be addressed during the next OMM period for this vehicle.

Waste Collection Subsystem

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

Airlock Support System

The airlock support system provided all of the support required for the EVA activities in a satisfactory manner.

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 System

The flight data system provided satisfactory support throughout the STS-100 mission. No in-flight anomalies were noted in the data.

Flight Software

The flight software performed as expected during the mission.

Flight Control Subsystem

The FCS performance was nominal throughout the mission. The FCS checkout was performed with no problems identified. Auxiliary power unit (APU) 3 was used to support the checkout with

a start time of 10:09:41:08 G.m.t. (10:15:00:26 MET), and a run time was 3 minutes 44 seconds.

The entry inertial guidance, navigation and control performance was nominal. The navigation-sensor (drag, TACAN, ADTA and MLS) data were incorporated into the onboard navigation state vectors at the expected regions of operations. No navigation editing was observed.

The inertial measurement unit (IMU) and star tracker performance was nominal throughout the mission. Only one in-flight adjustment of the onboard IMU accelerometer compensation values was required, and that occurred on IMU 3.

Displays and Controls Subsystem

The displays and controls subsystem performed nominally with the exception of a payload bay floodlight that failed and is discussed in the following paragraph.

At 117:17:31:15 G.m.t (07:22:50:33 MET), when the crew turned on the payload bay floodlights for the MPLM berthing operations, the ground observed a remote power controller (RPC) trip on mid power control assembly (PCA) main bus B. A 13.5-ampere spike was seen on the bus for 2.5 seconds. The crew confirmed that the mid port floodlight was out and returned the switch to the off position. This floodlight was considered failed for the remainder of the flight. The most likely cause of the problem is a failed Q6 transistor in ballast B of the floodlight electronics assembly (FEA) 1. The loss of this light did not impact normal payload bay operations.

Communications and Tracking Subsystem

The communications and tracking subsystem performed nominally in providing satisfactory communications throughout the mission.

During flight day 1, between approximately 8 and 17 hours MET, dropouts were observed over the S-band system. The dropouts were coincident with the selection of the lower left antenna path and had little or no correlation with the forward/aft beam selection. The data indicate that the reflected power was minimal with minor fluctuations during the period. There were also minor fluctuations in the forward (up) link automatic gain control (AGC) during the period. Postflight testing of the S-band lower left and lower right antennas, cables and connectors will be performed.

The Space-to-Space Communication System (SSCS) supported the first EVA and nominal communications were maintained throughout the EVA. With the installation of the new UHF antenna on the ISS during the EVA, the Space-to-Space Station Radio (SSSR) was cleared for on-orbit use. The antenna was successfully tested at the end of the EVA. The plan for the second EVA was to power on the SSSR prior to EVA crewmember egress and leave it on for the entire EVA. This provided a successful opportunity to monitor the link quality between the radios as the EVA crewmembers translated up and down the ISS.

The Ku-Band radar acquired the ISS at 119:17:47 G.m.t. (09:23:06 MET) at a range of 240 ft. The radar tracked the ISS during the fly-around and final separation until the system was placed back in the communication mode at 119:18:43 G.m.t. (10:00:02 MET) at a range of 3300 feet from the ISS. The separation rate was approximately 5.0 ft/sec.

The first use of the Space-to-Space Orbiter Radio (SSOR) and SSSR during the undocking/separation maneuvers was successfully performed. During the fly-around activity, the communications link was very satisfactory and no anomalous performance was noted.

Operational Instrumentation/Modular Auxiliary Data System

The operational instrumentation (OI) and modular auxiliary data system (MADS) performed satisfactorily throughout the mission. No in-flight anomalies were identified from the data evaluation.

Structures and Mechanical Subsystems

The structures and mechanical subsystems performed satisfactorily throughout the mission with no in-flight anomalies identified from the review of the data. The following table presents the landing and braking parameters for the flight.

LANDING AND BRAKING PARAMETERS

Parameter	From Threshold, Ft	Speed, Keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	2219.4	195.2	-3.87	N/A
Nose gear touchdown	5444.3	147.8	N/A	-5.16
Brake initiation speed		100.0 knots		
Brake-on time		29.39 seconds		
Rollout distance		10211.6 feet		
Rollout time		51.12 seconds		
Runway		22 (Concrete) EAFB		
Orbiter weight at landing		220,786.6 lb		
Brake sensor Location	Peak Pressure, Psia	Brake assembly	Gross energy, million ft-lb	
Left-hand inboard 1	838.2	Left-hand inboard	16.14	
Left-hand inboard 3	838.2			
Left-hand outboard 2	745.1	Left-hand outboard	15.52	
Left-hand outboard 4	745.1			
Right-hand inboard 1	911.8	Right-hand inboard	20.22	
Right-hand inboard 3	911.8			
Right-hand outboard 2	813.7	Right-hand outboard	18.01	
Right-hand outboard 4	813.7			

Structural flexing was observed on the left OMS pod during the SSME start sequence. The flexing was characterized as first and second harmonic motion over an area of about 1.5 by 2.5 feet just forward of the RCS stinger. The flexing damped out quickly (0.6 second), and no damage was observed and no tiles were lost. The period of maximum structural loading is during SSME start. The peak thermal loading occurred during entry. The same motion, but to a lesser degree, was also observed on the right OMS pod. There was no mission impact.

Inspection of the area at Dryden Flight Research Center (DFRC) revealed no unusual damage or evidence of tile movement. There was a 4-inch long segment of gap filler material protruding about 0.5 inch. More detailed inspections were performed at KSC and no anomalies were noted.

Films from 40 previous flights were viewed and motion was observed on two flights (STS-94 and STS-97 (two different Orbiters). The motion was less than that seen on the left OMS pod on this flight.

The payload bay doors were opened at 109:20:18:25 G.m.t. (00:01:37:43 MET). All voltages were nominal and the motors opened the doors in nominal dual-motor time.

The main landing gear tires were found to be in the typical condition from landing on a concrete runway. Ply undercutting was observed on the outboard edges of both left-hand main gear tires.

The ET/Orbiter (EO) separation devices EO-1, EO-2, and EO-3 functioned normally. The EO-2 and EO-3 fitting retainer springs appeared to be in the nominal configuration. No debris was found on the runway beneath the umbilicals.

The payload bay doors were closed and latched for the second KSC landing opportunity at 121:10:56:34 G.m.t. (11:16:15:52 MET). All voltages were nominal and the motors closed the doors in nominal dual-motor time.

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

Integrated Aerodynamics, Heating and Thermal Interfaces

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

Thermal Control Subsystem

The thermal control subsystem performed nominally. All temperatures were maintained within nominal limits. The heaters operated nominally and the temperatures at entry interface as well as the main landing gear tire pressures were within acceptable limits.

The flash evaporator system (FES) starboard feedline zone 3 heater system 1 temperature dropped below the thermostat set point of approximately 69 °F. The system-2 heater was enabled and cycled nominally for the remainder of the mission. A thermal analysis was made, and it showed the line would reach 32 °F within 2 to 3 hours if the string-2 heater failed off. A plan was developed to purge the starboard feedline in the event the string-2 heater failed off.

When the left OMS pod heaters were changed from system A to the system B heaters at approximately 115:10:39 G.m.t. (05:15:58 MET), the temperature response at the left orbital maneuvering engine (OME) cover-heaters thermostat showed the expected response (little change), but the fuel feedline temperature increased 5 °F while the oxidizer inlet temperature decreased 5 °F. When the heaters were reconfigured back to system A, both temperatures returned to their previous values, which were approximately 73 °F for the fuel feedline and 70 °F for the oxidizer inlet. Troubleshooting will be performed.

The left OMS pod inboard Y-web heater system A has a dithering thermostat that has been present for a number of missions. The thermostat is located on the oxidizer drain panel and monitored by two temperature sensors. The thermostat dithered throughout the mission with

the exception of one heater cycle that spiked up to 90 °F at 118:10:20 G.m.t. (08:15:39 MET). Typically, dithering thermostats are not replaced and some have been in the fleet for many years. However, it has also been observed that when a dithering thermostat becomes erratic, failure of the thermostat may soon occur. If that thermostat should fail, it would require operation of the left OMS pod system B heaters that have a higher set-point thermostat on the keel web heater. Thermostat replacement requires removal of the OMS pod. The thermostat will be removed and replaced.

Aerothermodynamics

Surface thermocouple temperature data, aileron deflection data, and yaw thruster firings all indicated a normal symmetric boundary layer transition.

The surface data on the centerline location indicates transition from laminar flow to turbulent flow occurred at Mach 7.2 (1279 seconds after entry interface). All centerline fuselage thermocouples recorded similar onset times. Unsteady flow was recorded starting 20 seconds earlier at Mach 7.7. Structural temperature data, aileron deflection data and yaw thruster firings all indicate a normal transition occurred.

The acreage heating data indicate that the vehicle experienced normal entry heating. One note of interest was that the OMS pod structure was very cold at touchdown.

The vehicle at entry weighed approximately 218,000 lb and it was entering from a high inclination orbit with boundary layer transition occurring early. The combined effect of these conditions was that both the maximum temperature and temperature-rise data on the skin (structural) were higher than normal along the lower surface mid-body. The wing skin temperature rise was on the high side, but not as much as the fuselage centerline. The difference between the left and right wing skin temperatures was 6.9 °F, which is normal. These data indicate that the area affected by early transition may be confined to the center and left-hand portion of the fuselage.

Local heating was normal. However, some damage was noted to one of the left-hand reinforced carbon carbon (RCC) panels. Also charred filler-bar was reported and it requires the replacement of one tile approximately two feet outboard of the left-hand ET door.

Thermal Protection Subsystem and Windows

The thermal protection subsystem (TPS) performed satisfactorily. Both the total number of Orbiter TPS damage sites and the number of damage sites one-inch or larger were well within the established family of experience.

Structural flexing, observed on the left OMS pod during the SSME start sequence, was noted in films of the launch. The flexing has been characterized as first and second harmonic motion over an area of about 1.5 by 2.5 feet just forward of the RCS stinger. The flexing damped out quickly (0.6 second) and no damage was observed and no tiles were lost. There was no mission impact, and the postflight inspection of this area uncovered no damage or anomalous conditions.

Entry heating was higher-than-normal based on lower-surface structural temperature response data. Boundary layer transition from laminar flow to turbulent flow occurred 1279 seconds after entry interface (EI).

The postlanding inspection of the Orbiter TPS identified a total of 92 damage sites of which 13 had a major dimension of 1-inch or larger. This total does not include the numerous damage sites on the base heat shield that are attributed to the flame arrestment sparkler system, SSME vibration/acoustics and exhaust plume recirculation. The distribution of these impacts on the vehicle is shown in the following table.

TPS DAMAGE SITES

Orbiter Surfaces	Hits > 1 Inch	Total Hits
Lower Surface	4	42
Upper Surface	0	0
Window Area	8	48
Right Side	0	0
Left Side	0	0
Right OMS Pod	1	2
Left OMS Pod	0	0
Total	13	92

The Orbiter lower surface sustained 42 hits of which 4 had a major dimension of 1-inch or larger. The majority of the lower surface damage sites occurred on the right-hand wing glove. Damage sites in this area were most likely caused by ice/frost from the LO₂ feedline or foam debris.

Although the number of damage sites on the left-hand lower surface were less than the right-hand lower surface, the largest lower-surface tile damage site was located on the left-hand wing glove forward of the main landing gear door. This shallow damage site measured 2.5 inches long by 1-inch wide by 0.125 inch deep, and the cause of this damage was most likely the result of an impact of low-density foam material. 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 -88	STS -96	STS -93	STS -103	STS -101	STS -92	STS -97	STS -98	STS-102	STS-100
Lower surface total hits	80	160	161	84	70	86	78	73	44	42
Lower surface Hits > 1 in.	21	66	42	13	19	14	10	8	10	4
Longest damage Site, in.	4.5	4.0	6.0	1.5	8	2	3	3	1	2.5
Deepest damage Site, in.	0.5	0.5	0.5	0.25	0.75	0.75	0.5	0.5	0.125	0.125

The tiles on the OMS pods had a typical amount of damage. No unusual tile damage or evidence of tile movement, as seen in the liftoff films, was observed on the OMS pods.

However, a four-inch long segment of gap filler material was protruding approximately 0.5 inch from the left-hand OMS pod tiles.

A segment of Ames gap filler, located immediately aft of the nose landing gear wheel well, was protruding 0.5 inch. There was no indication of entry heating or tile damage. A second Ames gap filler from the nose landing gear door was found on the runway after wheels stop, and it was left of the Orbiter and approximately 10 feet outboard of the Orbiter wing glove. The gap filler showed evidence of entry heating.

An advanced flexible reusable surface insulation (AFRSI) blanket was slightly debonded and protruding from the area immediately aft of the forward-firing RCS thrusters in the forward RCS.

STS-100 was the third flight using the forward RCS up-firing thruster plumes to help protect the windows from booster separation motor (BSM) particulate impingement during SRB separation. Hazing on windows 3 and 4 appeared to be greater than observed on the first two flights with the window protection system. Quantitative evaluation of the window hazing will be provided through optical testing at KSC.

Moderate hazing was noted on the upper portion of windows 2, 3, 4, and 5. In addition to hazing, streaks were observed on windows 3 and 4. The streaks are the result of impacts by room temperature vulcanizing (RTV) adhesive used on the forward RCS paper covers.

Damage sites on the window perimeter tiles were more than usual in quantity. A total of 48 damage sites were noted with 8 having dimensions greater than 1 inch. Damage to the window perimeter tiles on the forward-facing windows is also attributed to impacts by RTV adhesive used on the forward RCS paper covers.

The tile damage on the base heat shield was less than usual. The SSME 1 dome heat shield blankets were in good condition. Slight fraying was observed on the SSME 3 blanket from the 10 to 12 o'clock position. Two large damage sites (approximately 3 inches by 3 inches) on the body flap upper surface tiles adjacent to the body flap stub appear to be failed repair sites.

Gas Sample Analysis

The STS-100 mission was a successful flight for the gas sample bottles. The hardware provided six excellent gas samples. The data obtained during ascent in the gas-sample bottles were all in the acceptable range. The bottle-pressures were in the expected range. The oxygen data were within the bands of error as determined by the argon measurement, and the amount detected can be attributed to air.

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

Computations to determine the amount of hydrogen contributed by the pyrotechnic used to open and close the sampling bottle assumed the composition would match that of experimental values obtained under controlled conditions. These conditions indicated that the ratio of hydrogen to carbon monoxide was 0.54. The percent air and the oxygen from air are calculated from the amount of argon in the sample. The calculations assume normal air to be made up of 78.08-percent nitrogen, 20.95-percent oxygen, 0.934-percent hydrogen and 0.934-percent argon.

EXTRAVEHICULAR ACTIVITY

Two extravehicular activities (EVAs) were successfully completed. The first EVA had a duration of 7 hours 10 minutes and the second EVA lasted 7 hours 39 minutes. A third EVA, built into the pre-mission timeline as a placeholder for unscheduled EVA operations, was not required since all planned EVA tasks were completed in two EVAs.

FIRST EXTRAVEHICULAR ACTIVITY

The first extravehicular activity (EVA) was successfully completed and both extravehicular mobility units (EMUs) performed nominally during the EVA.

The major tasks completed during the first EVA were as follows:

1. Connection of the flight support equipment grapple fixture (FSEGF) umbilicals for Space Station Remote Manipulator System (SSRMS) keep-alive power;
2. Installation and deployment of the Ultra High Frequency (UHF) antenna on the U. S. Laboratory;
3. Superbolt quiver sidebar release (get-ahead task for EVA2);
4. Superbolt removal and initial raising of the SSRMS boom; and
5. Starboard Early Communications (ECOMM) antenna cable disconnect (preparation for EVA 2).

During EVA 1, the extravehicular crewmember (EV) 1 reported that he had an irritation in his left eye. EV1 purged his helmet to clear any particulates, but he felt no relief. Later, EV1 reported that the irritation had spread to both eyes. The irritation began to subside approximately 30 minutes later due to natural eye tearing.

Following the EVA, the crewmember stated that his disposable in-suit drink bag had leaked throughout the EVA. He suspected that the water may have contacted the helmet visor and subsequently his eyes.

EV1 also reported two instances of eye irritation during the second EVA. He also reported that the first instance occurred after water had escaped from the in-suit drink bag and was floating around near the visor. Residue samples were taken from each crewmember's face and helmet for postflight analysis.

SECOND EXTRAVEHICULAR ACTIVITY

The second EVA was successfully completed and both EMUs performed nominally during the 7 hour 39 minute event. The major tasks completed during the second EVA were as follows:

1. Reconfiguration of the J400 panel;
2. Configuration of the primary and redundant power through the PDGF (required disconnecting, inspection and reconnecting of the P6/P8 PDGF connectors);
3. Reconfiguration of the Superbolt Quiver tabs;
4. Starboard ECOMM antenna removal;
5. FSEGF umbilical release; and
6. Direct current switching unit (DCSU) transfer and installation on the External Stowage Platform (ESP).

After completion of several tasks, EV2 returned to the airlock and connected to the servicing and cooling umbilical (SCU) for 1 hour and 2 minutes while EV1 performed tasks that required only one crewmember. This allowed EV2 to conserve battery power for the task of stowing the DCSU on the pallet.

REMOTE MANIPULATOR SYSTEM

The Remote Manipulator System (RMS) performed nominally in meeting all requirements made of the system. Eight major tasks, which were all completed successfully, were performed using the RMS in support of the International Space Station (ISS) activities, and these tasks were:

- a. Mated the Spacelab Pallet (SLP) to the U. S. Laboratory Cradle Assembly (LCA);
- b. Provided extravehicular activity (EVA) support for UHF antenna installation;
- c. Supported the deployment, activation and checkout of the Space Station RMS;
- d. Supported the transfer and installation of the direct current switching unit (DCSU);
- e. Installed the Multi-Purpose Logistics Module (MPLM) on Node 1 of the ISS;
- f. Reberthed the SLP in the payload bay;
- g. Uninstall MPLM from ISS and berth the MPLM in the payload bay; and
- h. Performed survey operations of the ISS and Shuttle.

One in-flight anomaly occurred, and it is discussed in the following paragraph.

During the end effector (EE) portion of the remote manipulator system (RMS) checkout at 110:14:42 G.m.t. (00:20:01 MET), the rotational hand controller (RHC) capture/release switch appeared to stick when the EE snares were commanded closed in the manual EE mode (Flight Problem STS-100-V-02). This resulted in an extended stall period for the EE motor. The crew cycled the RHC capture/release switch and the condition cleared. The switch and the EE were subsequently retested and operated nominally, and the crew noted that the switch no longer had a sticky feel. Only the EE auto mode is normally used. Thermal analyses shows that the temperature increase in the motor windings was not sufficient to impact EE operations for this mission. The problem did not recur.

The RMS was powered up and uncradled at 112:08:10 G.m.t. (02:13:29:18 MET). The arm grappled the SLP and unberthed the hardware from the Orbiter. The SLP was installed on the LCA at 112:10:48 G.m.t. (02:16:07:18 MET), and the RMS released the SLP. During the EVA, the articulated portable foot restraint (APFR) was installed on the RMS, and the RMS supported the installation of the ultrahigh frequency (UHF) antenna on the ISS U. S. Laboratory and the assembly and deployment of the Space Station RMS (SSRMS). Following the unfolding and bolting of the SSRMS booms, the RMS was placed in a position where the raising of the SSRMS boom could be viewed. The arm was cradled and powered down at 112:20:05 G.m.t. (03:01:24:18 MET).

The Orbiter RMS was powered up and uncradled at 113:08:56 G.m.t. (03:14:15 MET). The arm was moved to the SSRMS walk-off viewing position, and supported the viewing of the SSRMS walk-off and checkout. After the successful checkout of the SSRMS, the Orbiter RMS was then used to grapple the multi-purpose logistics module (MPLM) in the payload bay. The Orbiter RMS maneuvered the MPLM to the pre-installation position over the Node 1 nadir common berthing module (CBM), and installation of the MPLM followed at 113:16:06 G.m.t. (03:21:25 MET). The Orbiter RMS then ungrappled from the MPLM and was cradled and powered down.

The Orbiter RMS was powered up and uncradled at 114:11:32 G.m.t. (04:16:51 MET). The arm was then used for EVA support to reconfigure the Laboratory J4000 panel connectors to route power and data to the Laboratory power and data grapple fixture (PDGF). At 114:16:57 G.m.t. (04:22:16 MET), the arm was maneuvered to the SLP uninstalled viewing-position to provide camera views of the SSRMS as it unberthed the SLP. Following the SLP unberthing, the SSRMS was maneuvered to the DCSU transfer position at 114:18:37 G.m.t. (04:23:56 MET).

During RMS berthing at 114:20:00 G.m.t. (05:01:19 MET), the forward manipulator positioning mechanism (MPM) pedestal manipulator retention latch (MRL) latch microswitch 1 failed to indicate on during latching. The associated latch motor 1 ran 19.4 seconds, while motor 2 ran for the nominal dual motor drive time of 5.7 seconds. The crew was requested to drive the latch closed for another 2 seconds (actual drive time was 4 seconds) with no change in the microswitch indication. Almost 2 hours later, upon coming out of a loss of signal (LOS), the microswitch indicated on. The power down of the arm occurred at 114:20:04 G.m.t. (05:01:23 MET). During RMS berthing on flight day 7, the failure of the microswitch to indicate on recurred and recovered about 3 minutes later. During RMS berthing on flight days 9 and 10, the microswitch performance was nominal. KSC troubleshooting, which consisted of extra latch cycles, was performed in an attempt to duplicate the anomaly.

The Orbiter RMS was powered up and uncradled at 115:10:14 G.m.t. (05:15:33 MET). The arm was maneuvered from the pre-cradle position to the SLP uninstal viewing-position in preparation for the SSRMS loaded tests, however, the SSRMS activities were cancelled because of ISS commanding issues.

At 115:22:40 G.m.t. (06:03:59 MET), the RMS was maneuvered from the SLP uninstal viewing-position to the arm's pre-cradle position to begin power down. The MRL were commanded closed at 115:22:52 G.m.t. (06:04:11 MET). Again latched indications were obtained for all latches except the forward motor 1 latch microswitch, which had exhibited similar behavior during RMS operations earlier in the mission. The microswitch indicated on three minutes later, and as before, the behavior had no impact on RMS operations. The RMS was powered down at 115:23:11 G.m.t. (06:04:30 MET).

The Orbiter RMS was powered up and uncradled at 117:17:34 G.m.t. (07:22:53 MET) in preparation for retrieval of the MPLM from the Node 1 nadir CBM. After the MPLM was berthed in the Orbiter payload bay, the arm was cradled and powered down at 117:21:24 G.m.t. (08:02:43 MET). Delayed transition of the forward MPM MRL 1 latch microswitch, which had been noted during the two previous RMS cradling operations, was not observed this time.

The Orbiter RMS was powered up and uncradled at 118:10:27 G.m.t. (08:15:46 MET). After the SSRMS had placed the SLP into a handoff position, the Orbiter RMS grappled the SLP at 118:20:43 G.m.t. (09:02:02 MET). The SSRMS then ungrappled and was maneuvered away from the SLP. The RMS berthed the SLP in the Orbiter payload bay at 118:22:50 G.m.t. (09:04:09 MET), and was then cradled and powered down. The forward MPM MRL 1 latch microswitch operated nominally.

GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

The government furnished equipment/ flight crew equipment (GFE/FCE) performed nominally with some problems noted. These are discussed in the following paragraphs.

On several occasions, beginning at 110:15:35 G.m.t. (00:20:54 MET), during the rendezvous tools checkout, the trajectory control sensor (TCS) command and display system (CADS) application displayed error messages regarding the failure of the TCS to complete the execution of a legal command and return a completion status to the payload and general support computer (PGSC). The problem appeared to be directly related to communications between the TCS CADS in the PGSC and the TCS unit. Analysis of the flight data confirmed that the TCS unit was correctly receiving and implementing commands and sending completion acknowledgements. However, some of the acknowledgements to the PGSC were not received and this resulted in the error messages.

Changing from the prime (STS-3) to the backup (STS-5) PGSC did not change the condition. The backup cable is a pre-routed cable to the Orbiter space vision system (OSVS). Due to timeline and system impacts, it was not utilized. Ground personnel monitored TCS operations and the possibility of this condition recurring was not ruled out. The TCS performed nominally during rendezvous and docking operations, but failed to automatically execute shutdown commands. Manual execution of the commands was successful and was the recommended workaround.

Troubleshooting with ground hardware duplicated the problem and confirmed that acknowledgements were not being received from the TCS unit prior to the software timing-window closing. The problem was eliminated when the master control interface unit (MCIU)/422 card was replaced with a Quatech card and the PGSC was taken off the network. The manual workaround continued to be used on this mission. Corrective action recommendations for future flights have been developed. The TCS performed nominally during the undocking and fly-around. As expected, some manual commanding was required.

The downlinked video from payload bay camera B appeared jittery at 112:18:13 G.m.t. (02:23:32 MET). The camera was commanded into different modes with no change to the jitter condition. The camera was subsequently power cycled at 112:20:10 G.m.t. (03:01:29 MET) and the jitter condition was cleared. The problem did not recur during the flight; therefore, no postflight KSC troubleshooting is required.

At 113:09:06 G.m.t. (03:14:25 MET), the crew reported a problem with the video setup for the ISS ingress operations. While video appeared normal in the camcorder viewfinder, there was no video at the Orbiter monitor. The audio function, however, was nominal. Crew troubleshooting identified that the pre-routed 42 ft. battery-powered speaker microphone unit (BPSMU) cable was the cause of the problem. A spare BPSMU cable restored normal operations.

At 114:23:46 G.m.t. (05:05:05 MET), the crew reported that use of the P4-to-Camcorder audio/video cable produced intermittent video. The crew was able to regain function through the use of a spare. At the same time, the crew reported that use of the 44 ft. BPSMU cable produced bad video with good audio. Again the crew was able to regain function through the use of a spare. Both cables were returned to JSC for troubleshooting.

With closed-circuit television (CCTV) camera A pointed at a light background, the camera's video revealed a thread-like piece of debris which moved along with the camera view when the

camera was panned or tilted. The ground controllers were unable to zoom in with camera D to determine the nature of the debris. The debris image could not be made sharper by adjusting the camera A focus. When the camera was focused, the debris was visible in the video image. A videotape of the condition was ordered for evaluation. The debris could possibly be a blanket fiber on the external surface of the camera lens. The camera was removed and sent to JSC for troubleshooting.

During the postflight inspection of the External Tank separation camera, the film was discovered in a jammed condition. Postflight troubleshooting of the camera will be performed in an effort to determine the cause of the jammed film.

CARGO INTEGRATION

Integration hardware performance was nominal throughout the mission.

POSTLAUNCH PAD INSPECTION

The postlaunch inspection of the mobile launch platform (MLP) -3, Launch Pad A, Fixed Service Structure (FSS) and Rotating Service Structure (RSS) was successfully completed approximately 5 hours after the launch. No flight hardware was found.

The Orbiter liftoff lateral acceleration data to predict stud hang-ups indicated that no hang-up had occurred. Erosion was typical for the north posts. North holddown post blast covers and the T-0 umbilical exhibited typical exhaust plume damage. Both SRB aft skirt gaseous nitrogen purge lines were intact, however, the protective tape layering was partially eroded, but braids were not exposed.

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

The GH₂ vent line latched in the eighth of eight teeth of the latching mechanism. The deceleration cable failed to catch the spool weldment, but no damage was noted. The ground umbilical carrier plate (GUCP) 7-inch quick disconnect (QD) sealing surface exhibited no damage. A detached identification tag (dog tag) metal was found around the GUCP purge QDs.

The Orbiter Access Arm (OAA) appeared to be intact with no evidence of plume impingement. All slide-wire baskets were secured in place. Basket 3 had a missing caution sign that was found nearby on the 195-ft. level. Baskets 5, 6 and 7 had damaged or missing guard rail bumpers.

The gaseous oxygen vent arm, hood, ducts and structure appeared to be in good shape with no indications of plume damage.

Debris found included a 4-foot by 1-foot section of deck grating that was lifted out of position on the FSS 115-ft. level; a 12-inch long piece of rusted unistrut was found on the FSS 155-ft. level; and a broken ½ inch diameter 1-inch long bolt was found on the pad surface near the elevator landing area.

Three grass fire areas east of the pad were inspected and no flight/facility debris was found.

Overall, the damage to the FSS/RSS and MLP appeared to be minimal. Minimal debris was noted of the pad apron and FSS.

**DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY
OBJECTIVES**

DEVELOPMENT TEST OBJECTIVES

DTO 261 - International Space Station On-Orbit Validation - This DTO of opportunity was to be performed during the International Space Station (ISS) reboost maneuvers and the Multi-Purpose Logistics Module (MPLM) installation on to the ISS. The crew time limits prevented internal wireless instrumentation system (IWIS) data collection during these activities. However, the Orbiter payload bay cameras collected photogrammetry data were recorded during the second ISS reboost maneuver.

DTO 264 - Space Station Remote Manipulator System Model Validation - No activities were performed during the mission due to the ISS command and control multiplexer/demultiplexer (C&C MDM) problems that prohibited the SSRMS loaded checkout operations.

DTO 700-14 - Single String Global Positioning System (GPS Operations Option/No Payload and Ground Support Computer - The miniature air-to-ground receiver-Shuttle (MAGR-S) DTO was completed successfully during the STS-100 mission with all mission objectives being met. Data analysis indicates good MAGR-S receiver performance throughout the entire mission. The specific details are as follows:

1. Prelaunch and ascent performance of the MAGR-S receiver was nominal. There were no occurrences of the MAGR marking any satellites "not usable". However, there was a brief period of multiple-satellite switching during the Orbiter roll-to-heads-up maneuver, as expected.
2. The MAGR-S was exercised during and following the FCS checkout activities. A commanded self-test was performed, followed by Operations (OPS) 2 test activities. The OPS 2 test includes power cycling the receiver, initialize command and a filter-restart command. The self-test yielded a warning indication. This indication has been seen on previous flights and during ground testing and is not a concern because other real-time health indicators were nominal. The OPS 2 test produced nominal results.
3. The MAGR Global Positioning System (GPS) receiver remained powered and operating entry/landing. The receiver lost some satellite signals during the plasma blackout region as expected. However, the receiver recovered quickly below 224,000 feet altitude (after plasma ended) and tracked satellites normally throughout the remainder of the mission. The figure of merit (FOM) remained good after the plasma blackout region and throughout the remainder of the entry and landing phase,

The MAGR-S receiver, however, did experience 6 tilts while On-Orbit. Quick analysis of these tilts indicates that these tilts were caused by the "greater-than-15-alternate-satellites" issue that will be addressed as part of the receiver Link-05 firmware upgrades. Data from these tilts has been forwarded to the vendor for review and confirmation.

DTO 700-22 - Crew Return Vehicle Space Integrated Global Positioning System - Activation of the crew return vehicle (CRV) space integrated global positioning system (SIGI) was performed successfully and the initial SIGI performance was nominal. Analysis of the data following the Star Line Maneuver (SLM) indicated SIGI performance was nominal.

Subsequently, the CRV SIGI experienced periods that indicated the CRV SIGI was not tracking the GPS satellites. Based on the docked attitude, this is not unexpected since one or possibly both of the GPS antennas can be blocked or not have a good line-of-sight to the GPS satellites. However, several new anomalies were identified and characterized in the docked vehicle configuration. One anomaly kept shutting down the SIGI GPS. Ground testing was able to duplicate the anomaly and a new SIGI command was defined and uploaded to the SIGI payload and general support computer (PGSC) for crew execution. This command provided a successful workaround for this anomaly. Several other crew workaround procedures were also defined and executed. Additionally, a WinDecom in interface problem related to incompatible baud rates was identified and resolved by the crew. SIGI firmware anomalies were identified and will be resolved for future flights. The SIGI worked well after undocking and produced data throughout entry, and this was a primary objective of the CRV SIGI DTO.

DTO 805 - Crosswind Landing Performance - The Crosswind Landing Performance DTO of opportunity was not completed during the STS-100 mission as the crosswind conditions did not meet the minimum requirements established for this DTO.

DETAILED SUPPLEMENTARY OBJECTIVES

DSO 493 - Monitoring Latent Virus Reactivation and Shedding in Astronauts - Samples were acquired during flight and will be assessed during postflight analysis. The results will be reported following the completion of analysis of the samples.

DSO 496 - Individual Susceptibility to Postflight Orthostatic Intolerance - Data were taken during the preflight and postflight periods as planned. The results of the analysis of these samples will be reported following completion of the analysis of the samples.

DSO 498 - Spaceflight and Immune Function - Samples were taken from the crewmembers during the preflight and postflight periods. The results will be reported following completion of the analysis of the samples.

DSO 499 - Eye Movements and Motion Perception Induced by Off-Nominal Axis Rotation at Small Angles of Tilt after Spaceflight - Data were taken during the preflight and postflight periods as planned. Results will be reported after postflight analysis is complete.

HUMAN EXPLORATION AND DEVELOPMENT OF SPACE TECHNOLOGY DEMONSTRATIONS

HDT 1402 - Micro-Wireless Instrumentation System Human Exploration and Development of Space Technology Demonstration (Objective 3 Only) - The Micro-Wireless Instrumentation System (Micro-WIS) sensors and recorders passively collected thermal data that will be used postflight to characterize thermal environments.

PHOTOGRAPHY AND TELEVISION ANALYSIS

LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS

The launch photography and video (23 videos and 20 films) were reviewed. The only significant item noted in the film review is discussed in the following paragraph.

Camera E18 shows what appears to be flexing of the left OMS pod outer surface during the Space Shuttle main engine (SSME) startup. The event began at 109:18:40:38:386 G.m.t. and lasted approximately 0.5 second. Because of this flexing appearance, 40 launch films were reviewed, of which 7 provided no data. Of the remaining 33 films, slight movement was seen on two launches (STS-94 and STS-98). The movement on those two flights was significantly less than that observed on STS-100.

ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS

A total of 36 hand-held photographs of the External Tank (ET) were acquired using the hand-held 5 mm Nikon F5 camera with a 400 mm lens. Timing data were present on the film with the first picture taken 16 minutes 56 seconds after liftoff. The ET was 2.7 km from the Orbiter in the first picture.

The ET appears to be in excellent condition with no anomalous conditions noted. Views of the nose, the aft dome, both of the limbs (+ and - Y), the near side (+Z) and the far side (-Z) of the ET were obtained. The ET was fully illuminated with very little shadowing in most of the views. However, some of the views of the ET were in full shadow because of the angle relative to the Sun angle. The minimum resolvable object size from the imagery at the distance of 2.7 km was estimated to be 8 inches.

The normal SRB separation burn scars and aero-heating marks were noted on the intertank and nose thermal protection system (TPS). The LO₂ tank/ojive TPS appeared to be in good condition. The +Y thrust panel appeared in satisfactory condition. No significant divoting of the thrust panel TPS was confirmed from the imagery. The -Y thrust panel also appeared to be in good condition with no divots seen on the visible portion of the -Y thrust panel. Likewise, no divots or unusual marks were seen on the LH₂ tank TPS and the ET aft dome.

LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSIS

The video from landing was reviewed and no anomalous conditions were noted during the review.

TABLE I.- STS-100 SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
APU Activation	APU-1 GG chamber pressure	109:18:35:54.929
	APU-2 GG chamber pressure	109:18:35:57.432
	APU-3 GG chamber pressure	109:18:35:59.605
SRB HPU Activation ^a	LH HPU System A start command	109:18:40:13.958
	LH HPU System B start command	109:18:40:14.078
	RH HPU System A start command	109:18:40:14.238
	RH HPU System B start command	109:18:40:14.398
Main Propulsion System Start ^a	ME-3 Start command accepted	109:18:40:35.422
	ME-2 Start command accepted	109:18:40:35.550
	ME-1 Start command accepted	109:18:40:35.656
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	109:18:40:41.988
Throttle up to 104.5 Percent Thrust ^a	ME-1 Command accepted	109:18:40:46.177
	ME-3 Command accepted	109:18:40:46.182
	ME-2 Command accepted	109:18:40:46.190
Throttle down to 72 Percent Thrust ^a	ME-1 Command accepted	109:18:41:13.057
	ME-3 Command accepted	109:18:41:13.063
	ME-2 Command accepted	109:18:41:13.071
Throttle up to 104.5 Percent Thrust ^a	ME-1 Command accepted	109:18:41:30.978
	ME-3 Command accepted	109:18:41:30.983
	ME-2 Command accepted	109:18:41:30.991
Maximum Dynamic Pressure (q)	Derived ascent dynamic pressure	109:18:41:43
Both RSRM's Chamber Pressure at 50 psi ^a	RH SRM chamber pressure mid-range select	109:18:42:39.79
	LH SRM chamber pressure mid-range select	109:18:42:40.71
End RSRM ^a Action ^a Time	RH SRM chamber pressure mid-range select	109:18:42:42.85
	LRH SRM chamber pressure mid-range select	109:18:42:43.80
SRB Physical Separation ^a	LH rate APU turbine speed - LOS	109:18:42:45.47
SRB Separation Command	SRB separation command flag	109:18:42:46
OMS Assist Ignition	Right engine bi-prop valve position	109:18:43:55.6
	Left engine bi-prop valve position	109:18:42:55.8
OMS Assist Cutoff	Right engine bi-prop valve position	109:18:44:38.0
	Left engine bi-prop valve position	109:18:44:38.2
3g Acceleration	Total load factor	109:18:48:06
Throttle Down for 3g Acceleration ^a	ME-1 command accepted	109:18:48:06.345
	ME-3 command accepted	109:18:48:06.351
	ME-2 command accepted	109:18:48:06.359
Throttle Down to 67 Percent Thrust ^a	ME-1 command accepted	109:18:49:00.746
	ME-3 command accepted	109:18:49:00.752
	ME-2 command accepted	109:18:49:00.761
SSME Shutdown ^a	ME-1 command accepted	109:18:49:06.946
	ME-3 command accepted	109:18:49:06.952
	ME-2 command accepted	109:18:49:06.961

^aMSFC supplied data

**TABLE I.- STS-100 SEQUENCE OF EVENTS
(Continued)**

Event	Description	Actual time, G.m.t.
MECO	MECO command flag	109:18:49:07
	MECO confirm flag	109:18:49:08
ET Separation	ET separation command flag	109:18:49:27
APU Deactivation	APU-1 GG chamber pressure	109:18:57:27.659
	APU 2 GG chamber pressure	109:18:57:49.403
	APU 3 GG chamber pressure	109:18:58:04.145
OMS-1 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Not performed - direct insertion trajectory flown
OMS-1 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	Not performed
OMS-2 Ignition	Left engine bi-prop valve position	109:19:24:24.4
	Right engine bi-prop valve position	109:19:24:24.4
OMS-2 Cutoff	Right engine bi-prop valve position	109:19:25:18.4
	Left engine bi-prop valve position	109:19:25:18.6
Payload Bay Doors (PLBDs) Open	PLBD right open 1	109:20:17:07
	PLBD left open 1	109:20:18:27
OMS-3 Ignition	Left engine bi-prop valve position	109:22:23:18.7
	Right engine bi-prop valve position	109:22:23:18.7
OMS-3 Cutoff	Right engine bi-prop valve position	109:22:24:11.3
	Left engine bi-prop valve position	109:22:24:11.3
OMS-4 Ignition	Left engine bi-prop valve position	N/A
	Right engine bi-prop valve position	110:10:42:37.5
OMS-4 Cutoff	Left engine bi-prop valve position	N/A
	Right engine bi-prop valve position	110:10:42:48.1
Cabin Depressurization to 10.2 psia	Cabin Pressure	110:18:15:20
OMS-5 Ignition	Left engine bi-prop valve position	110:20:52:12.3
	Right engine bi-prop valve position	110:20:52:12.4
OMS-5 Cutoff	Left engine bi-prop valve position	110:20:53:29.7
	Right engine bi-prop valve position	110:20:53:29.8
OMS-6 Ignition	Right engine bi-prop valve position	111:09:44:53.3
	Left engine bi-prop valve position	111:09:44:53.4
OMS-6 Cutoff	Right engine bi-prop valve position	111:09:45:20.8
	Left engine bi-prop valve position	111:09:45:20.9
OMS-7 Ignition	Left engine bi-prop valve position	111:11:17:25.1
	Right engine bi-prop valve position	N/A
OMS-7 Cutoff	Left engine bi-prop valve position	111:11:17:38.3
	Right engine bi-prop valve position	N/A
Initial ISS Contact	Initial contact	111:13:09:54
Docking with ISS	Docking ring final position	111:14:10:42
Spacelab Logistics Pallet Grapple	End effector rigidized	112:08:23:41
Spacelab Logistics Pallet Ungrapple	End effector extended	112:11:17:58
Airlock Depressurization (end)	Airlock differential pressure no. 1	112:11:43:02
Begin First Extravehicular Activity	Airlock differential pressure no. 1	112:11:48:
Cabin Repressurization (start)	Cabin pressure	112:11:59:43

**TABLE I.- STS-100 SEQUENCE OF EVENTS
(Continued)**

Event	Description	Actual time, G.m.t.
Airlock Repressurization (start)	Airlock differential pressure no. 1	112:18:55:27
End First Extravehicular Activity	Airlock differential pressure no. 1	112:18:58
Cabin Depressurization (end)	Cabin pressure	112:19:03:49
Cabin Repressurization (start)	Cabin pressure	112:19:23:28
Multi-Purpose Logistics Module Grapple	End effector rigidized	113:14:25:57
Multi-Purpose Logistics Module Ungrapple	End effector extended	113:16:16:03
First Reboost Maneuver (start)	As reported	113:19:50:54
Cabin Depressurization (end)	Cabin pressure	113:20:17:37
Airlock Depressurization (end)	Airlock differential pressure no. 1	114:12:31:29
Begin Second Extravehicular Activity	Airlock differential pressure no. 1	114:12:32
Cabin Repressurization (start)	Cabin pressure	114:12:50:02
Airlock Repressurization (start)	Airlock differential pressure no. 1	114:20:13:18
End Second Extravehicular Activity	Airlock differential pressure no. 1	114:20:11
Cabin Depressurization (end)	Cabin pressure	114:20:20:00
Cabin Repressurization (start)	Cabin pressure	114:20:29:44
Second Reboost Maneuver (start)	As reported	117:11:20:42
Multi-Purpose Logistics Module Grapple	End effector rigidized	117:18:06:38
Multi-Purpose Logistics Module Ungrapple	End effector extended	117:21:05:39
Spacelab Logistics Pallet Grapple	End effector rigidized	118:20:43:42
Spacelab Logistics Pallet Ungrapple	End effector extended	118:22:57:27
Undocking from ISS	Undock complete	119:17:34:04
Flight Control System Checkout		
APU Start	APU 3 GG chamber pressure	120:09:41:07.686
APU Stop	APU 3 GG chamber pressure	120:09:44:48.266
Payload Bay Doors Close	PLBD left close 1 PLBD right close 1	121:10:52:45 121:10:55:31
APU Activation for Entry	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	121:14:57:58.392 121:15:26:25.952 121:16:04:21.088
Deorbit Burn Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	121:15:02:47.2 121:15:02:47.2
Deorbit Burn Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	121:15:06:20.0 121:15:06:20.0
Entry Interface (400K feet)	Current orbital altitude above	121:15:39:17
Blackout end	Data locked (high sample rate)	No blackout
Terminal Area Energy Management	Major mode change (305)	121:16:04:32
Main Landing Gear Contact	LH main landing gear tire pressure 1 RH main landing gear tire pressure 2	121:16:10:43 121:16:10:43

**TABLE I.- STS-100 SEQUENCE OF EVENTS
(Concluded)**

Event	Description	Actual time, G.m.t.
Main Landing Gear Weight on Wheels	LH MLG weight on wheels	121:16:10:43
	RH MLG weight on wheels	121:16:10:43
Drag Chute Deployment	Drag chute jettison 1 CP Volts	121:16:10:45.0
Nose Landing Gear Contact	NLG LH tire pressure 1	121:16:10:53
Nose Landing Gear Weight On Wheels	NLG weight on wheels 1	121:16:10:53
Drag Chute Jettison	Drag chute jettison 1 CP Volts	121:16:11:16.4
Wheel Stop	Velocity with respect to runway	121:16:11:34
APU Deactivation	APU-1 GG chamber pressure	121:16:30:16.589
	APU-2 GG chamber pressure	121:16:30:35.603
	APU-3 GG chamber pressure	121:16:30:52.007

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

No.	Title	Reference	Comments
STS-100-V-01	FES Starboard Feedline Zone 3 Heater System 1 Failed Off	110:04:41 G.m.t. 00:10:11 MET IPR 108V-0004 CAR 100RF01	<p>As of 110:07:41 G.m.t. (00:13:00 MET) the flash evaporator system (FES) starboard feedline zone 3 temperature had dropped to approximately 53 °F. The zone was operating on the system 1 heater that has a thermostat set-point of 68.9 °F. Note that as indicated by the measurement, the heater typically cycles on in the 67 to 70 °F range. It is not believed that the heater has cycled since launch (note that temperature increases are observed in the zone when the FES is used). The system 2 heater was enabled at 110:12:01 G.m.t. (00:17:20 MET) and is operating nominally. Options for the loss of a system 2 heater on the feedline have been identified. There was no mission impact from the loss of the heater in zone 3.</p> <p>KSC: Troubleshooting and repair was performed. A deviation to the Orbiter Maintenance Instruction (OMI) was written to activate the heater during the ferry flight from DFRC.</p>
STS-100-V-02	RMS Rotational Hand Controller Capture/Release Switch Sticky	110:14:41 G.m.t. 00:20:00 MET IPR 108V-0006	<p>During the end effector (EE) portion of the RMS checkout at 110:14:41 G.m.t. (00:20:00 MET), the rotational hand controller (RHC) capture/release switch appeared to stick while the EE snares were commanded closed in the manual EE mode. This resulted in an extended stall period for the EE motor. The crew cycled the RHC capture/release switch and the condition cleared. The switch and the EE were subsequently retested and operated nominally. The crew noted that the switch did have a sticky feel. Only the EE automatic mode was used, thus this potential condition did not impact the mission operations. Thermal analyses show that the temperature increase in the motor windings was not sufficient to impact EE operations during the mission.</p> <p>KSC: Postflight troubleshooting was required.</p>

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

No.	Title	Reference	Comments
STS-100-V-03	WSB 3 Anomalous Temperature Response When Operating on Controller B	110:17:21 G.m.t. 00:22:40 MET IPR 108V-0009 CAR 100RF02	<p>The WSBs were configured to the B controllers at 110:17:21 G.m.t. (00:20:40 MET). After that time, the WSB 3 core, water tank, and GN₂ tank temperatures gradually increased. Initially, it was believed that the boiler core and water tank heaters, which turn on and off together as a function of the boiler temperature feedback to the WSB controller, had failed on. It is now believed that the response could have been caused by the GN₂ shutoff valve or the hydraulic bypass valve being continuously powered while on the B controller. A partial heater failure is still considered to be a possible cause of the anomaly. At 113:22:18 G.m.t. (04:03:37 MET), the WSB 3 A controller was selected and system temperatures returned to nominal values. A plan was developed for the management of the system for the remainder of the mission. WSB 3 remained on the A controller (there was no constraint to continuous operation of the WSB feedline heater). Also, since a failure of the GN₂ or hydraulic bypass valve could not be ruled out, APU 3 was started at TAEM during entry. In the event of an additional APU/hydraulic system failure, APU 3 could have been started as early as Mach 18 with a failed closed GN₂ shutoff valve. Data show that WSB 3 spray cooling began after landing.</p> <p>KSC: A troubleshooting plan was developed. It consisted of instrumenting WSB components with temperature sensors and powering the B controller. The B controller (likely source of failure) will be replaced. The GN₂ shutoff valve, hydraulic bypass valve, water tank heaters, and core heaters will be instrumented and monitored to determine the source of the heat. Inspection/testing of the water spray valve that is heated by the feedline heater when on the A controller is also planned. The A controller was powered for the ferry flight.</p>
STS-100-V-04	RCS Vernier Thruster R5D Low Chamber Pressure	119:16:50 G.m.t. 09:22:09 MET CAR 100RF07	<p>After the Orbiter assumed attitude control in preparation for undocking, vernier thruster R5D exhibited three consecutive pulses with a chamber pressure (P_c) of about 50 psia beginning at 120:16:50 G.m.t. (09:22:09 MET). The low P_c continued throughout the fly-around, separation and continued to be present during each firing of the thruster. Redundancy management (RM) did not deselect the thruster since the low-level limit for RM deselection of 26 psia. A thorough review of the data indicates low</p>

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

No.	Title	Reference	Comments
STS-100-V-04 (Continued)	RCS Vernier Thruster R5D Low Chamber Pressure	119:16:50 G.m.t. 09:22:09 MET CAR 100RF07	<p>Pc during firings of R5D earlier in the mission. During longer duration firings, and periods of frequent firings, the Pc gradually increased to the nominal range. The observed Pc signature is indicative of combustion byproducts blocking the Pc sense tube, a condition that has been seen in past missions. To avoid a possible fail-off of the thruster that would result in waking the crew, the Orbiter was configured for attitude control using the primary thrusters during the crew sleep periods. A return to vernier operations was made at the start of the FCS checkout.</p> <p>KSC: A visual inspection of the thruster will be performed using nominal checkout procedures. Replacement of the thruster was also likely.</p>

DOCUMENT SOURCES

In an attempt to define the official as well as the unofficial sources of data for the STS-100 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-100 Summary of Significant Events
17. Contractor Reports of Subsystem Operation

ACRONYMS AND ABBREVIATIONS

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

ABS	ammonia boiler system
ADTA	air data transducer assembly
AFRSI	advanced flexible reusable surface insulation
APFR	articulated portable foot restraint
APU	auxiliary power unit
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
ATCS	active thermal control system
BGA	beta gimbal assembly
BPSMU	battery-powered speaker/microphone unit
BSM	Booster Separation Motor
CADS	command and display system
CBM	common berthing mechanism
C&C	command and control
CCTV	closed circuit television
CEI	contract end item
CO ₂	carbon dioxide
CRV	crew return vehicle
CSR	Customer Support Room
CWC	contingency water container
DAP	digital autopilot
DCSU	Direct current switching unit
DFRC	Dryden Flight Research Center
DOSMAP	Bonner Ball Assembly/Deployment, Phantom Torso, and Dosimeter Mapping Instrument
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
ΔV	differential velocity
EAFB	Edwards Air Force Base
ECOMM	Early Communications
ECLSS	environmental control and life support system
EE	end effector
EGT	exhaust gas temperature
EI	entry interface
EMU	extravehicular mobility unit
EO	ET/Orbiter
EPDC	electrical power distribution and control
ESP	External Stowage Platform
e.s.t.	Eastern standard time
ET	External Tank
EV1, EV2	extravehicular crewmember designation
EVA	extravehicular activity
FCE	flight crew equipment
FCL	Freon coolant loop

FCMS	fuel cell monitoring system
FCP	fuel cell powerplant
FCS	flight control system/subsystem
FD	flight day
FEA	floodlight electronics assembly
FES	flash evaporator system
FOM	figure of merit
FSEGF	Flight Support Equipment grapple fixture
FSS	Fixed Service Structure
ft/sec	feet per second
GEI	ground environmental instrumentation
GFE	Government furnished equipment
GH ₂	gaseous hydrogen
G.m.t.	Greenwich mean time
GN ₂	gaseous nitrogen
GO ₂	gaseous oxygen
GPC	general purpose computer
GPS	Global Positioning System
GSE	ground support equipment
GUCP	ground umbilical carrier plate
HED	high-energy damper
HRF	Human Research Facility
ICBC3D	IMAX Cargo Bay Camera Three Dimension
IDRD	Increment Definition Requirements Document
IMAX3D	Three-Dimension Camera system
IMU	inertial measurement unit
IREDD	ISS Resistive Exercise Device
I _{sp}	specific impulse
ISS	International Space Station
ITCS	internal controller system
IWIS	Internal Wireless Instrumentation System
JSC	Johnson Space Center
keas	knots estimated air speed
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt/hour
lb	pound
lb/hr	pound/hour
lbm	pound mass
lb/min	pound per minute
LCA	Laboratory Cradle Assembly
LCC	Launch Commit Criteria
LDA	Launch Deployment Assembly
LH ₂	liquid hydrogen
LMSO	Lockheed Martin Space Operations
LO ₂	liquid oxygen
LOS	loss of signal
LP	Launch Package
MADS	Modular Auxiliary Data System
MAGR	Miniature Air to Ground Receiver

Max $q\alpha$	maximum dynamic pressure
MC	midcourse correction (rendezvous maneuver)
MCIU	master control interface unit
MCC	Mission Control Center
MCOR	medium-rate communications outage records
MDM	multiplexer/demultiplexer
MECO	main engine cutoff
MER	Mission Evaluation Room
MET	mission elapsed time
Micro-WIS	Micro-Wireless Instrumentation system
MILA	Merritt Island launch area
MLP	Mobile Launch Platform
MLS	microwave landing system
mmHg	millimeter mercury
MPEV	manual pressure equalization valve
MPLM	Multi-Purpose Logistics Module
MPM	manipulator positioning motor
MPS	main propulsion system\
MRL	manipulator retention latch
MSD	mass storage device
Msec	millisecond
MSFC	Marshall Space Flight Center
MSS	Mobile Servicing Structure
MTSAS	module-to-truss structure attachment system
NASA	National Aeronautics and Space Administration
N ₂	nitrogen
NC, NC2, NCC	circularization maneuvers (rendezvous maneuver)
NC3, NC4	circularization maneuvers (rendezvous maneuver)
nmi.	nautical mile
NPSP	net positive suction pressure
O ₂	oxygen
OAA	Orbiter Access Arm
OCR	on-orbit checkout requirements
OCS	Orbiter condensate separation
ODS	Orbiter Docking System
OI	operational instrumentation
OME	orbital maneuvering engine
OMM	Orbiter Major Modification
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OPS	operations
OSVS	Orbiter Space Vision System
OTDR	optical time domain reflectometer
OV	Orbiter Vehicle
P _c	chamber pressure
PCA	power control assembly
PDGF	power and data grapple fixture
PGME	Propylene Glycol Monomethyl Ether
PGSC	payload and ground support computer
PMA	pressurized mating adapter

PMBT	propellant mean bulk temperature
ppCO ₂	partial pressure carbon dioxide
ppm	parts per million
PRSD	power reactant storage and distribution
psi	pound per square inch
psia	pound per square inch absolute
psid	pound per square inch differential
Q _d	dynamic pressure
QD	quick disconnect
RCC	radial carbon carbon
RCS	reaction control subsystem
RHC	rotational hand controller
RM	redundancy management
RMS	Remote Manipulator System
RPC	remote power controller
RPCM	remote power controller module
RSP	Resupply/Return Stowage Platforms
RSR	Resupply Stowage Rack
RSRM	Reusable Solid Rocket Motor
RSS	rotating service structure
RTV	room temperature vulcanizing (material)
RU	Rigid Umbilical
S&A	safe and arm
SCU	service and cooling umbilical
SIGI	Space Integrated Global Positioning system Navigation System
SLF	Shuttle Landing Facility
SLM	star line maneuver
SLP	Spacelab Logistics Pallet
SLWT	super lightweight tank
S/N	serial number
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSCS	Space-to-Space Communications System
SSME	Space Shuttle main engine
SSOR	Space-to-Space Orbiter Radio
SSRMS	Space Station Remote Manipulator System
SSSR	Space-to-Space Station Radio
STS	Space Transportation System
SUPA	Solid Urine Pretreat Assembly
SWAR	Sea water activated release
TACAN	Tactical Air Navigation
TAEM	terminal area energy management
TCS	trajectory control sensor
TPS	thermal protection system/subsystem
TSA	tool stowage assembly
TSM	tail service mast
TVIS	treadmill vibration isolation system
UHF	ultra high frequency
UOP	utilization operations panel
V	Volts

VSC	video signal recorder
WCS	waste collection system
WDVA	water dispenser valve assembly
WSB	water spray boiler