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STS-79 SPACE SHUTTLE MISSION REPORT

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National Aeronautics and
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Lyndon B. Johnson Space Center
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NOTE

The STS-79 Space Shuttle Mission Report was prepared from inputs received from the Space Shuttle Operations Engineering Office as well as other organizations. The following personnel may be contacted should questions arise concerning the technical content of this document.

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SPACE SHUTTLE

MISSION REPORT

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INTRODUCTION

STS-79 was the fourth of nine planned missions to the Russian Mir Space Station and the first to exchange only American crewmembers and the second crewmember exchange mission. STS-79 was also the second Mir docking mission to carry the Spacehab module and the first to carry the double module. The forward portion of the Spacehab double module housed experiments that the crew conducted throughout the mission. The aft portion of the Spacehab double module primarily housed the logistics equipment that was transferred to the Mir Space Station and space for return items from the Mir.

The STS-79 Space Shuttle Program Mission Report summarizes the activities such as rendezvous and docking and experiment operations. The Report also discusses the Orbiter, External Tank (ET), Solid Rocket Booster (SRB), Reusable Solid Rocket Motor (RSRM), and the Space Shuttle main engine (SSME) systems performance during the seventy-ninth flight of the Space Shuttle Program. The flight was also the fifty-fourth flight since the return-to-flight, and the seventeenth flight of the Orbiter Atlantis (OV-104). In addition to the Orbiter, the flight vehicle consisted of an ET that was designated ET-82; three Phase II SSMEs that were designated as serial numbers 2012, 2031, and 2033 in positions 1, 2, and 3, respectively; and two SRBs that were designated BI-083. The two RSRMs were designated RSRM-56 with one installed in each SRB. The individual RSRMs were designated as 360T056A for the left SRB, and 360T056B for the right SRB.

The STS-79 Space Shuttle Program Mission Report fulfills the Space Shuttle Program requirement as documented in NSTS 07700, Volume VII, Appendix E. The requirement is that each organizational element supporting the Program will report the results of their hardware (and software) evaluation and mission performance plus identify all related in-flight anomalies.

The primary objectives of this flight were to rendezvous and dock with the Mir Space Station and perform the exchange of a Mir Astronaut. A double Spacehab module carried science experiments and hardware, Risk Mitigation Experiments (RMEs) and Russian Logistics in support of the Phase 1 Program requirements. Additionally, Phase 1 Program science experiments [including the Commercial Protein Crystal Growth (CPCG)] were carried in the middeck. Spacehab-05 operations were performed. The secondary objectives of the flight were to perform the operations necessary to fulfill the requirements of the Shuttle Amateur Radio Experiment-II (SAREX-II). Also, as a payload of opportunity the requirements of Midcourse Space Experiment (MSX) were completed.

The STS-79 mission was planned as a 9-day plus 1-day flight plus 2 contingency days. The plus-1day was to provide an opportunity for docking on flight day 4 should the phasing angle or other problems prevent docking on flight day 3. The two contingency days were available for bad weather avoidance or Orbiter contingency operations. The sequence of events for the STS-79 mission is shown in Table I, and the Space Shuttle Vehicle Engineering Problem Tracking List is shown in Table II. The Marshall Space Flight Center (MSFC) Problem Tracking List is shown in Table III. Appendix A lists the sources of data, both formal and informal, that were used to prepare this report. Appendix B provides the definition of acronyms and abbreviations used throughout the report. All times during the flight are given in Greenwich mean time (G.m.t.) and mission elapsed time (MET).

The six-person crew for STS-79 consisted of William F. Readdy, Captain, U. S. Naval Reserve, Commander; Terrence W. Wilcutt, Lt. Col., U. S. Marine Corp, Pilot; Jerome Apt, Civilian, Ph. D., Mission Specialist 1; Thomas D. Akers, Col., U. S. Air Force, Mission Specialist 2; Carl E. Walz, Lt. Col., U. S. Air Force, Mission Specialist 3, John E. Blaha, Col. U. S. Air Force Ret., Mission Specialist 4 (Ascent); and Shannon W. Lucid, Civilian, Ph. D., Mission Specialist 4 (Descent). STS-79 was the sixth flight for Mission Specialist 4 (Descent), the fifth flight for Mission Specialist 4 (Ascent), the fourth space flight for Mission Specialists 1 and 2, the third space flight for the Commander and Mission Specialist 3, and the second space flight for the Pilot.

MISSION SUMMARY

The STS-79 vehicle was launched at 260:08:54:48.991 G.m.t. (3:54:49 a.m. c.d.t. on September 16, 1996) after a countdown that experienced no unexpected holds. The launch phase, on an orbital inclination of 51.6 degrees, was completed satisfactorily; and the vehicle was inserted into the nominally planned orbit with no orbital burning subsystem (OMS) 1 burn required.

The flight performance of the SSMEs, ET, and main propulsion system (MPS) was satisfactory. All SSME and RSRM start sequences occurred as expected, and launch phase performance was satisfactory in all respects. First stage ascent performance was as expected. The SRB separation, entry, deceleration, and water impact occurred nominally, and both SRBs were recovered and returned to Kennedy Space Center for disassembly and refurbishment. An in-flight anomaly was identified in the right-hand SRB forward skirt during the disassembly process when a wrench was found (Flight Problem STS-79-B-01). Also, an in-flight anomaly was identified in the right-hand RSRM nozzle when striated axial erosion was noted on the throat and forward exit cone (Flight Problem STS-79-M-01). The erosion resulted in negative margins of safety (-0.07 at 287.5 degrees and -0.01 at 39 degrees). This is the most extreme nozzle erosion in the history of the Program.

The fuel cell 2 pH sensor read high for 40 minutes (259:19:41 G.m.t.) during fuel cell start-up and also read high for three short periods of time between start-up and launch. The first and third high-pH indications also tripped the common pH sensor that is downstream of the individual fuel cell pH sensors. This type of indication (usually a 28- to 30-minute high pH reading at start-up) is common in fuel cells that have been idle for 10 months or more, and often occurs in new or newly refurbished fuel cells. This fuel cell (S/N 108) had its pH sensor, stack, regulator and O_2 flow-meter replaced in April 1996. The high pH reading is normally caused by metallic ions in the stagnant water within the fuel cell, and therefore is not indicative of electrolyte in the product water that corresponds with fuel-cell flooding. Since all other fuel cell 2 parameters were nominal and the pH sensor was off prior to launch, the fuel cell was considered acceptable for flight.

Approximately 10 minutes after launch at 260:09:04:33 G.m.t. (000:00:09:44 MET), the pH sensor read high for 19 minutes. The common pH sensor was also triggered, but fuel cell performance remained satisfactory. As a precautionary measure, fuel cells 2 and 3 were bus-tied. Also, the valves to water tanks A and B were closed, and the fuel cell water was directed into tank C. This configuration protected the water in tanks A and B from possible electrolyte that may have been in the product water. Fuel cell performance did not show any degradation, which would be expected to occur if fuel cell flooding was occurring. The crew performed a litmus test on the product water before using the water and found the water to be satisfactory.

Because of the fuel cell 2 high-pH problem, an analysis was performed that confirmed that no concern existed with the supply water for either consumption by the Orbiter crew or transfer to the Mir. No additional high-pH indications occurred on fuel cell 2, and fuel cell 2 performed satisfactorily for the remainder of the mission.

Postflight tests at Kennedy Space Center (KSC) have shown that the fuel cell is operating satisfactorily and it will not be replaced. However, engineering analyses have indicated that that there was KOH in the product water when the high Ph was indicated.

It is believed by engineering personnel that the KOH was caused by the manner in which the fuel cell was built.

During SSME start, the SSME 3 gaseous hydrogen (GH_2) outlet pressure measurement failed off-scale low. This pressure measurement is used for postflight flow control valve (FCV) analysis. All three FCVs are scheduled to be removed and replaced before STS-81(next mission of this vehicle).

Auxiliary power unit (APU) 2 had an unexplained shutdown after main engine cutoff (MECO) at 260:09:08:02 G.m.t. (00:00:13:13 MET). The APU 1 and 3 performance was nominal. As a result of the early APU 2 shutdown, hydraulic system 2 exhibited speedbrake motor backdriving. The hydraulic system 2 supply pressure dropped to 1670 psia and then increased to 2000 psia for approximately 23 seconds before dropping to 0 psia. The vehicle experienced a similar backdriving occurrence on the same system during APU post-ascent deactivation on STS-74.

The results of the data review and analysis of the loss of APU 2 enabled the Mission Management Team (MMT) to decide that the mission could proceed to the nominal end-of-mission as planned.

About four seconds after liftoff, while reacquiring the Global Positioning System (GPS) satellites, the GPS receiver apparently began tracking a 'phantom' satellite (Flight Problem STS-79-V-02). This GPS "runaway" condition has been seen previously at the Kennedy Space Center (KSC) and reproduced at the Orbiter Contractor Facility. Power was cycled to the receiver just before powering down the backup flight system (BFS). When the receiver was powered back on, a +6 hour deviation between the receiver and the general purpose computer (GPC) existed.

As planned, the payload general support computer (PGSC) was connected to the GPS during flight day 3 activities to monitor GPS performance. The crew noted during a later inspection that the GPS data cable had been connected to the wrong connector during the earlier GPS activation, and this condition resulted in the blank screen on the PGSC. The crew reconfigured the cabling, and the GPS worked properly for the remainder of the on-orbit period.

At 260:09:37:42 G.m.t. (000:00:42:53 MET), a two-engine straight-feed 48-second OMS-2 burn was performed, and a differential velocity (ΔV) of 76 ft/sec was imparted to the vehicle, raising perigee to 85 nmi.

At 260:12:35:23 G.m.t. (000:03:40:34 MET), a dual-engine, straight-feed OMS-3 (NC1) burn was initiated. This first rendezvous burn was 53 seconds in duration, and an 84 ft/sec ΔV was imparted to the vehicle. At 261:00:51:39 G.m.t. (000:15:56:50 MET), a left-engine, straight-feed OMS-4 (NC2) burn was initiated. The second rendezvous burn was 10.6 seconds in duration, and an 8 ft/sec ΔV was imparted to the vehicle. The subsystem performance as well as the results of both burns were nominal.

At 261:01:27 G.m.t. (000:16:33 MET), the crew reported a poll fail that tripped the built-in test equipment (BITE) flag on cathode ray tube (CRT) 1. A "CRT BITE 1" fault message was also annunciated. The data indicate a memory parity error occurred. The crew performed the specified malfunction procedure for this condition and successfully recovered the CRT. The CRT performed nominally for the remainder of the mission.

The NC4 rendezvous burn was performed using the reaction control subsystem (RCS) at 262:00:29 G.m.t. (001:15:34 MET). The firing provided a 4.4 ft/sec ΔV with

11 pulses from each of two thrusters, L3A and R3A. Trim for the burn was provided by thrusters F3D, F4D and R1U.

The Orbiter docking system (ODS) was powered up for docking-ring extension at 262:01:00 G.m.t. (001:16:05 MET). The docking ring was extended from the final position to the initial position in preparation for docking. The ODS performed nominally throughout the docking-ring extension procedure.

At 262:11:37:32 G.m.t. (002:02:42:43 MET), a straight-feed two-engine OMS 5 burn (NC5) was initiated. The rendezvous burn was 46.5 seconds in duration, and a ΔV of 74 ft/sec was imparted to the vehicle.

At 262:23:00:21 G.m.t. (002:14:08:32 MET), a straight-feed dual-engine OMS 6 rendezvous burn (NC-6) was initiated. This burn was 69.6 seconds in duration, and a ΔV of 114 ft/sec was imparted to the vehicle. At approximately 262:23:35:40 G.m.t. (002:14:40:51 MET), the corrective combination (NCC) rendezvous burn was executed using the RCS. The terminal initiation (TI) rendezvous burn, a straight-feed left engine (OMS 7) firing, was initiated at 263:00:32:58 G.m.t. (002:15:38:09 MET). This burn was 13.4 seconds in duration, and a ΔV of 11 ft/sec was imparted to the vehicle. The RCS was used to provide trim during the OMS firings; it was also used during the final approach to the Mir. The RCS was operating in the right OMS interconnect configuration throughout the rendezvous and docking. Subsystem performance was nominal during these burns.

The ODS was powered up for docking at 263:02:19:50 G.m.t. (002:17:25:01 MET) and all docking system temperatures were well within the limits. The Orbiter successfully docked with the Mir at 263:03:21:18 G.m.t. (002:18:26:29 MET), and the hatches were opened at 263:05:41 G.m.t. (002:20:46 MET). The ODS performance was nominal. At the time of docking, the contact conditions were well within the allowable limits. The angular misalignments appeared to be less than 1 degree per axis, and the lateral misalignment appeared to be approximately 0.5 inch. At the time of post contact thrust (PCT) initiation, the closing velocity was approximately 0.1 ft/sec. The PCT was initiated with approximately two inches of interface separation. Capture occurred at 263:03:13:18 G.m.t. (002:18:18:29 MET). The resulting docking loads were reconstructed from flight data and showed a maximum axial load of about 1000 kg, compared to an allowable of 1900 kg. Five seconds after capture, the high-energy dampers were activated by automatic sequence and remained on for 30 seconds. The auto sequence started extending the docking ring 60 seconds after capture, and the crew depressed the power-on switch, as planned, to interrupt the auto sequence and allow further damping. The relative motion damped quickly and developed less than one degree of rotation. The crew initiated the ring-in command to drive the ring to the final position. The structural hooks closed within 2.5 minutes in the dual-motor operational mode after activation by the ready-to-hook signal, and this completed the docking operations.

Following docking with the Mir, the crew successfully performed the pressurization and leak checks of the vestibule. The pressures were equalized between the Orbiter and the Mir with a final pressure of 14.23 psia. The hatch was opened at 263:05:41 G.m.t. (002:20:46 MET), and the crew installed the Mir air-transfer duct between the ODS and the docking module shortly thereafter.

The project team concluded that the Active Rack-Isolation System Experiment (ARIS) hardware has successfully passed the proof-of-concept demonstration for the operational design that will be used in the ISS. However, the ARIS had recurring problems with the upper actuator/pushrods (7 and 8), but a total of 19 of the 21 major ARIS experiment objectives was accomplished including 10 secondary objectives. A total of 128 data sets was collected for postflight analysis.

The active rack-isolation system (ARIS)/vernier RCS test was performed beginning at 265:06:02 G.m.t. (004:21:07 MET) with thrusters L5L and R5R each fired three times for one second. During the test, the RCS regulator reconfiguration from the A to the B regulators was also performed. The RCS was in the left OMS interconnect configuration during this test.

An unexplained Ku-band bus control element (BCE) bypass occurred at 265:18:50:52 G.m.t. (005:09:56:03 MET). At the time, the Ku-band was in standby as the result of the group B powerdown. The Ku-band system was power cycled and then an input/output (I/O) reset was commanded, resulting in recovery of the Ku-band system operation. The bypass did not repeat and there was no mission impact as a result of this occurrence.

A total of 20 CWCs, containing approximately 2025 lb of water, was filled and transferred to the Mir. The original planning was to provide the Mir with 15 CWCs of water; however, at the request of the Russian Management five additional CWCs were filled and transferred to the Mir.

Cabin pressurization using O_2 for atmospheric exchange with the Mir was initiated at 267:02:06 G.m.t. (006:17:11 MET). The Orbiter hatch to the ODS vestibule was closed at 267:12:23 G.m.t. (007:03:28 MET) with the total pressure at the planned levels of 15.42 psia and the O_2 partial pressure at 3.96 psia. The vestibule was depressurized at 267:12:30 G.m.t. (007:03:35 MET), and the leak check was completed at 267:13:15 G.m.t. (007:04:20 MET).

The ODS performed nominally during the undocking of the Orbiter from the Mir. The ODS was powered up at 268:00:50:54 G.m.t. (007:15:56:05 MET). The structural hooks were activated in the open direction at 268:01:31:29 G.m.t. (007:16:36:40 MET). The hooks traveled from approximately 92 to 5 percent and were deactivated at 268:01:33:48 G.m.t. (007:16:38:59 MET). The ODS was powered down at 268:01:43:35 G.m.t. (007:16:48:46 MET).

The RCS operated nominally during the undocking and separation from Mir. A low-Z-axis undocking burn took place at 268:01:31:34 G.m.t. (007:16:36:45 MET) and primary RCS thrusters L3A, R3A, F1F, and F2F along with thrusters F3D and F4D were used to back away from the Mir. A fly-around of the Mir was then performed using mainly the forward RCS thrusters. The separation burn took place 268:03:36:49 G.m.t. (007:18:42:00 MET) and consisted of a +X-axis burn with aft RCS thrusters L3A and R3A firing for 11 seconds.

The PRSD H_2 tank 3 system B heater failed to energize at 268:18:11 G.m.t. (008:09:16 MET). The previous heater cycle, which ended at 268:17:30 G.m.t. (008:35:11 MET), had been nominal. The system A heater on H_2 tank 3 functioned nominally for the remainder of the mission and was used to deplete the tank.

The RCS operated nominally during the Vernier RCS Reboost Demonstration Development Test Objective (DTO) 837, which demonstrated the capability to reboost the Hubble Space Telescope on a future flight using only the RCS vernier thrusters. DTO 837 was performed in left OMS interconnect and without the use of the aft yaw thrusters. The DTO began at 269:05:50 G.m.t. (008:20:55 MET) and continued for

18 minutes 44 seconds. During the DTO, 72 lbm of fuel and 117 lbm of oxidizer (1.5 percent of propellant in left OMS tanks) were used. Following the DTO, the digital autopilot (DAP) was set to preclude further vernier thruster firings to allow an evaluation of the thruster cool-down rates. Flight control system performance during the DTO was nominal.

Because of the failure of APU 2 during ascent, the flight control system (FCS) checkout was performed using the hydraulic system 2 circulation pump instead of the APU. Flight control system performance was nominal. Circulation pump 2 was started at 269:07:32:00.2 G.m.t. (008:22:38:11.2 MET) and ran for approximately 7 minutes 36 seconds. All hydraulic system parameters appeared normal during the FCS checkout. The maximum circulation pump pressure reached was 313 psi. There were frequent, but expected, pressure drops to as low as 88 psi due to over-demand when the elevon actuators were cycled.

The RCS hot-fire was performed beginning at 269:08:35 G.m.t. (008:23:40 MET) with each thruster being fired once. There were no fail-off or fail-leak conditions, and good chamber pressures and injector temperatures were noted on all thrusters.

All entry stowage and deorbit preparations were completed in preparation for entry on the nominal end-of-mission landing day. The payload bay doors were successfully closed and latched at 270:08:28 G.m.t. (009:23:33 MET).

The deorbit burn for the first landing opportunity at the KSC Shuttle Landing Facility (SLF) was performed on orbit 159 at 270:11:06:14 G.m.t. (010:02:11:25 MET), and the burn was 196 seconds in duration with a ΔV of 343.9 ft/sec.

During entry while performing the first programmed test input (PTI) for DTO 255 - Wraparound DAP Flight Test Verification - unexpected RCS yaw-thruster firings occurred when there should have been no thruster firings (Flight Problem STS-79-V-06). Evaluation of the data identified the source of the unexpected thruster firings as a configuration problem to the flight software load because of overlapping yaw RCS deadbands. The testing in the Shuttle Avionics Integration Laboratory revealed that the same problem existed for this PTI during the STS-80 mission. A decision was made to change the procedures to prevent the PTI from starting while operating in the overlapping deadbands area.

Entry was completed satisfactorily on two APUs because of the failure of APU 2. Shortly after air data probe deployment (approximately 3 seconds), the redundancy management (RM) declared an air data dilemma (Flight Problem STS-79-V-05). The crew recognized the dilemma and deselected and reselected air data transducer assembly (ADTA) 1 using normal procedures, thus resetting the RM. No further air data problems were encountered during the entry and landing phases of the flight.

Main landing gear touchdown occurred on concrete runway 15 at 270:12:13:13 G.m.t. (010:03:18:24 MET) on September 26, 1996. The Orbiter drag chute was deployed at 270:12:13:21 G.m.t. and the nose gear touchdown occurred 8 seconds later. The drag chute was jettisoned at 270:12:13:57 G.m.t. with wheels stop occurring at 270:12:14:34 G.m.t. The rollout was normal in all respects. The flight duration was 10 days 3 hours 18 minutes and 24 seconds. The APUs were shut down 17 minutes 54 seconds after landing.

PAYLOADS

The Phase 1 mission science was very successful. Many of the payloads and experiments were stowed and operated in the double Spacehab module, which performed anomaly-free throughout the mission. The Spacehab provided ample volume and crew-support hardware, which enhanced the operational effectiveness of the Spacehab.

The payloads on this mission were varied and divided into seven categories:

a. Fundamental Biology;
b. Phase 1 payloads;
c. Commercial Payload;
d. Risk Mitigation Experiments
e. IMAX Camera;
f. Shuttle Amateur Radio Experiment -II; and
g. Midcourse Space Experiment.

In addition, the Enhanced Orbiter Refrigerator/Freezer (EOR/F) provided satisfactory cold-storage conditions for the items that were returned to Earth for analysis.

FUNDAMENTAL BIOLOGY

The fundamental-biology area of research continued as the investigations study the effects of the space environment on the biological systems of plants as well as the radiation of the Mir and its possible impact on the International Space Station (ISS). Four areas of investigation were included in this category, as follows:

a. Environmental Radiation Measurements;
b. Greenhouse-Integrated Plant Experiments;
c. Human Life Sciences; and
d. Assessment of Humoral Immune Function During Long Duration Flight.

The results of the fundamental biology research will be reported at a later date in separate publications.

PHASE 1 PAYLOADS

Five payloads were manifested, three of which were transferred to the Mir and will be returned to Earth on STS-81, with the remaining two completed during the STS-79 mission. These payloads are:

a. Biotechnology System: The Biotechnology System (BTS) was transferred to the Mir for data collection. The results of the payload operations will be reported in a separate document.

b. Commercial Generic Bioprocessing Apparatus: The results of this payload's operation will be reported in separate documentation.

c. Material in Devices as Superconductor: This Materials in Devices as Superconductor (MIDAS) payload was transferred to the Mir for data collection.
d. Commercial Protein Crystal Growth Experiment: The Commercial Protein Crystal Growth (CPCG) experiment was transferred to the Mir and operated

without incident. The quality of the science will be determined from postflight analysis.

e. Mechanics of Granular Materials: The Mechanics of Granular Materials (MGM) facility successfully processed three test cells. The deactivation procedure following the initial sample run on flight day 3 was deferred, and coincided with a small water leak from a relief valve. It was determined that the leak was caused when the system software erroneously over-pressurized the system instead of incrementally depressurizing it after the deferred deactivation. A software update and changes to the deactivation procedure successfully corrected the problem.

COMMERCIAL PAYLOAD

Extreme Temperature Translation Furnace: The objectives of the Extreme Temperature Translation Furnace (ETTF), which was the last commitment of the Commercial Middeck Augmentation Module (CMAM) contract, were two-fold in nature: science, and facility demonstration. The science objective was not fully met in that only one of the four ampoules was processed. The facility demonstration objective did not demonstrate the capability to reach the target temperatures that were in excess of 1600 °C. Two attempts to reach the higher target temperatures resulted in opening the power circuit breaker and an inability to exceed 979 °C. The late hardware-completion after rework that was required because of test failures prevented a full-up preflight checkout. The partial preflight tests also failed to reach the desired temperature. Neither the crew nor the flight control team was made aware of the preflight anomalies.

Mechanically, sample 1 could not initially be installed in the furnace because of an out-of-tolerance condition on the ampoule flange. This problem was corrected on-orbit by the crew. Sample 1 was successfully processed during the mission. Samples 2 and 3 were not processed satisfactorily, and processing of sample 4 was not attempted because of the temperature problem observed on other samples.

RISK MITIGATION EXPERIMENTS

The Risk Mitigation Experiments (RMEs) were flown on STS-79. These were:

a. **RME 1302 - Mir Electric Field Characterization:** The Mir Electric Field Characterization (MEFC) data collection was performed on the Shuttle during pre-docking and post-separation, and on the Mir during the docked phase. The data collection activities revealed the need to change the experiment boot-up procedures because the PGSC was locking up during activation. Analysis showed that additional time was required between powering of the Spectrum Analyzer and the PGSC to properly establish device communication. These procedures were incorporated and successful operation was achieved

b. **RME 1303 - Shuttle/Mir Experiment Kit Transport:** The equipment for this RME was successfully transferred to the Mir.

c. **RME 1310 - Shuttle/Mir Alignment Stability Experiment:** Shuttle-Mir relative alignment data were collected for this experiment.

d. **RME 1312 - Intra-Vehicular Radiation Environment Measurement by the Real-Time Radiation Monitor:** System operation and data collection were nominal for this experiment.

e. **RME 1313 - Active Rack Isolation System Experiment:** The Active Rack-Isolation System Experiment (ARIS) had recurring problems with the upper actuator/pushrods (7 and 8). Preliminary analysis concluded that snubber support-arm flexibility was underestimated, and this condition may have allowed excessive rack travel that resulted in compression of the actuator/pushrods. The ARIS hardware consisted of eight sets of actuator/pushrods that attenuate oscillations, and seven of the eight actuator/pushrods are necessary for operation. Three spare actuator/pushrods were stowed in the ARIS stowage, and were used during the several in-flight maintenance (IFM) recovery procedures that were performed as a result of three episodes of divergent ARIS oscillation instability during the flight.

The vernier RCS test was performed at 265:06:02 G.m.t. (04:21:07 MET) with thrusters L5L and R5R each firing three times for one second. A total of 19 of the 21 major experiment objectives were accomplished including 10 secondary objectives. A total of 128 data sets were collected for postflight analysis. The project team has concluded that the hardware has successfully passed the proof-of-concept demonstration for the operational ARIS design that will be used in the ISS.

On flight day 2, the crew reported that the ARIS rack was shaking in a divergent oscillation and further investigation revealed that actuator/pushrod 7 was disconnected and bent. The actuator/pushrod was replaced and operations were continued.

On flight day 3, the Three Dimensional Accelerometer (3DMA) locked up; however, nominal system operation was recovered with a ground-commanded rack 1 power cycle. Downlink of the critical 3DMA files using the Orbiter communication adapter (OCA) was required as a result of poor communications with the ground. On flight day 3, actuator/pushrod 8 failed and was replaced, and an alignment adjustment was made.

On flight day 5, actuator/pushrod 8 came loose during another ARIS divergent oscillation and the crew confirmed that it was damaged. The actuator/pushrod was removed to enable further operations. A subsequent flight day 6 inspection and hyperextension test resulted in the replacement of actuator/pushrod 7.

A new ARIS rack inspection procedure was uplinked on flight day 7, and actuator/pushrod 8 was replaced. Later during the flight day 7 sleep period, the crew reported a banging sound during a third divergent oscillation. Investigation the next morning revealed that actuator/pushrod 7 was damaged, but actuator/pushrod 8 was nominal. Actuator/pushrod 7 was removed and was taped down for stowage. Actuator/pushrod 8 was realigned, and hyperextension-tested as a precaution before data gathering operations continued.

f. **RME 1319 - Inventory Management System:** The inventory management system (IMS) was successfully performed and all required data were collected.

IMAX CAMERA

The IMAX camera was used to document activities on the Atlantis and on Mir. Footage from this mission plus STS-63, STS-71, and STS-74 will be incorporated into a large-format feature film about NASA's cooperation with Russia.

SHUTTLE AMATEUR RADIO EXPERIMENT-II

Overall, the Shuttle Amateur Radio Experiment-II (SAREX-II) performed satisfactorily. Three school contacts (Celina, Ohio; Andover, Kansas; and Haslemere, Surrey, England) were completed as planned beginning on flight day 5. Over 750 students participated in the contacts, and 37 question were asked and 34 were answered. Additional contacts were made on flight day 7.

Some of the ground stations reported weak audio levels during the contacts, as well as weak signals. Adjusting the placement of the microphone corrected the weak audio levels in most cases. The SAREX-II team evaluation has postulated two theories on the weak signals, which are:

a. Marginal Orbiter attitude to support the contact (occurred during inertial attitudes - mostly during docked periods).
b. Ground station problems (VK61U reported problems with their antenna array after the last contact).

MIDCOURSE SPACE EXPERIMENT

A 10-second +X axis firing of the primary RCS was performed at 268:16:55:57 G.m.t. (008:08:01:08 MET). The data from the Midcourse Space Experiment (MSX) indicate that the MSX spacecraft successfully acquired and tracked the Orbiter. The MSX acquired the Orbiter in darkness and began to track as it moved into daylight. During this time, the Orbiter was positioned slightly below the field-of-view of its Ultraviolet and Visible Imagers and Spectrographic Imagers (UVISI) instrument. This orientation would allow optimal viewing of the RCS plume. All indications are that this event was a complete success. It also appears that the MSX successfully tracked the Orbiter's S-band frequency modulation (FM) (continuous-wave low-power) signal, which would allow future MSX events to be planned without the need for the Orbiter's S-band phase-modulated (PM) signal.

RENDEZVOUS AND DOCKING

RENDEZVOUS

The rendezvous with the Russian Mir Space Station was successfully completed as planned with no in-flight anomalies noted during the process.

The rendezvous flight phase was initiated with the phasing (NC) burn. This burn was used to adjust the catch-up rate between the two vehicles. The local vertical local horizontal (LVLH) components of the burn were 114.1, 0.0, and 4.5 ft/sec for the X axis, Y axis, and Z axis LVLH, respectively. The time-of-ignition (TIG) for the dual-engine OMS 6 burn was 262:23:00:21.8 G.m.t. (002:14:29:32.8 G.m.t). The Orbiter apogee and perigee increased from 202.9 by 137.4 nmi. to 204.3 by 201.4 nmi., as a result. The ΔV trim residuals were 0.2 ft/sec or less, indicating good guidance/flight control performance.

The target state vector was uplinked prior to the phasing burn and was followed soon after by the rendezvous guidance being enabled. The initial range to the target was 2,356,957 ft. (approximately 393 nmi.). After the burn was completed, the Orbiter was burned to the -Z axis target-tracking attitude for the first star-tracker pass. The initial star-tracker measurement residuals (difference from the expected) were very small, and after the first eleven marks the horizontal and vertical residuals were 0.00 degree.

During the star tracker pass, the corrective combination (NCC) burn solution was computed three times and compared to the ground-computed solution for reasonability. The following table summarizes the star tracker pass and NCC burn solution computations. The burn was executed on-time at 262:23:35:17 G.m.t. (002:14:40:28 MET) using a multiple-axis RCS thruster configuration. The Orbiter apogee and perigee following the NCC burn were 203.4 by 200.4 nmi., respectively.

NCC Maneuver Solution	Differential Velocity in X, Y, and Z axis, ft/sec	No. Of Navigation Marks
Preliminary	-1.0, -0.7, 1.3	0
Intermediate	-1.1, -0.6, 1.8	119
Final	-1.2, -0.5, 2.1	126

After the transition back to major mode (MM) 201, the rendezvous radar (RR) pass was initiated. During the RR pass, the terminal initiation (TI) burn solution was computed three times and compared to the ground-computed solution for reasonability. The following table summarizes the RR pass and TI burn-solution computations. The burn (OMS 7) was executed at the guidance-computed inertial attitude and on-time at 263:00:32:59.2 G.m.t. (002:15:38:11.2 MET). The left OMS engine was used to execute the 11 ft/sec burn, and the ΔV residuals were less than 0.3 ft/sec. The Orbiter apogee and perigee after the burn was 209.0 by 201.7 nmi, respectively.

Between the TI burn and target intercept, the midcourse correction (MC) burns, one through four, were executed to correct for dispersions in the relative trajectory and to insure that target intercept would occur in sunlight. All four of these

TI Maneuver Solution	Differential Velocity in X, Y, and Z axis, ft/sec	No. Of Navigation Marks
Preliminary	10.9, -0.1, 1.7	0
Final	10.9, -0.0, 1.8	156

burns are nominally zero, and if not, are usually less than 2.0 ft/sec. The MC 1 burn solution was 0.3 ft/sec in XLVLH, 0.2 ft/sec in YLVLH, and 0.9 ft/sec in ZLVLH. The burn was performed manually using the RCS thrusters while maintaining target-track attitude.

The TIG of MC 2 varies depending on the elevation angle between the local horizontal of the Orbiter and the line-of-sight to the target. The desired elevation angle is used to ensure that the target is illuminated during proximity operations. The nominal amount of variation between the planned and the actual TIG is +7 minutes and -3 minutes. For this rendezvous, the MC 2 TIG slip was +4 minutes 2 seconds. The final burn solution was -0.4 ft/sec in XLVLH, -0.2 ft/sec in YLVLH, and 1.6 ft/sec in ZLVLH with a TIG of 263:01:26:37 G.m.t. (002:16:31:48 MET). The burn was performed in the target-track attitude using the RCS thrusters.

The MC 3 and MC 4 burn solutions were nominal and no burns were required at 10 and 20 minutes after MC2, respectively. During the RR pass, no rendezvous navigation marks were rejected with over 650 marks incorporated. The rendezvous was successfully completed with RBAR arrival (350 ft.) at approximately 263:02:13:00 G.m.t. (002:17:18:11 MET).

PROXIMITY OPERATIONS AND DOCKING

Shortly after the fourth midcourse correction, which was performed at 263:01:46:37 G.m.t. (02:16:51:48 MET), the manual trajectory control phase was initiated by performing the corridor approach while simultaneously establishing RBAR (vector from the Mir to the center of the Earth). A center-of-Earth track with the Orbiter's -X body pointing vector (BPV) was initiated to aid the crew efforts to maintain the RBAR approach (pitch angle error = 0 when on the Mir RBAR) while maintaining visual contact with the Mir Docking port.

The ODS was powered up for docking at 263:02:19:43 G.m.t. (002:17:24:54 MET), and capture occurred at 263:03:13:18 G.m.t. (002:18:18:29 MET). At this point, the translation hand controller (THC) was used to operate the ± X RCS thrusters to maintain the Orbiter on the RBAR while the +Z RCS thrusters controlled the approach rate. The pre-determined range-to-range-rate gates were used to control the approach, and at the first gate the range was 2000 ft and closing rate was -4 ft/sec.

Once the range to the Mir was less than 1000 ft, the DAP was moded to low power to reduce the RCS thruster impingement on the Mir's solar panels. The tail-forward burn was initiated by changing the universal pointing track attitude parameter, Omicron, from 0 degree (nose forward) to 180 degrees (tail forward).

At a range to the Mir of 500 ft, the Ku-band radar was moded to low power to protect the Mir and the Ku-band antenna. Also, at that time, as the range to the target decreased, the RR navigation marks became noisier because of RR beam-wander over the increasingly larger subtended angle of the Mir and the RCS thruster firings during proximity operations.

The first stationkeeping point came at 170 ft. The range-rate was allowed to decrease to nearly zero while the RBAR was maintained by using the THC and the ± X RCS thrusters. At the appropriate time, the approach timeline was initiated by performing the procedures for final approach (DAP A8 configuration, establish/maintain 8-degree corridor, activate the TCS, prepare cockpit, and initiate the approach using the + Z RCS thrusters). Prior to docking with the Mir, stationkeeping at 30 ft was established for a short period of time. The initial contact conditions were well within the allowable limits. The angular misalignments appeared to be less than 1 degree per axis, and the lateral misalignment appeared to be approximately 0.5 inch. At the time of post contact thrust (PCT) initiation, the closing velocity was approximately 0.1 ft/sec. The PCT was initiated with approximately two inches of interface separation. The resulting docking loads were reconstructed from flight data and showed a maximum axial load of about 1000 kg, compared to a maximum allowable of 1900 kg. All automated functions of docking were completed as planned, and the rendezvous navigation was disabled.

UNDOCKING

The ODS was powered up at 268:00:50:54 G.m.t. (007:15:56:05 MET). The structural hooks were activated in the open direction at 268:01:31:29 G.m.t. (007:16:36:40 MET). The hooks traveled from approximately 92 to 5 percent and were deactivated at 268:01:33:48 G.m.t. (007:16:38:59 MET) after completion of the undocking sequence.

A low-Z-axis undocking burn took place at 268:01:31:34 G.m.t. (007:16:36:45 MET) and primary RCS was used to back away from the Mir. A fly-around of the Mir was then performed using mainly the forward RCS thrusters during which the forward RCS propellants were reduced to near zero remaining. The separation burn took place 268:03:36:49 G.m.t. (007:18:42:00 MET) and consisted of a +X-axis burn for 11 seconds.

VEHICLE PERFORMANCE

The flight evaluation results showed that all SSME and RSRM start sequences occurred as expected, and launch phase performance was satisfactory in all respects. First stage ascent performance was nominal. The SRB separation, entry, deceleration, and water impact occurred as anticipated. Both SRBs were successfully recovered and returned to Kennedy Space Center (KSC) for disassembly and refurbishment. Performance of the SSMEs, ET, and main propulsion system (MPS) was nominal.

Two in-flight anomalies were identified from the post-recovery inspection of the SRB/RSRM hardware. These are discussed in the following two sections of the report.

SOLID ROCKET BOOSTERS

All Solid Rocket Booster (SRB) systems performed nominally. The SRB prelaunch countdown was normal, and no SRB Launch Commit Criteria (LCC) or Operational Maintenance Requirements and Specifications Document (OMRSD) violations occurred. One in-flight anomaly was identified during the disassembly process when a wrench was found in the right-hand SRB forward skirt (Flight Problem STS-79-B-01). An Anomaly Team has been formed to investigate this incident.

In addition to the in-flight anomaly, one limit was exceeded and the cause has been identified. Data showed that the right SRB tilt system hydraulic power unit (HPU) turbine speed had exceeded the upper limit (108 percent) of the 100-percent operating-speed control band by 0.33 percent for one data sample. An investigation showed that the system was in a high-load condition and the primary speed control valve was opened in response to the load that caused the turbine wheel's speed increase. The actuator reached null at this time, suddenly removing the load from the system. The turbine speed continued to increase under the reduced load after the last valve cycle leading to the specification being exceeded. The amount that the limit was exceeded was well within the experience base (109 percent on STS-41, and 108.33 percent seen on STS-53 and STS-78). The limit being exceeded in this case is understood and is not considered a problem as control was maintained.

Analysis of the Orbiter accelerometer data indicates that a stud hang-up occurred at liftoff. Postflight examination of the hardware and review of liftoff films confirmed that a stud hang-up occurred during liftoff at hold-down post (HDP) 3. This condition has been noted on a number of the previous flights, and a team has been formed to determine the cause.

Both SRBs were successfully separated from the External Tank (ET) at liftoff plus 122.084 seconds, and reports indicated that the deceleration subsystems performed as designed. Both SRBs were recovered and returned to Kennedy Space Center (KSC) for disassembly and refurbishment.

REUSABLE SOLID ROCKET MOTORS

Data indicate that the flight performance of both Reusable Solid Rocket Motors (RSRMs) was well within the allowable performance envelopes, and was typical of the performance observed on previous flights. The RSRM propellant mean bulk temperature (PMBT) was 81 °F at liftoff. The propulsion performance is shown in the table on the following page. The maximum trace shape variation of pressure versus time was well within limits and was calculated to be -0.54 percent at 75 seconds for the left motor and 1.17 percent at 69 seconds on the right motor.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 81 °F		Right motor, 81 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10^6 lbf-sec	66.91	67.39	67.12	67.35
I-60, 10^6 lbf-sec	177.80	178.90	178.27	179.23
I-AT, 10^6 lbf-sec	296.82	296.91	296.84	296.45
Vacuum Isp, lbf-sec/lbm	268.6	268.7	268.6	268.3
Burn rate, in/sec @ 60 °F at 625 psia	0.3704	0.3719	0.3711	0.3736
Burn rate, in/sec @ 81 °F at 625 psia	0.3760	0.3775	0.3767	0.3793
Event times, seconds[a]				
Ignition interval	0.232	N/A	0.232	N/A
Web time[b]	107.7	106.6	107.3	105.9
50 psia cue time	117.3	117.0	116.9	116.2
Action time[b]	119.3	119.5	119.0	118.3
Separation command	122.2	122.1	122.8	122.1
PMBT, °F	81	81	81	81
Maximum ignition rise rate, psia/10 ms	90.4	N/A	90.4	N/A
Decay time, seconds (59.4 psia to 85 K)	2.7	3.4	2.7	3.1
Tailoff Imbalance Impulse differential, Klbf-sec	Predicted		Actual	
	N/A		1027.7	

Impulse Imbalance = Integral of the absolute value of the left motor thrust minus right motor thrust from web time to action time.
[A] All times are referenced to ignition command time except where noted by a [b]
[B] Referenced to liftoff time (ignition interval).

Power-up and operation of all field and igniter joint heaters was accomplished as planned. The field joint heaters operated for 12 hours 50 minutes during the countdown. The igniter heaters operated for 12 hours 41 minutes during the countdown. All RSRM temperatures were maintained within acceptable limits. For this flight, the low-pressure heated ground-purge in the SRB aft skirt operated for 5 hours 17 minutes and was used to maintain the nozzle/case joint temperatures within the required LCC ranges. During the LCC time frame, the nozzle/case joint sensor temperatures ranged from 80 to 86 °F and 82 to 86 °F for the left and right motors, respectively. At T-15 minutes, the purge was changed to high pressure to inert the SRB aft skirt.

One in-flight anomaly was identified during the postflight disassembly process. Striated axial erosion was noted on the throat and forward exit cone of the right-hand RSRM nozzle (Flight Problem STS-79-M-01). The erosion resulted in negative margins of safety (-0.07 at 287.5 degrees and -0.01 at 39 degrees). This is the most extreme nozzle erosion in the history of the Program. The cause of this condition continues to be evaluated as this report is being written. All other engineering and contract end item (CEI) requirements were met on all other components.

EXTERNAL TANK

The ET loading and flight performance was excellent with all objectives and requirements for propellant loading and flight operations being met. All ET electrical equipment and instrumentation operated satisfactorily. The ET purge and heater operations were also satisfactory. No ET LCC or OMRSD violations were identified, nor were any in-flight anomalies identified from the data review.

This was the first loading that used the new 25 kW heater that was installed on launch pad A for the nose cone purge, and the heater and temperature control system operated very successfully. The nose-cone compartment set point temperature was lowered to ensure that the heater outlet temperature would not exceed the maximum OMRSD temperature limit. Tests of the new heater controller are continuing at this writing in an effort to reduce the maximum heater outlet temperature. The measured nose-cone flow rate was within the Interface Control Document (ICD) requirement of 9 to 16 lbm/min.

No unexpected ice/frost formations were observed on the ET during the countdown. No ice or frost was observed on the acreage areas of the ET. Normal quantities of ice or frost were present on the liquid oxygen (LO_2) and liquid hydrogen (LH_2) feed-lines, the pressurization-line brackets, and along the LH_2 protuberance air load (PAL) ramps. These observations were acceptable based on NSTS-08303. The Ice/Frost Red Team reported that no anomalous thermal protection system (TPS) conditions were found.

STS-79 was the first flight of the new type of foam for the aft dome and the new hard-point closeout, and no in-flight anomalies were observed. Post-separation photographs of the ET showed divots, marks on the foam, and small areas of missing or damaged foam at four locations. Similar items have been noted on previous flights.

The ET pressurization system functioned properly throughout engine-start and flight. The minimum LO_2 ullage pressure experienced during the ullage pressure slump was 13.6 psid.

ET separation was confirmed, and the postflight predicted ET impact point was approximately 13 nautical miles uprange of the preflight predicted impact point.

SPACE SHUTTLE MAIN ENGINES

All Space Shuttle main engine (SSME) parameters were normal throughout the prelaunch countdown and were typical of prelaunch parameters observed on previous flights. Engine-Ready was achieved at the proper time, all LCC were met, and engine start and thrust buildup were normal.

Flight data indicate that the SSME performance during mainstage, throttling, shutdown, and propellant dump operations was normal. The high pressure oxidizer turbopump (HPOTP) and high pressure fuel turbopump (HPFTP) temperatures were well within specification throughout engine operation. Main engine cutoff (MECO) occurred at 514.039 seconds after liftoff. The specific impulse (Isp) was rated as 452.0 seconds based on trajectory data. There were no failures or significant problems identified from the review of the data.

STS-79 was the first flight with a new commanded SSME mixture ratio of 6.020. Postflight reconstruction of propellant residuals compare favorably with predictions.

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 the system inhibits were turned off at the appropriate times.

All SRSS measurements indicated that the system operated as expected throughout the countdown and flight, except that the right-hand SRB signal-strength dropped below the 2.1-Vdc requirement approximately 100 seconds after liftoff and remained low until after SRB separation (Flight Problem STS-79-B-01). Since the lowest observed right-hand SRB signal strength remained above the specified command sensitivity, the performance of the system was not degraded. The low signal strength was caused by continued tracking of the vehicle from the Cape Kennedy tracking site instead of handing over to the Jonathan Dickinson tracking site at T + 100 seconds.

As planned, the SRB S&A devices were safed, and SRB system power was turned off prior to SRB separation. No in-flight anomalies were identified from the data review.

The ET SRSS was deleted from the vehicle.

ORBITER SUBSYSTEMS PERFORMANCE

Main Propulsion System

The overall performance of the main propulsion system (MPS) was nominal. LO_2 and LH_2 loading was completed as planned with no stop flows or reverts. There were no OMRSD or LCC violations, nor any in-flight anomalies.

Throughout the period of preflight operations, no significant hazardous gas concentrations were detected. The maximum hydrogen concentration level measured in the Orbiter aft compartment occurred at the start of fast fill and was approximately 154 ppm, which compares favorably with previous data for this vehicle.

The LH_2 loading operations were normal through chill-down, slow fill, fast-fill, topping and replenish. A comparison of the LH_2 load at the end of replenish, which was 231,375 lbm, with the predicted load of 231,322 lbm provides a difference of +0.02 percent. This value is well within the required loading accuracy of ±0.37 percent.

The LO_2 loading operations were normal through chill-down, slow fill, fast fill, topping and replenish. A comparison of the flight load of 1,388,990 lbm with the predicted load of 1,388,277 lbm yields a difference of +0.05 percent, well within the required accuracy of ±0.43 percent.

During SSME start, the SSME 3 gaseous hydrogen (GH_2) outlet pressure measurement failed off-scale low. This pressure measurement is used for postflight FCV analysis. Postflight troubleshooting revealed that the connector to the transducer had come loose. Inspection showed no damage had occurred to the connector. This loose connector caused the problem. Based on data review, all three FCVs performed nominally and are scheduled to be removed and replaced for modification prior to STS-81 (next mission of this vehicle).

Ascent MPS performance was normal, and data indicate that the LO_2 and LH_2 pressurization systems performed as planned, and that all net positive suction pressure (NPSP) requirements were met throughout the flight. The gaseous oxygen (GO_2) fixed orifice pressurization system performed nominally. Reconstructed data from the engine and MPS parameters closely matched the actual ET ullage-pressure measurements.

Review of MPS performance data showed that the LH_2 inboard fill-and-drain valve opened faster than expected when the valve was opened for the MPS propellant dump at 260:09:05:19 G.m.t. (00:00:10:30 MET). The OMRSD File IX required opening time is 5 to 14 seconds, and the valve opening time was 4.382 seconds. Postflight, the closing and opening solenoids were leak checked and no appreciable leakage was found. If further ground checkouts reveal no anomalies, the valve will be flown as-is, and most likely replaced at the next OV-104 vehicle OMDP.

Also, the data review has shown that the MPS 750-psi pneumatic system pressure-decay rate was faster than expected following the post-ascent deactivation of the system. The OMRSD File IX requirement for the decay rate is 2.4 psi/min (maximum), and the decay rate was calculated as 3.8 psi/min. Postflight tests revealed over 100 scim of leakage, a significant portion of which was from the solenoid valve (LV22) that opens the SSME 3 LH_2 prevalve. The LV22 valve will be replaced and retested in accordance with established procedures. There was no flight impact as sufficient helium existed to support the leak rate when the system was repressurized during entry/landing, and the valve was not cycled again during the mission.

Reaction Control Subsystem

The reaction control subsystem (RCS) performed nominally during the mission and no in-flight anomalies were noted. Propellant consumption during the mission was 3,708.3 lbm from the RCS tanks and 3,423.9 lbm from the left and right OMS tanks.

The RCS was used for the NC 4 rendezvous burn as well as the NCC burn, and the final Mir rendezvous and docking burns.

A low-Z-axis undocking burn was performed at 268:01:31:34 G.m.t. (07:16:36:45 MET), and it was followed by a fly-around of the Mir during which an extensive depletion of the forward RCS propellants occurred. At 268:03:36:49 G.m.t. (07:18:42:00 MET), the aft RCS thrusters L3A and R3A were fired for 11 seconds to provide the +X-axis separation from the Mir proximity.

The Vernier RCS Reboost DTO 837 began at 269:05:50 G.m.t. (08:20:55 MET) and continued for 18 minutes 44 seconds. During the DTO, 1.5 percent of the left OMS propellants were used and this represented 72 lbm of fuel and 117 lbm of oxidizer. The DAP was set to preclude further vernier thruster firings after the DTO so that thruster cool-down rates could be evaluated. The approximate ΔV during the 18-minute 44-second period was 7.2 ft/sec (7.1 ft/sec predicted). The burn was performed in an attitude such that the deorbit burn ΔV was reduced by 7.0 ft/sec.

The RCS hot-fire test, which consisted of one-firing per thruster, was satisfactorily performed with no thruster problems at 269:08:35 G.m.t. (08:23:40 MET).

The RCS thrusters performed satisfactorily during entry. As the forward RCS propellants had been depleted to 4.4 percent oxidizer and 1 percent fuel during the fly-around of the Mir, the forward RCS depletion firing was not performed during entry.

Orbital Maneuvering Subsystem

The orbital burning subsystem (OMS) operated in a satisfactory manner throughout the flight with no in-flight anomalies noted. A total of 18,828.0 lbm of OMS propellants were consumed during the mission. The RCS used 3423.9 lbm of OMS propellants during interconnect operations. The OMS 1 burn was not required because a direct-insertion trajectory was flown as planned. The following table provides data concerning the OMS burns.

OMS FIRINGS

OMS firing	Engine	Ignition time, G.m.t./MET	Firing duration, seconds	ΔV, ft/sec
OMS-2	Both	260:09:37:42 G.m.t. 000:00:42:53 MET	47.8	76
OMS-3 (NC-1)	Both	260:12:35:23 G.m.t. 000:03:40:34 MET	53.0	84
OMS-4 (NC-2)	Left	261:00:51:39 G.m.t. 000:15:56:50 MET	10.6	8
OMS-5 (NC-5)	Both	262:11:37:32 G.m.t. 002:02:42:43 MET	46.5	74
OMS-6 (NC-6)	Both	262:23:00:21 G.m.t. 002:14:08:32 MET	69.6	114
OMS-7 (TI)	Left	263:00:32:58 G.m.t. 002:15:38:09 MET	13.4	11
Deorbit	Both	270:11:06:14 G.m.t. 010:02:11:25 MET	196.0	343.9

Inlet pressures, chamber pressure, and regeneration jacket temperatures for both engines were as expected. The OMS firing times and propellant consumption were consistent with preflight predictions, and also verified proper subsystem performance. The purge valves operated as commanded with gaseous nitrogen (GN_2) usage as expected, verifying no flow restrictions existed. Proper oxidizer tank pressure verified that the vapor isolation valves had opened as commanded.

Pressure/temperature data during coast periods indicated no detectable propellant tank leakage. Gage data from the engine firings indicated no loss of propellant from the aft compartment, confirming the bulkhead screen integrity. The OMS software firing-sequence functions, which include engine firing, helium and vapor isolation valve operation and purge valve operation, were performed nominally.

Power Reactant Storage and Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem performed nominally throughout the STS-79 mission. The PRSD subsystem provided 2697 lbm of oxygen (O_2) and 340 lbm of hydrogen (H_2) for the production of electrical energy by the fuel cells. Also, the PRSD supplied 176 lbm of oxygen to the environmental control and life support system (ECLSS) for crew breathing and supply to the Mir. Based on reactant quantities remaining after landing, a two-day mission extension would have been possible at the average power levels.

The H_2 tank 3 heater failed to energize at 268:18:09 G.m.t. (008:09:14 MET) with 62.1 percent H_2 remaining in the tank (Flight Problem STS-79-V-03). The redundant heater was used to pressurize the tank for the remainder of the mission. Previous failures have occurred in this heater circuit on other H_2 tanks and the cause was isolated to a broken fuse element. The postflight investigation of this anomaly also revealed a broken fuse element.

At 266:17:41:20 G.m.t. (006:08:46:31 MET), ground telemetry showed a false-closed indication of the power reactant storage and distribution (PRSD) system hydrogen (H_2) manifold 1 isolation valve. Evaluation of the data verified that the valve was open. The associated fault detection and annunciation (FDA) alarm was not generated because it had been inhibited on flight day 1 to avoid nuisance alarms. The crew confirmed that the on-board talkback also showed a closed indication. This condition was seen on the same hardware on STS-71 and STS-74 (OV-104 flights 14 and 15) and could not be repeated in ground testing. The problem did not repeat on STS-76 (OV-104 flight 16). The PRSD H2 manifold 1 isolation valve was closed for crew sleep at 267:14:31 G.m.t. (007:05:36 MET). When the valve was re-opened at 268:00:30 G.m.t. (007:15:35 MET), both ground telemetry and on-board talkback indicated the correct position of the valve. This condition had no impact on the mission. The valve is scheduled to be removed during the 1998 Orbiter Maintenance Down Period (OMDP) of OV-104.

Fuel Cell Powerplant Subsystem

Performance of the fuel cell powerplant (FCP) subsystem was nominal. The average electrical power level and load were 16.1 kW and 526 amperes, respectively. The fuel cells produced 3,922 kWh of electrical energy and 3,037 lbm of potable water from 2,697 lbm of oxygen and 340 lbm of hydrogen.

Four purges of the fuel cells, using both the automatic and manual modes, were satisfactorily performed during the mission. The actual fuel cell voltages at the end of the mission were 0.05 Vdc, 0.15 Vdc, and 0.20 Vdc above the predicted for fuel cells 1, 2, and 3, respectively.

The fuel cell 2 O_2 flow-meter failed at 262:10:00 G.m.t. (002:01:05 MET). The indication began to slowly decrease and ceased responding to changes in the load and during purges. During entry, the measurement began to increase and was operating nominally postlanding. This problem did not impact the flight.

The fuel cell 2 pH sensor read high for 40 minutes (259:19:41 G.m.t.) during fuel cell start-up and also read high for three short periods of time between start-up and launch. The first and third high pH indications also tripped the common pH sensor which is downstream of the individual fuel-cell pH sensors. This type of indication (usually a 28- to 30-minute high pH reading at start-up) is common in fuel cells which have been idle for 10 months or more, and often occurs in new or newly refurbished fuel cells. This fuel cell (S/N 108) had its pH sensor, stack, regulator and O_2 flow-meter replaced in April 1966. The high pH reading is normally caused by metallic ions in the stagnant water within the fuel cell, and therefore is not indicative of electrolyte in the product water that occurs during fuel-cell flooding. Since all other fuel cell 2 parameters were nominal and the pH sensor was off prior to launch, the fuel cell was considered acceptable for launch.

Approximately 10 minutes after launch, the pH sensor read high for 19 minutes beginning at 260:09:04:33 G.m.t. (000:00:09:44 MET). The common pH sensor was also triggered, but fuel cell performance remained satisfactory. As a precautionary measure, fuel cells 2 and 3 were bus-tied, and the valves to tanks A and B were closed, to route the fuel cell water into tank C. This configuration protected the water in tanks A and B from possible electrolyte contamination. Fuel cell performance did not show any degradation, which would be expected to occur if fuel cell flooding was actually occurring. The crew performed a litmus test on the product water and found the water to be satisfactory.

Because of the fuel cell 2 high-pH problem, an analysis was performed that confirmed that there was no concern with using the supply water for either consumption by the Orbiter crew or transfer to the Mir. No further high-pH indications occurred on fuel cell 2, and fuel cell 2 performed satisfactorily for the remainder of the mission.

Postflight testing at KSC determined that the fuel cell was in satisfactory condition and would remain in the vehicle. However, engineering analyses have indicated that there was KOH in the product water when the high pH's were indicated. It is believed by the Engineering personnel that this condition was caused by the manufacturing process. The asbestos matrix in each cell is soaked in a KOH solution prior to stacking the individual cells into the fuel cell. Tension is applied to the tie rods holding the cells together and this places the cells in compression, which squeezes out some of the KOH. The stack is then drained and this ends what previously had been a three-day build-up process. On this particular fuel cell, the process was performed over a six-day period, and it is believed that this allowed evaporation to occur and deposit a thin film of KOH on the stack. When the fuel cell was wetted in preparation for flight, the film went into solution, and this lead to the high pH indications. Review of the build-up process is on-going, and a return to the shorter time for the build-up process will probably be implemented.

The process of filling CWCs was initiated with the first three CWCs having silver biocide and minerals added and these containers were later transferred to the Mir as potable water. A total of 20 CWCs were filled with water (2025 lb) and transferred to the Mir.

Auxiliary Power Unit Subsystem

Auxiliary power unit (APU) 1 and 3 performed satisfactorily throughout the mission. However, APU 2 had an uncommanded shutdown at 260:09:08:02 G.m.t. (00:00:13:13 MET). An intensive review of APU-related data following the incident resulted in a Mission Management Team (MMT) decision to complete the mission as planned. The data show that the APU speed control stopped (i.e. gas generator valve module fuel valve pulsing stopped and fuel flow stopped), and then when the turbine speed subsequently decreased to 80 percent, the controller issued an underspeed shutdown and closed the fuel isolation valve. APU 2 was not used for the remainder of the flight.

As a result of the early APU 2 shutdown, hydraulic system 2 experienced speedbrake motor backdriving. The hydraulic system 2 supply pressure dropped to 1670 psia and then increased to 2000 psia for approximately 23 seconds before dropping to 0 psia. A similar backdriving occurred on the same system during post-ascent APU deactivation on STS-74.

At 265:15:15 G.m.t. (005:06:20 MET), both APU 2 fuel drain-line pressure indications began dropping from their initial value of approximately 18 psia when the drain line relief valve began leaking. Within five hours, the pressure had decreased to vacuum. This condition has been seen on previous flights. Relief valve cracking pressure should occur at 28 psia and reseat at a pressure of 20 to 22 psia. The APU 2 relief valve is a

-0002 configuration, which has a history of leakage. The APU 2 fuel-pump inlet pressure did not drop, indicating good seal-integrity across the fuel-pump seal.

Hydraulic circulation pump 2 was used for flight control system (FCS) checkout because of the failure of APU 2. Similarly, APU 2 was not used during entry, and APUs 1 and 3 were set to normal speed at entry interface minus 6 minutes and were transitioned to high speed at terminal area energy management (TAEM) minus 6 minutes. The two APUs performed normally in high speed through landing after which the APUs were returned to normal speed. A hydraulic-load test was performed postlanding followed by the APU shutdown.

Postflight testing of the APU and its circuitry on the vehicle has not revealed the cause of the failure. However, testing is continuing as this report is being written. All three APUs were removed from the vehicle and sent to the vendor for refurbishment.

The following table summarizes APU run time and propellant consumption by APU serial number.

APU RUN TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (a)	(S/N 208)	APU 2	(S/N 406)	APU 3 (a)	(S/N 310)
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption lb
Ascent	19:56	48	17:57	44	20:07	47
FCS checkout	(b)	(b)	(b)	(b)	(b)	(b)
Entry[a]	62:34[(c)]	143	(b)	(b)	89:53[(c)]	162
Total	82:30	191	17:57	44	110:00	209

[a] APUs 1 and 3 were shut down 17 minutes 46 seconds after landing.
[b] No APU was used for the FCS checkout, nor was APU 2 used during entry.
[c] APU 1 and 3 experienced 8 minutes 59 seconds of high-speed operation during entry.

Hydraulics/Water Spray Boiler Subsystem

The hydraulics/water spray boiler (WSB) subsystem performance was nominal during the STS-79 mission with no in-flight anomalies noted. Because of the uncommanded shutdown of APU 2, FCS checkout was performed with circulation pump 2 in lieu of the APU 2.

The entry was performed on hydraulic systems 1 and 3 because of the decision not to attempt a restart of APU 2 after the ascent anomaly. Hydraulic system 1 did not achieve heat-exchanger mode during entry due to low hydraulic-reservoir-fluid temperature. This condition was not a problem or concern for operations. An 18.1 °F overcooling condition (specification is no greater than 15 °F) was observed on hydraulic system 3 with a drop of lubrication oil temperature from 255.5 °F to 237.4 °F before the temperature returned to the steady-state cooling level of 253.2 °F. This condition did not impact the flight.

After landing, a modified hydraulic-loads test was performed. Normally, two hydraulic systems are alternately taken to low pressure and the aerosurfaces are cycled. Because of the use of only two hydraulic systems during entry, the decision was made to perform the loads test with both APUs operating at normal speed. No anomalous behavior was noted.

The WSB system 3 regulator outlet pressure transducer failed off-scale after landing. Previous flights of this vehicle have produced the same behavior for this transducer.

Electrical Power Distribution and Control Subsystem

The electrical power distribution and control (EPDC) subsystem performed nominally. All pertinent data were reviewed and no in-flight anomalies were noted.

Environmental Control and Life Support System

The environmental control and life support subsystem (ECLSS) performed satisfactorily throughout the mission with no in-flight anomalies noted.

The atmospheric revitalization system (ARS) performed nominally throughout the flight. The ascent heat exchanger outlet air temperature peaked at a value of 72.63 °F at 260:09:04:48 G.m.t. (000:00:10:00 MET). Also, the cabin air temperature peaked at 83.8 °F five hours into the flight, and the humidity peaked at 38.8 percent at 261:12:04:48 G.m.t. (001:03:10 MET).

The on-orbit air temperature peaked at 80.0 °F on flight day 3, cabin humidity peaked at 54.05 percent on flight day 9, and partial pressure of carbon dioxide ($PPCO_2$) peaked at 3.92 mmHg on flight day 1. The avionics bay 1, 2, and 3 peak temperatures were 97.5 °F, 100.98 °F, and 83.41 °F on flight day 10, 9, and 2, respectively. The avionics bays 1, 2, and 3 water coolant loop (WCL) heat exchanger outlet temperatures peaked at 77.41 °F, 81.01 °F, and 70.53 °F on flight day 9, 9, and 2, respectively. The avionics bays 1, 2, and 3 WCL cold-plate outlet temperatures peaked at 82.01 °F, 84.58 °F, and 78.20 °F on flight day 9, 9, and 7, respectively.

The heat exchanger outlet temperature was 53.14 °F at landing with a peak at 65.57 °F at landing plus 45 minutes 19 seconds. The cabin air temperature at landing was 74.7 °F with a peak temperature of 80.19 °F at landing plus 1 hour 54 minutes. The cabin humidity at landing was 43.65 percent with a peak of 48.4 °F at 9 minutes 10 seconds after landing.

The atmospheric revitalization pressure control system (ARPCS) performed normally throughout the duration of the flight. Following docking, the Orbiter and Mir docking system interface was checked by pressurizing and leak checking the vestibule. The joint life support document allowable-leak-rate is 2 mmHg in 15 minutes; however, the Mir crew reported a pressure change of 4 mmHg in 15 minutes. As a result, the crew was permitted to open the interface hatches and ingress based on a joint flight rule (STS-79 Flight Rule Annex, Rule 4.6-5) that allows ingress for leakage of less than 16 mmHg over a 15-minute period. Further data review found that the vestibule structural temperature was colder than the air temperature used to pressurize the vestibule. The vestibule structural temperature continued to increase during the leak test period, and with the structural temperature increasing, the vestibule pressure dropped and this caused the data to indicate a higher-than-normal leak rate.

The Orbiter and Mir volume pressures were equalized to a total pressure of 14.23 psia and Orbiter/Mir transfer hatches were opened. The crew installed the Mir air-transfer duct between the ODS and the docking module shortly thereafter. The entire Orbiter/Mir volume was then repressurized from 14.23 psia to 14.7 psia using the normal Orbiter ARPCS repressurization configuration. The ARPCS provided a 14.7-psia atmospheric pressure control for the combined volume until it was pressurized to 15.42 psia prior to hatch closure using the oxygen transfer system.

Total consumables transferred to the Mir during the docked phase was 43.2 lbm of nitrogen and 69.2 lbm of oxygen. The nitrogen was used for Mir pressurization, and the oxygen was used for crew metabolic consumption during docked operations and for raising the total pressure and PPO_2 to 15.42 psia and 3.96 psia, respectively.

The supply water sample failed the launch minus three-day requirement for the level of bacteria. The high microbial count, 317 Colony-Forming units (CFUs), were all identified as pseudomonas cepecia. The tank was partially drained and replenished with fuel cell water prior to launch. The tank had an iodine level greater than 3 ppm, which was adequate to control the bacteria. The normal water handling procedures purged the hot-water side of the galley prior to launch. The crew performed a purge of the galley cold-water system (filled two to three drink bags) prior to consumption. By purging the galley, the iodine level in the galley water was raised and the crew was assured of good water.

Supply water tank B incurred occasional quantity data dropouts. The transducer operated nominally between the dropout areas. This condition has been seen previously on other water tank transducers and is a known problem. The transducer will be replaced during the next OV-104 OMDP.

Supply water was managed through the use of the flash evaporator system (FES), water dump system, and water transfer to the Russian Mir Space Station. One supply water dump was made during the mission and it was simultaneous with a waste water dump. The average dump rate was 1.76 percent/min (2.9 lb/min). The supply water dump line temperature was maintained between 60 and 94 °F throughout the mission with the operation of the line heaters.

Twenty CWCs, filled with a total of 2,025 lb of water, were transferred to the Mir. Twelve CWCs had only silver biocide added while 8 had silver biocide and minerals. The CWCs were filled at an average rate of 2.11 lb/min.

Waste water was gathered at approximately the predicted rate. Three waste water dumps were performed at an average dump rate of 1.99 percent/minute (3.28 lb/min). The waste water dump line temperature was maintained between 54 and 74 °F, and the vacuum vent nozzle temperature was maintained between 133 and 189 °F.

The waste collection system performed normally throughout the mission.

Airlock Support Subsystem

Use of the airlock depressurization valve was not required because no extravehicular activity (EVA) was planned or performed. After docking to Mir, the external airlock-to-vestibule hatch equalization valve was used to equalize the Mir and Orbiter habitable-volume pressures. The active system monitor parameters indicated normal output throughout the duration of the flight.

Smoke Detection and Fire Suppression Subsystem

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

Avionics and Software Support Subsystems

The avionics and software support subsystem performed satisfactorily throughout the mission with no in-flight anomalies.

The on-orbit flight control system performance was nominal, and all on-orbit flight control mission objectives were accomplished. No dynamic interaction stability concerns were noted, and data showed that Mir control performance was nominal.

The inertial measurement units (IMUs) performed satisfactorily throughout the flight. Only one adjustment of the onboard IMU accelerometer compensations was required during the 10-day flight. The IMUs are acceptable for the next flight of this vehicle.

Unexpected RCS yaw thruster firings occurred during performance of the first programmed test input (PTI) of DTO 255 (Flight Problem STS-79-V-06). A detailed discussion of this DTO and the yaw thruster firings during the first PTI is contained in the Development Flight Test Objective section of this report.

The Orbiter controlled the mated stack with the vernier RCS for the entire mated phase except for a single 90-minute period of Mir control. (The Mir assumed control to perform an alignment of the inertial basis with the backup Mir star tracker.) The vernier RCS deadbands of 5 degrees and 1 degree were used for control, and a review of the propellant usage during periods of inertial hold indicated that the preflight estimates matched the flight consumption within 5 percent.

Many of the Orbiter burns of the mated stack were performed using DAP B12 with a 0.05 deg/sec burn rate. For the larger burns, this low rate caused the burn duration to exceed the 30-minute allowable duration established in the Joint Agreement Document 3408-4. These excesses were coordinated with the Mission Control Center-Moscow (MCC-M) in real-time during the flight.

Prior to undocking of the Orbiter, the control system was late in being transitioned to the free-drift mode at only two minutes prior to separation. It appeared that the ODS hooks had already begun to drive which violated the design condition that Orbiter control will only be performed on a fully hooked Shuttle/Mir configuration. However, no thruster firings occurred during this period. Discussions with the crew during postflight debriefings revealed that the crew was temporarily unable to mode the DAP to free drift during the Mir undocking procedures. The moding to free drift was attempted several times during this period. The data confirmed that the DAP moding problem resulted from an unfortunate timing coincidence between execution of the inhibit-switch-RM item entry and the attempted DAP moding actions. Flight experience has shown that power-up transients within the translation hand controller can cause unexpected primary RCS thruster firings. To prevent these inadvertent firings, the switch RM is inhibited during certain periods. Inhibiting switch RM prevents DAP moding via the pushbutton.

Analysis of the Orbiter downlist data during the Mir control period indicates that the Mir attitude control system (ACS) performed nominally, and all of the data have been given to the Russians. Prior to the selection of Mir control, the Shuttle attitude quaternion was transmitted to the MCC-M and uplinked to the Mir for use as a coarse alignment. Near the end of the 90-minute Mir control period, a precise alignment was completed using the Mir star tracker. The Orbiter attitude errors indicated a structural misalignment between the two vehicles of approximately 0.5 degree.

Descent navigation was nominal. No in-flight anomalies were noted, nor were any deselections made by the RM system. Drag measurement incorporation was started at a nominal 232,000 ft. and ended at 85,000 ft. The TACAN station acquisition occurred at 137,000 ft., and the TACAN data were not used from approximately 59,300 ft. to 27,900 ft. as the vehicle was operating in the cone of confusion. The microwave scanning beam landing system (MSBLS) processing was nominal as was the backup flight system (BFS) data.

An air data dilemma occurred at 270:12:04:47 G.m.t. (010:03:09:58 MET) approximately three seconds following probe deployment (Flight Problem STS-79-V-05). The crew recognized the dilemma and deselected and reselected ADTA 1 in accordance with standard procedures. This reset the RM, and no further problems were noted with the ADTA subsystem for the remainder of entry and landing.

The postflight review of the data showed that the right-side pneumatics had a 10- to 15-second lag in the pressure sensing. The lag caused the pressures from the right-side and left-side to differ by more than 500 milli-inches of mercury (Hg), with all other pressures tracking normally. Based on the data, it appears that there was a problem with either the right-side probe or the pneumatic line.

At 261:01:27 G.m.t. (000:16:33 MET), the crew reported a poll fail that tripped the built-in test equipment (BITE) flag on CRT 1. A "CRT BITE 1" fault message was also annunciated (Flight Problem STS-79-V-04). The data indicate a memory parity error occurred. The crew performed the specified malfunction procedure for this condition and successfully recovered the CRT. The CRT performed nominally for the remainder of the mission. In the past, similar symptoms have been indicative of failures in the memory page; however, replacement of the display electronics unit (DEU), which contains the CRT, will be performed.

Post-mission, the crew reported that the CRT 2 display had shrunk twice horizontally by approximately 10 percent (Flight Problem STS-79-V-08). The crew report indicated that the first occurrence was early in the mission, and the second occurrence was during entry near the time of ADTA probe deployment. The crew also indicated that each occurrence had a duration of 2 to 3 seconds. The downlisted data did not show any indication of a problem. Troubleshooting of the CRT is in progress at the time of this writing.

Displays and Controls Subsystem

The displays and controls subsystem performed nominally throughout the flight.

Communications and Tracking Subsystems

The discussion of GPS performance is contained in the Development Test Objective section of this report under the heading DTO 700-14 - Single String Global Positioning System.

An unexplained Ku-band bus control element (BCE) bypass occurred at 265:18:50:52 G.m.t. (005:09:56:03 MET) (Flight Problem STS-79-V-07). At the time, the Ku-band was in standby as part of the group B power-down. The Ku-band system power was cycled off and on and an input/output (I/O) reset was commanded, resulting in the recovery of Ku-band I/O to the general purpose computer (GPC). There was no mission impact as the I/O was recovered.

The Ku-band fail-safe flag changed from "enabled" to "disabled" without being commanded while the system was in standby at 266:15:42 G.m.t. (006:06:47 MET). It was commanded back to "enable" at 266:15:48 G.m.t. (006:06:53 MET). The event recurred at approximately 267:16:18 G.m.t. (007:07:23 MET) while the system was in standby. Ku-band system performance was not affected. An analysis of the ground control interface logic (GCIL) circuit determined that this condition can occur with the Ku-band system in standby. Therefore, this condition is considered explained.

The discussion of TCS performance is found in the Development Test Objective Section of this report under the heading of DTO 700-5 - Trajectory Control Sensors.

During the flight, the onboard intercommunications (ICOM) channel experienced audio crosstalk in that audio and caution and warning tones could be heard bleeding onto the air-to-ground (A/G) audio channels. The crew confirmed that A/G 2 audio was bleeding onto the ICOM A channel but not onto ICOM B. The crew reported during postflight debriefings that there was a volume imbalance between the two vehicles. Both ICOM channels were required to be used simultaneously to hear ICOM audio originating from Spacehab. Also, the audio originating from the middeck audio terminal unit (ATU) was heard at a much higher volume level in Spacehab than audio originating from the flight deck ATU.

Downlink video originating from Spacelab exhibited a low-level color burst that resulted in the video being black and white on the ground while the crew reported good color video onboard. It was confirmed during the flight that the Spacehab video exhibited the same signature when downlinked via the S-band frequency modulation (FM) system.

Operational Instrumentation/Modular Auxiliary Data System

The operational instrumentation (OI) and the modular auxiliary data system (MADS) performed satisfactorily, and no in-flight anomalies were noted. Some minor problems were noted and these are discussed in the following paragraphs.

During the STS-79 prelaunch, the FES zone 3 starboard feed-line temperature, registered 105 °F prior to the cryogenic loading period. A waiver was taken on the FES water line 100 °F OMRSD limit, as no LCC exists for this temperature.

During the on-orbit phase, the FES zone 3 starboard feed-line temperature rose to 113 °F while heater system 2 was operating. As in all previous flights of this vehicle since STS-51J, both the A and B thermostats, which control the zone 3 heaters on the starboard feed-water line, dithered. The FES zone 3 starboard water line B thermostat will be replaced during vehicle turnaround processing.

An instrumentation problem was also noted on the nose landing gear right wheel temperature. This measurement read off-scale low (-74 °F) during the prelaunch period until approximately six hours into the mission, at which time the temperature reading appeared correct.

Structures and Mechanical Subsystems

The structures and mechanical subsystems performed satisfactorily with no in-flight anomalies or problems noted. The tires and brakes were in average condition for a landing on the Kennedy Space Center (KSC) runway. The following table presents the most pertinent parameters of the landing and braking data.

LANDING AND BRAKING PARAMETERS

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	807	217.0	~ 4.2	N/A
Nose gear touchdown	5760	151.8	N/A	-3.6

Brake initiation speed	89 knots
Brake-on time	58.5 seconds
Rollout distance	10,981 feet
Rollout time	78.2 seconds
Runway	15 (Concrete) KSC
Orbiter weight at landing	216,019 lb

Brake sensor location	Peak pressure, psia	Brake assembly	Gross energy, million ft-lb
Left-hand inboard 1	600	Left-hand inboard	13.30
Left-hand inboard 3	612	Left-hand outboard	7.33
Left-hand outboard 2	468	Right-hand inboard	10.59
Left-hand outboard 4	576	Right-hand outboard	9.44
Right-hand inboard 1	576		
Right-hand inboard 3	660		
Right-hand outboard 2	624		
Right-hand outboard 4	576		

The ET/Orbiter separation devices (EO-1, EO-2, and EO-3) functioned normally. No ordnance fragments were found on the runway beneath the umbilical cavities. Virtually no umbilical closeout foam or white RTV dam material adhered to the umbilical plate near the LH_2 recirculation line disconnect.

Orbiter Docking System

The Orbiter Docking System (ODS) performed nominally throughout the docking ring extension, docking with the Mir, and undocking from the Mir.

The ODS was powered up for the docking ring extension at approximately 262:01:00:36 G.m.t. (001:16:05:47 MET). The docking ring was extended from the final position to the initial position in preparation for docking. Actuation of the docking ring drive occurred at 262:01:04:41 G.m.t. (001:16:09:52 MET), with the docking ring at the final position (ball-screw linear advance of approximately 6 percent). The docking ring extended to the initial position (ball-screw linear advance of approximately 70 percent) with the removal of ring drive actuation at 262:01:07:19 G.m.t. (001:16:12:30 MET). The ODS was then powered down at 262:01:13:34 G.m.t. (01:16:18:45 MET).

The ODS avionics hardware performed nominally throughout the docking sequence. The ODS was powered up for docking at 263:02:19:43 G.m.t. (002:17:24:54 MET), and all docking system temperatures were well within the limits. At the time of capture, the contact conditions were well within the allowable limits. The angular misalignments appeared to be less than 1 degree per axis, and the lateral misalignment appeared to be approximately 0.5 inch. At the time of post contact thrust (PCT) initiation, the closing velocity was approximately 0.1 ft/sec. The PCT was initiated with approximately two inches of interface separation. Capture occurred at 263:03:13:18 G.m.t. (002:18:18:29 MET). The resulting docking loads were reconstructed from flight data and showed a maximum axial load of about 1000 kg, compared to a maximum allowable of 1900 kg. Five seconds after capture, the high-energy electromagnetic brakes (dampers) were activated by automatic sequence, and remained active for the nominal 30 seconds. Twenty-six seconds later, the electromagnetic brakes were deactivated and the automated sequence drove the docking ring toward the forward position. In accordance with the new procedure, the crew depressed the Androgynous Peripheral Docking System (APDS) power switch on the APDS control panel, and this halted the automated sequence and allowed the relative motion between the two vehicles to be dampened. When damping was complete and since the docking ring was aligned, the crew initiated a ring-in command at 263:03:15:57 G.m.t. (002:18:21:08 MET). The docking ring was driven towards the final position. At 263:03:18:32 G.m.t. (002:18:23:43 MET), the ball-screw linear advance of approximately 8 percent was reached, and the structural hooks were activated with the ready-to-hook signal. The structural hooks were closed and reached a linear advance of 92 percent at 263:03:21:03 G.m.t. (002:18:26:14 MET). The docking ring was then extended to allow the capture latches to open. The capture latches were activated at 263:03:21:11 G.m.t. (002:18:26:22 MET). The capture latches then opened and were deactivated at 263:03:21:13 G.m.t. (002:18:26:24 MET). The docking ring proceeded to the final position thus ending the automated docking sequence at 263:03:21:25 G.m.t. (002:18:26:36 MET). The ODS was powered down at 263:03:35:22 G.m.t. (002:18:40:33 MET). The hatches were opened at 263:05:41 G.m.t. (002:20:46 MET).

The ODS was powered up for undocking at 268:00:50:54 G.m.t. (007:15:56:05 MET). The structural hooks were activated in the open direction at 268:01:31:29 G.m.t. (007:16:36:40 MET), traveled from approximately 92 percent to 5 percent and were deactivated at 268:01:33:50 G.m.t. (007:16:39:01 MET). The ODS was powered down at 268:01:43:35 G.m.t. (007:16:48:46 MET).

Integrated Aerodynamics, Heating and Thermal Interfaces

The ascent and entry aerodynamics were nominal.

The prelaunch thermal interface purges were nominal. The ascent aerodynamic heating and plume heating was nominal. The entry aerodynamic heating to the SSME nozzles was also nominal.

Thermal Control Subsystem

The thermal performance of the OV-104 thermal control subsystem (TCS) was nominal during all phases of the mission. A few instrumentation and minor heater problems occurred that did not impact the mission. All subsystem temperatures were maintained within acceptable limits. Although no specific thermal DTOs were flown, DTO 837 -

Vernier RCS Reboost - provided data applicable to thruster thermal-model correlation. The beta angle ranged from approximately -21.7 degrees at orbital insertion to +22 degrees at entry interface (EI). The orbital inclination was 51.6 degrees and the orbital altitude ranged from 151 to 210 nautical miles during this mission.

Problems included an erratic starboard outboard main landing gear rim temperature, a failed starboard nose landing gear wheel temperature sensor, and a high-temperature on the zone 3 starboard flash evaporator system (FES) feedline. These problems are discussed in the Operational Instrumentation/Modular Auxiliary Data System section of this report.

During the on-orbit period of the mission, seven thermal analyses were made to evaluate changes to the planned attitude timelines (ATLs). In early ATL versions, the OMS oxidizer high-point bleed line quick disconnect temperature was predicted to approach the 20 °F minimum limit during the nose Sun (type 10.3.1) attitudes that had the Sun biased to the port side. As the flight progressed, changes to the planned ATL were made to ensure that the limit was not violated. As a result of these changes, the OMS high-point bleed line quick disconnect minimum temperature experienced during the Shuttle/Mir docked phase was 30 °F.

Aerothermodynamics

The acreage heating as well as the local heating was nominal. Boundary layer transition was nominal.

DTO 255 - Wraparound DAP Flight Test Verification, Part 1 - was performed during entry. Five PTIs were performed. Yaw thruster firing occurred during the first PTI and this was not expected. A detailed discussion of the results of this DTO is found in the Development Test Objective section of this report.

Thermal Protection Subsystem and Windows

The TPS performed satisfactorily. Based on lower-surface structural temperature response data (temperature rise), entry heating was nominal; however, both fuselage sides experienced higher rises in temperature than on previous flights of this vehicle but lower than other vehicles in the fleet. This side-heating increase is a result of the entry angle-of-attack (alpha) profile beginning earlier than normal. The angle-of-attack dropped to an average value of approximately 39 degrees beginning 10 minutes after entry interface; normally the tip-over from 40-degree angle-of-attack occurs about 13 to 15 minutes after entry interface.

Boundary layer transition from laminar flow to turbulent flow occurred much later than usual at approximately 1357 seconds after entry interface at the forward-most centerline of the vehicle. There were no measurements or other evidence to indicate that an asymmetric transition occurred.

Based on data from the postlanding debris inspection, the debris damage was significantly less than average. Of the total of 103 impacts, only 65 were recorded on the lower surface with 8 having a major dimension greater than one-inch. This number of damage sites was much below the lower-surface average of 88 hits and 14 hits having a major dimension greater than one inch. Base heat shield peppering was less than usual. None of impacts was identified as being caused by micrometeorites or on-orbit debris. The table on the following page delineates the number of hits by area of the Orbiter.

TPS DAMAGE SITES

Orbiter Surfaces	Hits > 1 Inch	Total Hits
Lower Surface	8	65
Upper Surface	2	20
Right Side	0	3
Left Side	1	4
Right OMS Pod	0	7
Left OMS Pod	0	4
Total	11	103

The largest lower surface damage site was located outboard and aft of the right main landing gear door and measured 6 inches in length by 1 inch in width by 0.125 inch in depth. The damage was most likely caused by an ice impact from the ET LO_2 feedline bellows and support brackets.

The restricted -441 chin-panel gap-filler breach showed no obvious further degradation/propagation, and the gap-filler will be flown again to provide flight data to increase the OMRSD replacement interval.

Tile damage sites aft of the LH_2 and LO_2 ET/Orbiter umbilicals were typical. The damage was most likely caused by impacts from umbilical ice or shredded pieces of umbilical purge barrier material flapping in the airstream. One Ames gap filler inboard of the right main landing gear door protruded 0.5 inch by 2.5 inches from the lower surface tiles. Two nose landing gear door tiles sustained corner damage.

All three SSME dome mounted heat shield (DMHS) closeout blankets were in excellent condition.

No ice adhered to the payload bay door (PLBD). The reddish-brown discoloration on the leading edge of the left-hand PLBD did not change in appearance from the prelaunch condition. No unusual tile damage was observed on the leading edges of the vertical stabilizer and OMS pods. However, two tiles on the leading edge of the vertical stabilizer were damaged; the damage measured 3.5 inches by 1.5 inches by 0.25 inch.

A white tile above window 1 had a piece approximately 2.5 inches by 1.5 inches by 1.0 inch missing from the forward-most corner of the tile. Filler bar was visible and a part of the strain isolation pad (SIP) appeared to be missing. Hazing and streaking of Orbiter windows 2, 3, 4, and 5 was typical. Window 4 had two spatter marks which were most likely caused by impacts from the forward RCS room temperature vulcanizing (RTV) material. Damage sites on the window perimeter tiles (three hits on window 2 and four hits on window 3) were most likely a combination of some new hits and old repair material flaking off.

The upper-body flap impingement area of the vernier RCS thrusters was not affected by the DTO 837 RCS Reboost Maneuver which had thruster firings of over 18 minutes on each side.

A walkdown of the runway immediately after landing revealed no debris from the landing operations except the drag chute and associated material, which was retrieved.

FLIGHT CREW EQUIPMENT/GOVERNMENT FURNISHED EQUIPMENT

The flight crew equipment/Government furnished equipment (FCE/GFE) performed satisfactorily throughout the mission. No in-flight anomalies were identified in this equipment.

During the rendezvous and docking process, the crew noted that the black paint was peeling from the cross of the center line of the docking target. An IFM was developed to increase the visibility of the cross. The crew wrapped one-third-inch strips of Kapton tape around the base and tip of each finger of the cross. Also, two tie-wraps were added to the inner Kapton strips to mechanically secure the strips to the cross should the adhesive not hold. The IFM kept the paint in place, thus preserving the black-on-white paint contrast of the docking target cross. The small amount of tape added did not add a significant amount of reflectivity to the cross because the Kapton will haze after being exposed to atomic oxygen.

CARGO INTEGRATION

The integration hardware performance was nominal throughout the flight with no issues or anomalies identified.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DEVELOPMENT TEST OBJECTIVES

DTO 255 - Wraparound DAP Flight Test Verification, Part 1 - Data were collected for this DTO during entry when the preplanned programmed test inputs (PTIs) were performed. A preliminary comparison between the various simulator sources and the actual flight data shows a good match of the dynamic response of the PTI's.

Unexpected RCS yaw thruster firings occurred during the Wraparound DAP part of the first PTI (Flight Problem STS-79-V-06). The first PTI burn was a roll doublet with the first roll pulse using the Wraparound DAP and the second roll pulse using the current baseline DAP. The Wraparound DAP I-loads for the RCS yaw thruster deadbands had been set to zero on STS-79 so that a test of the core no-yaw-thruster mode could be performed. Postflight examination of the STS-79 flight data show that RCS yaw thrusters fired during the Wraparound DAP part of the PTI when there should have been absolutely no yaw thruster firings.

The flight software community identified the source of the unexpected thruster firings. During the reconfiguration process, the flight I-Loads were merged with the flight software to build an executable load for flight. The mapping of the I-Load measurements to their actual locations in the flight software was defined with parameter specification file (PSF) cards. The PSF cards that define the first pass initialization values for the Wraparound DAP RCS yaw thruster deadband values were omitted from the STS-79 flight software build. As a result, the initial values for these deadbands defaulted to the hard-coded values used during the development of the Wraparound DAP.

The STS-79 Shuttle Avionics Integration Laboratory (SAIL) testing did not reveal this problem because of where the PTI execution started. There are two sets of RCS yaw deadbands; one set for low-q conditions (qbar < 40 psf), and one set for high-q conditions (qbar > 40 psf). The code that reinitializes the deadband values when transitioning from low-q to high-q conditions or vice versa works properly, as the PSF cards are properly defined for the piece of the flight code. Therefore, once the trajectory reaches the high-q condition, the RCS yaw thruster deadbands are properly set to the I-load values. The window for the first PTI on STS-79 was to occur between a qbar of 35 and a qbar of 50, which spans the low-q/high-q switching point. The first PTI on the STS-79 SAIL test was executed shortly after high-q conditions were achieved and therefore, worked as expected. However, the first PTI on the actual flight of STS-79 was executed shortly before high-q conditions were achieved and did not work as expected. Re-examination of the STS-80 SAIL testing repeated the problem seen during the STS-79 flight. On STS-80 SAIL testing, the first PTI was executed before high-q conditions were set and the thrusters fired. Since STS-80 is the only other flight to perform this DTO under these conditions, a decision was made to not change the STS-80 software, but change the procedures to prevent the PTI from starting before the high-q condition switch point.

The detailed results of the evaluation of the data from this DTO will be documented in a separate report.

DTO 301D - Ascent Structural Capability Evaluation - This DTO is data-only, with the data being recorded on the modular auxiliary data system (MADS) recorder. The data were dumped from the recorder after landing and were given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DTO 307D - Entry Structural Capability - This DTO is data-only, with the data being recorded on the MADS recorder. The data were dumped from the recorder after landing and were given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DTO 312 - ET TPS Performance (Methods 1 and 3) with +X Translation Maneuver Only - Photography of the ET (after separation) was acquired with a Nikon 35 mm camera with a 300 mm lens and a 2X extender. The early OMS-2 attitude pitch burn was performed. Fourteen good-to-excellent quality views of the ET were received. The base of the ET, as well as the -Z axis, the +Z axis, and the +Y axis were imaged. Timing data are present on the film. The first picture was taken on September 16, 1996, approximately 19.5 minutes after liftoff, and the last picture was taken approximately 1½ minutes later. The ET was measured to be 2.2 kilometers from the Orbiter on the first ET picture. An apparent divot is visible on the -Z axis LH_2 tank/intertank close-out flange. A second possible divot is visible on the LH_2 tank/intertank close-out flange on the +Z axis (in the -Y direction from the left leg of the ET/Orbiter forward bipod). The aero-heating marks and the booster separation motor burn scars appear typical of previous missions.

The dark composite intertank access door is visible on the photography. STS-79 is the first flight of the composite door, which replaced the previously used foam-covered door. The composite intertank access door appears smoother and more reflective on the STS-79 photography than on the previous mission hand-held photography of the foam-covered door.

Good views of the new thermal protection system (TPS) agent (NCFI 24-57) used for the first time on the STS-79 H_2 tank aft-dome were acquired. Multiple faint, light-colored marks are visible on the charred H_2 tank aft-dome TPS. On hand-held photography of previous mission ETs, the H_2 tank aft dome appeared dark (charring from aero-heating) with few or no light-colored marks.

Three rolls of umbilical well camera film were also reviewed. All of the film provided good coverage of the SRB separation; however, darkness was present at MECO and ET separation and no usable film was retrieved of those sequences.

DTO 700-5 - Trajectory Control Sensor - The performance of the trajectory control sensor (TCS) in support of the Mir docking and undocking phases is described in the following paragraph.

The TCS 1 sensor was activated by the crew at 263:01:01 G.m.t. (002:16:06 MET). Approximately 40 seconds later, the shutter opened and the TCS 1 unit began the automatic acquisition at approximately 2800 feet. The TCS 1 tracking phase began about 4 minutes later at a range of 6010 feet. The tracking was marginal until a range of 5200 feet was reached at which time the unit began to provide a solid range value.

The second TCS unit was activated at 263:01:55 G.m.t. (002:17:00 MET) and began tracking two minutes later at a range of 925 feet. Both units experienced difficulty maintaining a solid track during the pulse-to-continuous-wave (CW) laser handoff. The handoff problems corrected themselves at a range of approximately 600 feet. Another problem involved both units tracking the European Space Agency (ESA) retroreflectors. Since these reflectors have been coated to prevent TCS tracking, further analysis is underway to resolve this issue. The TCS units were shut down by the crew upon completion of the docking phase.

After undocking at 268:01:33:48 G.m.t. (008:16:38:59 MET), the TCS sensors were activated for the fly-around and separation phase. Both sensors had difficulty in acquiring the target on the Mir. The apparent cause of this difficulty was a bad reference (seed) value from the Rendezvous Proximity Operations Program (RPOP). The crew was provided a new seed value of 18 feet for manual acquisition, and both units began tracking the target approximately 20 minutes after the initial acquisition of the TCS units. Both sensors tracked the retroreflectors for most of the first fly-around; however, the sensors reacquired and lost the retroreflectors several times during the second fly-around. The sensors failed to track after the separation burn from the Mir. Attempts to have the crew manually acquire the Mir were unsuccessful because of the high crew activity during this phase of the mission. This failure to reacquire the Mir was not a concern or a problem to the completion of the mission.

DTO 700-10 - Orbiter Space Vision System Flight Video Taping - All activities for this DTO were accomplished, and the data have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DTO 700-14 -Single String Global Positioning System - Data were recorded on-board as well as being downlinked using the OCA. These valuable data have been given to the sponsor for evaluation. The following paragraphs discuss the problems that occurred with the GPS.

About four seconds after liftoff while reacquiring the global positioning system (GPS) satellites, the GPS receiver apparently began tracking a 'phantom' satellite (Flight Problem STS-79-V-02). This GPS "runaway" condition has been seen previously at the Kennedy Space Center (KSC) and reproduced at the Orbiter Contractor Facility. Power was cycled to the receiver just prior to powering down the backup flight system (BFS). When the receiver was powered back on, a +6 hour deviation between the receiver and the GPC was noted.

As planned, the payload general service computer (PGSC) was connected to the GPS during flight day 3 activities to monitor GPS performance. The crew noted during a later inspection that the GPS data cable had been connected to the wrong connector during the earlier GPS activation, and this condition resulted in the blank screen on the PGSC. The crew reconfigured the cable, and the GPS worked properly for the remainder of the on-orbit period.

DTO 805 - Crosswind Landing Performance - Weather conditions were not compatible at landing to perform this DTO.

DTO 837 - Vernier RCS Reboost Demonstration - The RCS operated nominally during the Vernier RCS Reboost Demonstration DTO. DTO 837 was performed in left OMS interconnect and without the use of the aft yaw thrusters. The DTO began at 269:05:50 G.m.t. (008:20:55 MET) and continued for 18 minutes 44 seconds. An effective -Z reboost burn was produced by toggling the ± yaw commands to force continuous firing of the one forward and two aft vernier RCS thrusters. During the DTO, 72 lb of fuel and 117 lb of oxidizer (1.5 percent of propellant in left OMS tanks) were used, and 7.6 ft/sec ΔV resulted. Following the DTO, the digital autopilot (DAP) was set to preclude further vernier thruster firings to allow an evaluation of the thruster cool-down rates. Flight control system performance during the DTO was nominal. The crew reported that the procedure was usable. Data from the DTO have been given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

DTO 840 - Hand Held Lidar Procedures - The Hand Held Lidar operated satisfactorily during the rendezvous, fly-around, and separation phases. The data have been given to the sponsor for evaluation, and the results of the evaluation will be reported in separate documentation.

DTO 1118 - Photographic and Video Survey of Mir Space Station - The activities required by this DTO were completed satisfactorily. The film and video have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DETAILED SUPPLEMENTARY OBJECTIVES

DSO 487 - Immunological Assessment of Crewmembers (Preflight and Postflight Only) - The activities planned for this DSO were completed satisfactorily. The data have been given to the sponsor for evaluation, and the results of the evaluation will be reported in separate documentation.

PHOTOGRAPHY AND TELEVISION ANALYSIS

LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS

The launch photography and video data analysis was completed with the review of twenty-three 16 mm films, seventeen 35 mm films, and twenty-four videos. The only item of significance noted in the review was a bolt hang-up on the right SRB hold-down post M-3 at liftoff. No debris fragments were seen near the debris containment system (DCS) during the hang-up and bolt release. No anomalous conditions were noted.

ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS

No on-orbit photography analysis requirements were levied. Likewise, no conditions arose during the on-orbit phase that required evaluation.

LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSIS

Eleven videos were received of landing at KSC. The review of the videos did not identify any anomalous conditions.

TABLE I.- STS-79 SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
APU Activation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	260:08:49:59.891 260:08:50:00.945 260:08:50:01.850
SRB HPU Activation[a]	LH HPU System A start command LH HPU System B start command RH HPU System A start command RH HPU System B start command	260:08:54:21.121 260:08:54:21.281 260:08:54.21.441 260:08:54:21.561
Main Propulsion System Start[a]	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	260:08:54:42.418 260:08:54:42.538 260:08:54:42.691
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	260:08:54:48.991
Throttle up to 104 Percent Thrust[a]	ME-3 Command accepted ME-2 Command accepted ME-1 Command accepted	260:08:54:52.898 260:08:54:52.898 260:08:54:52.931
Throttle down to 67Percent Thrust[a]	ME-3 Command accepted ME-2 Command accepted ME-1 Command accepted	260:08:55:15.778 260:08:55:15.778 260:08:55:15.812
Maximum Dynamic Pressure (q)	Derived ascent dynamic pressure	260:08:55:38
Throttle up to 104 Percent[a]	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	260:08:55:50:972 260:08:55:50.979 260:08:55:50.979
Both RSRM's Chamber Pressure at 50 psi[a]	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	260:08:56:45.151 260:08:56:45.911
End RSRM [a] Action[a] Time	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	260:08:56:47.521 260:08:56:48.681
SRB Physical Separation[a]	LH rate APU turbine speed - LOS RH rate APU turbine speed - LOS	260:08:56:51.031 260:08:56:51.071
SRB Separation Command	SRB separation command flag	260:08:56:52
Throttle Down for 3g Acceleration[a]	ME-1 command accepted ME-2 command accepted ME-3 command accepted	260:09:02:21.539 260:09:02:21.545 260:09:02:21.548
3g Acceleration	Total load factor	260:09:02:21.6
Throttle Down to 67 Percent Thrust[a]	ME-1 command accepted ME-2 command accepted ME-3 command accepted	260:09:03:16.580 260:09:03:16.586 260:09:03:16.589
SSME Shutdown[a]	ME-1 command accepted ME-2 command accepted ME-3 command accepted	260:09:03:23.020 260:09:03:23.026 260:09:03:23.030
MECO	MECO command flag MECO confirm flag	260:09:03:24 260:09:03:24
ET Separation	ET separation command flag	260:09:03:43

[a]MSFC supplied data

TABLE I.- STS-79 SEQUENCE OF EVENTS (Continued)

Event	Description	Actual time, G.m.t.
APU Deactivation	APU-2 GG chamber pressure APU 1 GG chamber pressure APU 3 GG chamber pressure	260:09:07:57.245 260:09:09:55.641 260:09:10:09.018
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	
OMS-2 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	260:09:37:42.4 260:09:37:42.5
OMS-2 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	260:09:38:30.2 260:09:38:30.3
Payload Bay Doors (PLBDs) Open	PLBD right open 1 PLBD left open 1	260:10:25:32 260:10:26:51
OMS-3 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	260:12:35:23.6 260:12:35:23.7
OMS-3 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	260:12:36:16.6 260:12:36:16.7
Port Radiator Deploy	Port radiator deploy 1	260:12:09:17
Starboard Radiator Deploy	Starboard radiator deploy 1	260:12:09:17
OMS-4 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	261:00:51:39.6 N/A
OMS-4 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	261:00:51:50.2 N/A
Starboard Radiator Stow	Starboard Radiator Latch 7-12 Latch 2	262:11:03:28
OMS-5 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	262:11:37:33.0 262:11:37:33:1
OMS-5 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	262:11:38:19.5 262:11:38:19.6
OMS-6 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	262:23:00:21.8 262:23:00:21.9
OMS-6 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	262:23:01:31.5 262:23:01:31.6
OMS-7 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	263:00:32:59.2 N/A
OMS-7 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	263:00:33:12.6 N/A
Docking - Complete	Docking ring final position	263:03:21:18
Initiation of Undocking	Actuation of hooks no. 1 drive	268:01:31:29
Undocking - Complete	Undock complete	268:01:33:48
Flight Control System Checkout Circulation Pump Start Circulation Pump Stop	 Hyd. Sys. 2 circulation pump pressure Hyd. Sys. 2 circulation pump pressure	 269:07:32:00.2 269:07:39.36.4
Port Radiator Stow	Port Radiator Latch 7-12 Latch 2	269:11:42:17
Payload Bay Doors Close	PLBD left close 1 PLBD right close 1	270:08:25:42 270:08:27:23

TABLE I.- STS-74 SEQUENCE OF EVENTS (Concluded)

Event	Description	Actual time, G.m.t.
APU Activation for Entry	APU-3 GG chamber pressure APU-1 GG chamber pressure APU-2 GG chamber pressure	270:11:01:13.609 270:11:28:21.049 N/A
Deorbit Burn Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	270:11:06:14.0 270:11:06:14.2
Deorbit Burn Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	270:11:09:30.0 270:11:09:30:2
Entry Interface (400K feet)	Current orbital altitude above	270:11:41:23
Blackout end	Data locked (high sample rate)	No blackout
Terminal Area Energy Mgmt.	Major mode change (305)	270:12:06:46
Main Landing Gear Contact	LH main landing gear tire pressure 1 RH main landing gear tire pressure 2	270:12:13:13 270:12:13:13
Main Landing Gear Weight on Wheels	LH main landing gear weight on wheels RH main landing gear weight on wheels	270:12:13:13 270:12:13:13
Drag Chute Deployment	Drag chute deploy 1 CP volts	270:12:13:21.5
Nose Landing Gear Contact	NLG LH tire pressure 1	270:12:13:29
Nose Landing Gear Weight On Wheels	NLG weight on wheels 1	270:12:13:29
Drag Chute Jettison	Drag chute jettison 1 CP Volts	270:12:13:56.9
Wheel Stop	Velocity with respect to runway	270:12:14:34
APU Deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	270:12:30:56.031 N/A 270:12:31:07.418

TABLE II.- STS-79 ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-79-V-01	APU 2 Unexplained Shutdown	260:09:07:58 G.m.t. 000:00:13:09 MET CAR 79RF01 IPR 81V-0004	After ascent and main engine cutoff (MECO), prior to the time for APU shutdown, APU 2 experienced an unexplained shutdown. Initial review of data shows nominal performance up to the time of the shutdown. Subsequent data review showed that fuel stopped flowing to the gas generator causing the turbine speed to decrease. Data also indicate that the APU controller responded to an 80-percent speed indication and properly closed the isolation valve. Review of historical data for the three APU's has been completed. Currently, the most probable causes for the shutdown involve wiring or controller problems. The pressure, turbine speed, and temperature signature of the shutdown are not indicative of a fuel delivery system blockage or a turbine problem. Circulation pump 2 was used for FCS checkout. For entry, a nominal APU pre-start was performed for all three systems prior to the deorbit maneuver. APU 3 was started at TIG-5 minutes and APU 1at EI-13 minutes. High speed will be selected for APU's 1 and 3 from TAEM through touchdown. An APU 2 start was not attempted because neither APU 1 or 3 shut down. KSC: A recommended post-flight troubleshooting plan has been prepared. KSC performed an auto BITE test and no problems were found. The controller checkout was performed and no problems were found, and the GGVM test was performed and no anomalies were found. All testing of the APU has been completed on the vehicle with no anomalies found, and APU removal Is in work.
STS-79-V-02	GPS Position and Time Anomalies	260:11:03 G.m.t. 000:02:08 MET CAR 79RF07 COM-4-A-0017	At liftoff plus 4 seconds, the GPS receiver appeared to lose track on three of the four channels with poor tracking indicated on the fourth channel. It was observed that the GPS navigation solution deviated significantly from that of the BFS throughout the liftoff through the ET separation period. During this flight phase, it has been concluded that the receiver had encountered the 'runaway' anomaly previously seen during ground testing at KSC. After ET separation, the receiver was still not able to track four satellites. The deviations between the navigation state vector of the GPS receiver and the BFS continued and increased significantly between ET separation and the OMS 2 maneuver. These deviations are consistent with the fact that the receiver was unable to adequately track satellites. After the OMS 2 maneuver, the receiver power was cycled prior to powering off the BFS. When the receiver was powered back on, a + 6 hour deviation between the receiver and the general purpose computer (GPC) was noted. This anomaly was also observed during ground testing

TABLE II.- STS-79 ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-79-V-02 (Continued)	GPS Position and Time Anomalies (Continued)	(Continued)	at KSC during the week of September 8, 1996. The BFS was then powered down and this resulted in the loss of the GPS downlist data. After two troubleshooting attempts, the GPS and PGSC were properly connected, and the crew reported nominal GPS receiver performance. With respect to the 'runaway' anomaly, preliminary analysis indicates that the software in the receiver most probably executed the software error previously identified by the GPS developer. The software error essentially polluted the receiver's navigation solution with bad data which caused the deviation in position accuracy as well as the receivers ability to track satellites. The bias time error is under investigation. During entry, the GPS runaway anomaly recurred.
STS-79-V-03	PRSD Hydrogen Tank 3 Heater B Fail Off	268:18:11 G.m.t. 008:09:16 MET CAR 79RF10 IPR 81V-0012	At 268:18:11 G.m.t. (008:09:16 MET), the hydrogen tank 3 system B heater failed off. Prior to this event, the B heater had been properly cycling with the A heater. The system A heater on hydrogen tank 3 continued to energize nominally and was used to deplete the tank. KSC: Troubleshooting has verified that the heater was failed off, and that the fuse was failed open. Failure analysis will be performed on the fuse. A new fuse was installed.
STS-79-V-04	CRT 1 Poll Fail	270:12:27 G.m.t. 000:16:32 MET CAR 79RF13 IPR 81V-0006	The crew reported a poll fail and tripped BITE flag on CRT 1. The condition occurred while entering an item 4 on spec. 20. A CRT BITE 1 fault message was also annunciated. The data indicate a memory parity error. No user notes exist that explain a condition of this nature. Malfunction procedure 5.4 (I/O Error CRT) was performed and the CRT was reassigned. Following reassignment, the CRT functioned nominally. CRT 1 did not experience any other problems. KSC: DEU 1 is being evaluated for removal and replacement.
STS-79-V-05	Air Data Dilemma	270:12:04:47 G.m.t. 010:03:09:58 METY CAR 79RF12	Shortly after air data probe deployment (approximately 3 seconds), the RM declared an Air Data Dilemma. The crew recognized the dilemma and deselected and re-selected ADTA 1 using normal crew procedures, thus resetting the RM. No further problems were noted with air data for the remainder of entry or landing. When in primary avionics software system (PASS), the RM uses only pressure data to declare failures and dilemmas. Postflight data review showed that the right-side pneumatics had a 10- to 15-second lag on the Pau pressure. The lag caused the comparison of the Pau pressures between the right-side ADTA's (2 and 4) and the left-side ADTA's (1 and 3) to differ by greater than the cross-side comparison limit in the RM. All other pressure data

TABLE II.- STS-79 ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-79-V-05 (Continued)	Air Data Dilemma (Continued)	270:12:04:47 G.m.t. 010:03:09:58 METY CAR 79RF12 (Continued)	tracked normally. The data from the past three flights (STS-71, STS-74, and STS-76), was nominal during probe deployment. The problem on STS-79 could have been caused by blockage of the port or the tube. KSC: The troubleshooting plan has been developed and agreed on by all parties.
STS-79-V-06	Unexpected RCS Thruster Firings during Entry PTI DTO 255	S/W DR-110271	There were unexpected yaw RCS thruster firings during the Wraparound DAP portion of PTI 1 during the STS-79 entry. The PTI maneuver was a roll doublet with the first roll pulse using the Wraparound DAP and the second roll pulse using the current baseline DAP. The Wraparound DAP I-Loads for the yaw RCS thruster deadbands were set to zero on STS-79 so that a test of the core "no yaw thruster" mode of the Wraparound DAP could be performed. Postflight examination of the flight data reveal that yaw RCS thrusters fired during the Wraparound DAP portion of the PTI when there should have been absolutely no thruster firings. Evaluation by the flight software community identified the source of the unexpected RCS thruster firings. During the reconfiguration process, the flight I-Loads were merged with the flight software to build an executable load for flight. The mapping of the I-Load measurements (MSID's to their actual locations in the flight software was defined with parameter specification file (PSF) cards. The PSF cards that define the first pass initialization values for the Wraparound DAP yaw RCS thruster deadband values were omitted from the STS-79 flight software build. As a result, the initial values for these deadbands defaulted tot he hard-coded values used during the development of the Wraparound DAP. The STS-79 Shuttle Avionics Integration Laboratory (SAIL) testing did not show this problem because of where the PTI started execution. There are two sets of yaw RCS deadbands; one set for low q conditions (qbar < 40 psf), and one set for high q conditions (qbar > 40 psf). The code that reinitializes the deadband values when transitioning from low q to high q conditions or vice versa works properly as the PSF cards are properly defined for this piece of the flight code. Therefore, once the trajectory reaches the high q condition, the yaw RCS thruster deadbands are properly set to the I-Load values. The window for the first PTI on STS-79 was I-Loaded to occur between a qbar of 35 and a qbar of 50, which spans the low q/high q switching point. The first PTI on the STS-79 SAIL test was executed shortly after high q conditions were achieved and therefore, worked as expected. However, the

TABLE II.- STS-79 ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-79-V-06 (Continued)	Unexpected RCS Thruster Firings during Entry PTI DTO 255 (Continued)	S/W DR-110271 (Continued)	first PTI on the actual flight of STS-79 was executed shortly before high q conditions were achieved and set in the system and so did not work as expected. Re-examination of the STS-80 SAIL testing shows the same problem as seen on the STS-79 flight. On STS-80 SAIL testing, the first PTI was executed before high q conditions were set and the thrusters fired. Since STS-80 is the only other flight to perform this DTO under these conditions, a decision was made to not change the STS-80 software and the procedures would be changed to prevent the PTI from starting before the high q condition switch point.
STS-79-V-07	Ku-Band BCE Bypass - FF3/PF1	265:18:50:52 G.m.t. 005:09:56:03 MET CAR 79RF09 IPR 81V-0011	An unexplained Ku-Band BCE bypass occurred at the time shown in the previous column. At the time, the Ku-Band was in standby as part of the Group B power-down. The Ku-Band system was power cycled and then an I/O reset was commanded, resulting in recovery of Ku-Band I/O to the GPC. There was no mission impact because I/O was recoverable. KSC: A troubleshooting plan has been developed for the problem.
STS-79-V-08	CRT 2 Display Shrunk Momentarily	Postlanding Report by Crew	The crew reported post-mission that the CRT 2 display shrunk twice horizontally by approximately 10 percent during the mission. The crew stated that the first occurrence was early in the mission and the second was during entry near the time of ADTA probe deployment. The crew stated that the condition existed for approximately 2 to 3 seconds each time. No indications of any problem have been seen in the downlisted data.

TABLE III.-MSFC PROBLEM TRACKING LIST

No.	Title	Time	Comments
S STS-79-M-01	Right-Hand Nozzle Striated Axial Erosion on the Throat and Forward Exit Cone	Postflight disassembly and inspection	The postflight inspection and disassembly of the RSRM nozzle revealed striated axial erosion on the throat and forward exit cone. The erosion resulted in negative margins of safety of -0.07 at 287.5 degrees and -0.01 at 39 degrees. This was the first occurrence of nozzle erosion to this extreme.
STS-79-B-01	Wrench found in Right SRB Forward Skirt	Postflight disassembly and inspection	During the postflight inspection and disassembly, a 7/16-inch Armstrong combination wrench and the metal identification plate for the dedicated signal conditioner were found in the right-hand SRB forward skirt. Preflight closeout photographs show the identification plate installed. An anomaly team has been formed that is made up of representatives from KSC, MSFC, USA and USBI, and an investigation is in progress. The exact location of the foreign object during flight could not be determined; however, the investigation and analysis show no potential for damage to SRB components. The investigation identified two potential sources, which were manufacturing operations and sabotage. USBI uses Armstrong tools, and interior forward skirt operations require the use of 7/16-inch tools. No evidence was found to support or disprove the possibility of sabotage, and it is not considered a likely source of the damage. The corrective action, which will begin with STS-80, will include initiating a Kaizen team to implement a more effective tool control system. All tools will be marked, shadow box tool boxes will be used, and the total number of tools will be reduced;

DOCUMENT SOURCES

In an attempt to define the official as well as the unofficial sources of data for this mission report, the following list is provided.

1. Flight Requirements Document
2. Public Affairs Press Kit
3. Customer Support Room Daily Science Reports
4. MER Daily Reports
5. MER Mission Summary Report
6. MER Problem Tracking List
7. MER Event Times
8. Subsystem Manager Reports/Inputs
9. MOD Systems Anomaly List
10. MSFC Flash Report
11. MSFC Event Times
12. MSFC Interim Report
13. Crew Debriefing comments
14. Shuttle Operational Data Book

ACRONYMS AND ABBREVIATIONS

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

ACS	attitude control system (Mir)
ADTA	air data transducer assembly
A/G	air-to-ground
APDS	Androgynous Peripheral Docking System
APU	auxiliary power unit
ARIS	Active Rack Isolation System
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
ATU	audio terminal unit
BCE	bus control element
BFS	backup flight system
BITE	built-in test equipment
BTS	Biotechnology System
c.d.t.	central daylight time
CFU	Colony Forming Unit
CGBA	Commercial Generic Bioprocessing Apparatus
CPCG	Commercial Protein Crystal Growth experiment
CRT	cathode ray tube
CW	continuous wave
CWC	contingency water container
DAP	digital autopilot
DCS	debris containment system
DMHS	dome-mounted heat shield
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
ΔV	differential velocity
ECLSS	Environmental Control and Life Support System
EOR/F	enhanced Orbiter refrigerator/freezer
EPDC	electrical power distribution and control
ESA	European Space Agency
ET	External Tank
ETTF	Extreme Temperature Translation Furnace
EVA	extravehicular activity
FCE	flight crew equipment
FCP	fuel cell powerplant
FCS	flight control system
FCV	flow control valve
FDA	fault detection and annunciation
FES	flash evaporator system
FM	frequency modulation
ft/sec	feet per second
GCIL	ground control interface logic
GFE	Government furnished equipment
GGVM	gas generator valve module

GH_2	gaseous helium
G.m.t.	Greenwich mean time
GN_2	gaseous nitrogen
GO_2	gaseous oxygen
GPC	general purpose computer
GPS	Global Positioning System
H_2	hydrogen
Hg	Mercury
HPFTP	high pressure fuel turbopump
HPOTP	high pressure oxidizer turbopump
ICOM	intercommunications
IFM	in-flight maintenance
IMAX	Canadian developed large format motion picture camera
IMS	Inventory Management System
IMU	inertial measurement unit
I/O	input/output device
Isp	specific impulse
ISS	International Space Station
JSC	Johnson Space Center
kg	kilogram
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt/hour
lb	pound
lbm	pound mass
lb/min	pound per minute
LCC	Launch Commit Criteria
LH_2	liquid hydrogen
LMES	Lockheed Martin Engineering and Science
LO_2	liquid oxygen
LVLH	local vertical local horizontal
MADS	modular auxiliary data system
MC	midcourse correction (maneuvers)
MCC-M	Mission Control Center - Moscow
MECO	main engine cutoff
MEFC	Mir Electric Field Characterization
MET	mission elapsed time
MGBX	middeck glove-box
MGM	Mechanics of Granular Materials
MIDAS	Material in Devices as Superconductor
MM	major mode
MMT	Mission Management Team
MPS	main propulsion system
MPU	magnetic pickup unit
MSBLS	microwave scanning beam landing system
MSFC	Marshall Space Flight Center
MSX	Midcourse Space Experiment
NASA	National Aeronautics and Space Administration
NC1- 6	rendezvous maneuvers (four)
NCC	corrective combination maneuver

nmi.	nautical mile
NPSP	net positive suction pressure
NSTS	National Space Transportation System (i.e., Space Shuttle Program)
O_2	oxygen
OCA	Orbiter Communications Adapter
ODS	Orbiter docking system
OI	operational instrumentation
OMDP	Orbiter Maintenance Down Period
OME	orbital maneuvering engine
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
PAL	protuberance air load
PCT	post contact thrust
PGSC	payload general support computer
pH	parts hydrogen
PLBD	payload bay door
PM	phase modulation
PMBT	propellant mean bulk temperature
$PPCO_2$	partial pressure carbon dioxide
PRSD	power reactant storage and distribution
PSF	parameter specification file
psi	pound per square inch
psia	pound per square inch absolute
PTI	programmed test input
Rbar	radius vector axis
RCS	reaction control subsystem
RM	Redundancy Management
RME	Risk Mitigation Experiment
RPOP	Rendezvous Proximity Operations Program
RR	rendezvous radar
RSRM	Reusable Solid Rocket Motor
RTV	room temperature vulcanizing (material)
S&A	safe and arm
SAIL	Shuttle Avionics Integration Laboratory
SAREX-II	Shuttle Amateur Radio Experiment
SIP	strain isolation pad
SLF	Shuttle Landing Facility
S/N	serial number
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSME	Space Shuttle main engine
STS	Space Transportation System
TACAN	tactical air control and navigation
TAEM	terminal area energy management
TCS	thermal control subsystem/trajectory control sensor
TI	terminal phase initiation
TIG	time of ignition
TPS	thermal protection system/subsystem
U. S.	United States

UVIS	Ultraviolet and Visible Imagers and Spectrographic Imagers
Vdc	volts direct current
WCL	water coolant loop
WCS	waste collection system
WSB	water spray boiler
3DMA	Three Dimensional Accelerometer

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