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STS-76 SPACE SHUTTLE MISSION REPORT

May 1996

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

NOTE

The STS-76 Space Shuttle Mission Report was prepared from inputs received from the Space Shuttle Vehicle 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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STS-76 Table of Contents

STS-76 Table of Contents

List of Tables

INTRODUCTION

The STS-76 Space Shuttle Program Mission Report summarizes the Payload activities as well as 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-sixth flight of the Space Shuttle Program, the fifty-first flight since the return-to-flight, and the sixteenth flight of the Orbiter Atlantis (OV-104). In addition to the Orbiter, the flight vehicle consisted of an ET that was designated ET-77; three SSMEs that were designated as serial numbers 2035, 2109, and 2019 in positions 1, 2, and 3, respectively; and two SRBs that were designated BI-079. The RSRMs, designated RSRM-46, were installed in each SRB and the individual RSRMs were designated as 360T046A for the left SRB, and 360T046B for the right SRB.

The STS-76 Space Shuttle Program Mission Report fulfills the Space Shuttle Program requirement as documented in NSTS 07700, Volume VII, Appendix E. The requirement stated in that document 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 transfer one U. S. Astronaut to the Mir. A single Spacehab module carried science equipment and hardware, Risk Mitigation Experiments (RMEs), and Russian Logistics in support of the Phase 1 Program requirements. In addition, the European Space Agency (ESA) Biorack operations were performed.

The STS-76 mission was planned as a 9-day flight plus 1 day for payload contingency operations plus 2 contingency days that were available for weather avoidance or Orbiter contingency operations. The sequence of events for the STS-76 mission is shown in Table I, and the Space Shuttle Vehicle Engineering In-Flight Anomaly (IFA) list is shown in Table II. The Government Furnished Equipment/Flight Crew Equipment (GFE/FCE) IFA 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-76 consisted of Kevin P. Chilton, Col., U. S. Air Force, Commander; Richard A. Searfoss, Lt. Col., U. S. Air Force, Pilot; Ronald M. Sega, Civilian, Ph. D., Mission Specialist 1; M. Richard Clifford, Civilian, Mission Specialist 2; Linda M. Godwin, Civilian, Ph. D. Mission Specialist 3; and Shannon W. Lucid, Civilian Ph.D., Mission Specialist 4. STS-76 was the third space flight for the Commander and Mission Specialist 2 and Mission Specialist 3, the fifth space flight for the Mission Specialist 4, and the second space flight for the Pilot and Mission Specialist 1. Five of the six crewmembers are credited with 221 hours 15 minutes and 53 seconds of space flight for this mission. The sixth crewmember, Mission Specialist 4, became a member of the Mir-21 crew at 53 hours 17 minutes MET.

MISSION SUMMARY

After a flawless countdown, the STS-76 liftoff occurred at 082:08:13:03.999 G.m.t. (March 22, 1996, at 2:13 a.m. c.s.t.), and the launch phase was completed satisfactorily. The orbital maneuvering subsystem (OMS) 2 dual-engine maneuver was performed at 082:08:55:26.0 G.m.t. (00:00:42:22 MET) with a differential velocity (ΔV) of 76.0 ft/sec. The planned orbit of 85 nmi. by 160 nmi. was achieved. The payload bay door opening was completed at 082:09:48:09 G.m.t. (00:01:35:05 MET).

An evaluation of SSME and SRB propulsive performance using vehicle acceleration and preflight propulsion prediction data showed an average flight-derived engine specific impulse (I_{sp}) of 452.54 seconds as compared with the predicted (tag) value of 452.87 seconds. The I_{sp} was calculated for the time period from SRB separation to the start of 3g throttling.

One in-flight anomaly was identified in that the fuel preburner chamber channel A igniter failed to indicate on at engine start on SSME 2 (Flight Problem STS-76-E-1). This is the first occurrence of an igniter failing to indicate on at engine start. The lack of a spark indication may be real or may be a failure in the monitoring circuit. Troubleshooting is continuing in an effort to isolate the cause of the anomaly. Checkout tests have not duplicated the anomaly on channel A; however, the fuel preburner chamber channel B igniter has failed to spark during tests.

During the ascent phase, a hydraulic leak from system 3 was noted. Analysis of the hydraulic system 3 leak data showed a significant decrease in the hydraulic system 3 reservoir quantity of approximately 1 percent/minute of run time. The quantity decreased from 63 percent to 54 percent with a slight increase to 56 percent prior to auxiliary power unit (APU) shutdown. The thrust vector control (TVC) isolation valve for this system was closed in an attempt to halt the decrease; however, the reservoir quantity continued to decrease. APU 3 was taken to the low-pressure mode shortly after valve closure. APUs 1 and 2 were shut down while APU 3 was left running in the low-pressure mode for an additional four minutes. No significant quantity decrease was noted during low-pressure operation. The APU was shut down and the hydraulic system was returned to the normal-pressure mode after shutdown. Approximately 48 hours later, the hydraulic system 3 reservoir quantity showed a slight decrease to 44.0 percent. A comparison of the rate plots of quantity versus temperature for each of the hydraulic systems showed a similar quantity decrease rate on each system, which indicated that system 3 was not leaking while shut down.

The hydraulic system data were presented to the Mission Management Team (MMT) for a final determination of the manner in which the mission was to be completed. The decision was made to continue the mission to the planned landing time on March 31, 1996, with some tightening of the landing constraints concerning crosswinds, cloud coverage and landing-site selection.

Analysis of data revealed two periods of under-cooling occurred on water spray boiler (WSB) systems 1 and 3 (to 265 °F and 307 °F, respectively). System 2 experienced one period of over-cooling to 195 °F. These conditions did not impact APU or hydraulic system operations.

The crew observed gas bubbles in the water after galley activation. After performing the galley-purge procedure, the crew reported an acceptable level of bubbles in the hot water and no bubbles in the cold water.

Nominal deployment of the Ku-band antenna was performed at 082:12:30 G.m.t. (00:02:17 MET). The port radiator was deployed to provide cooling and contribute to conservation of water for transfer to the Russian Mir space station.

Extravehicular mobility unit (EMU) checkout began at approximately 083:05:13 G.m.t. (00:21:00 MET). Both EMUs performed nominally during the checkout and were ready to support the extravehicular activity (EVA) on flight day six.

At 082:11:55:29.8 G.m.t. (000:03:42:25.8 MET), the OMS was used to perform the NC1 (OMS-3) Mir-rendezvous maneuver. This was a 42.8-second dual-engine, straight-feed firing. The ΔV was 69 ft/sec, and this placed the vehicle in a 159 by 123 nmi. orbit. The NC2 (OMS-4) Mir-rendezvous maneuver occurred at 082:23:49:04.2 G.m.t. (00:15:36:00.2 MET) using the right OMS engine configured for straight feed. The maneuver was 9.8 seconds in duration with a resulting ΔV of approximately 8 ft/sec, raising the orbit to 158.8 by 126.4 nmi. A 57.2-second dual-engine straight-feed NC3 (OMS-5) Mir-rendezvous maneuver occurred at 083:09:24:26.8 G.m.t. (01:01:11:22.8 MET) with a ΔV of 93 ft/sec and a resulting orbit of 210 by 127 nmi. OMS performance was nominal during all three of these maneuvers.

The docking system was initially powered up at 083:09:45 G.m.t. (01:01:32 MET). The guide ring was extended to the ready-to-dock position in dual-motor time, after which the system was powered off. The ball-screw position data were nominal and similar to STS-74 data. The temperature of the docking system ranged from 51 to 65 ° F, which was well within limits.

The port radiator panels were stowed at 083:23:14:04 G.m.t. (01:15:01:00 MET). The Russian Mission Control Center personnel requested that the aft compartment vent doors be closed to preclude contamination by any free hydraulic fluid that might have existed in that area. In response to this request, port vent doors 8 and 9 were closed at 084:00:25 G.m.t. (01:16:12 MET), and starboard vent doors 8 and 9 were closed three minutes later.

Two additional OMS maneuvers were performed in support of the Mir rendezvous. The dual-engine NC4 (OMS-6) firing was executed at 083:22:16:37.6 G.m.t. (01:14:03:33.6 MET) and was 85.4 seconds in duration with a resultant ΔV of 141 ft/sec. The left orbital maneuvering engine (OME) was used for the terminal phase initiation (TI) maneuver (OMS-7) at 083:23:51:38.2 G.m.t. (01:15:38:34.2 MET). The firing duration was 11 seconds and the resulting ΔV was 9 ft/sec.

The Orbiter docking system (ODS) was powered on at 084:01:54 G.m.t. (01:17:41 MET) in preparation for the docking. The ODS temperatures ranged from 60 °F to 78 °F, which was well within limits. The Ku-band radar acquired Mir at 083:23:09 G.m.t. (01:13:56 MET) at a range of 137,861 feet (approximately 23 nmi.). Mir was tracked to a range of 330 feet at 084:01:50 G.m.t. (01:17:37 MET), at which time the Ku-band was configured to the communications mode for downlink of docking video. The trajectory control sensors (TCSs) 1 and 2 were activated at 083:23:58 G.m.t. (01:15:45 MET) and 084:01:22 G.m.t. (01:17:09 MET), respectively. Both units tracked the target until after the Mir docking was completed. Docking was completed at 084:02:50:09.9 G.m.t. (01:18:37:05.9 MET) and vestibule pressurization followed. After hatch opening at 083:28:31 G.m.t. (01:20:18 MET) and pressure equalization with Mir, the Orbiter cabin pressure was 14.23 psia.

The crew could not locate a camera bayonet bracket that was to be used during EVA. It was determined that this hardware had been inadvertently omitted from the hardware shipment to Kennedy Space Center (KSC) for stowage in the Spacehab module. A workaround was developed that enabled the camera to be used for the EVA operations.

Revised limits for the control of the hydraulic system 3 circulation pump were uplinked to the Orbiter at 084:12:47 G.m.t. (02:04:34 MET). Circulation pump operations were controlled by lower-than-normal temperatures to minimize the frequency and duration of pump use.

A total of eight hydraulic system 3 circulation pump runs occurred during the mission. Prior to these runs, the circulation pump inlet temperature was as low as 13 °F and the rudder speedbrake (RSB) return line was as low as -37 °F. The hydraulic system 3 reservoir quantity stabilized at approximately 41.6 percent during the third circulation pump run and remained at approximately the same level for the remainder of the mission.

In preparation for the planned EVA, depressurization of the ODS vestibule was performed at 086:11:45 G.m.t. (04:03:32 MET). Depressurization of the cabin to 10.4 psia was subsequently completed at 086:12:40 G.m.t. (04:04:27 MET). The airlock depressurization was initiated at 87:06:15 G.m.t. (04:22:02 MET). The EVA was initiated at 087:06:34 G.m.t. (04:22:21 MET). The cabin was repressurized to 14.7 psia at 87:07:10 G.m.t. (04:22:57 MET).

The first EVA during Orbiter/Mir docked operations was completed satisfactorily at 087:12:36 G.m.t. (05:04:23 MET) with a duration of six hours two minutes. The major portion of the EVA was spent installing the Mir Environmental Effects Payload (MEEP) clamps and equipment on the docking module. The crew also retrieved a video camera that was mounted on the docking module for return on the Orbiter. Some minor problems were noted with an incomplete switch throw and loss of some biomedical data, but these had no impact on the mission.

The crew reported that a camcorder in the Spacehab had experienced a cassette eject failure. An in-flight maintenance (IFM) procedure to clear the tape from the camcorder was available, but this camcorder was not required. There were four additional camcorders onboard, two of which were scheduled to remain on Mir.

The oxygen repressurization of the Orbiter/Mir stack by the Orbiter continued until hatch closure. The Orbiter achieved the targeted cabin total pressure at hatch closure of 15.5 psia, with an oxygen concentration of 25 percent of the total module pressure.

Fifteen contingency water containers (CWCs) were filled with a total of approximately 1500 lb of Orbiter supply water for transfer to the Mir during the flight.

A decision was made by the MMT to attempt to land one day early, on Saturday, March 30, 1996, at Kennedy Space Center, because of the forecasted unacceptable weather conditions on Sunday, the planned landing day.

Difficulties were experienced communicating with Mir. Transmissions from Mir were heard onboard the Orbiter, but Orbiter transmissions were not heard on Mir. The crew performed troubleshooting procedures with the very high frequency (VHF) radio prior to undocking. These procedures were unsuccessful in restoring the VHF link between the Orbiter and Mir. Shortly after the crew terminated the troubleshooting procedures, the Mir communications system was reconfigured, allowing successful two-way communications between Moscow and Mir. The assessment is that the VHF problems were due to the Mir communications configuration.

The ODS performance was nominal during the undocking phase of the mission. Final hatch closure was completed as scheduled at 088:12:43 G.m.t. (06:04:30 MET). Vestibule hatch closure was performed at 088:13:08 G.m.t. (06:04:55 MET), followed by depressurization starting at 088:13:15 G.m.t. (06:05:02 MET), all in preparation for undocking.

The ODS was powered up at 089:00:37 G.m.t. (06:16:24 MET). The structural hook actuators were activated at 089:01:05:46.1 G.m.t. (06:16:52:42.1 MET) and both hook gangs opened with dual-motor operation in approximately 2.5 minutes. The undocking-complete signal was received at 089:01:08:03.4 G.m.t. (06:16:54:59.4 MET).

The reaction control subsystem (RCS) supported Mir undocking with a low-Z maneuver at 089:01:08 G.m.t. (06:16:55 MET). The final separation maneuver utilizing two thrusters was performed at 089:02:08 G.m.t. (06:17:55 MET) and lasted 12.5 seconds. Thruster firings were nominal. The Orbiter digital autopilot (DAP) rates were very close to the preflight predictions.

The two TCS units were activated at 089:00:15 G.m.t. (06:16:02 MET) to support Mir undocking, and TCS 2 began tracking the target eight minutes later. TCS 1 did not respond as expected, and a power cycle and re-execution of startup procedures were performed. TCS 1 subsequently began tracking the target at 089:00:53 G.m.t. (06:16:40 MET). Both sensors tracked until the reflectors went out of the field of view at a range of approximately 500 feet. The sensors reacquired the reflector at least twice during the fly-around and separation, and the last measured distance was 1232.1 feet.

As a result of the system 3 hydraulic leak during ascent, the decision was made not to run an APU for flight control system (FCS) checkout. The checkout was instead performed using the hydraulic system 1 circulation pump, and this verified essential flight control capabilities for entry. The circulation pump was started at 089:04:53:29.3 G.m.t. (06:20:40:25.3 MET) and ran for 9 minutes 24 seconds. Performance was nominal.

During the RCS hot-fire, primary thrusters L2U and R4R were deselected by RCS redundancy management (RM) as failed-off because of low chamber pressure (Pc). This was the first attempted firing of these thrusters this flight. The maximum Pc reached was 13 psia and 10 psia, for L2U and R4R, respectively. Nominal Pc is 150 psia. The injector temperatures both dropped due to evaporative cooling, indicating that partial pilot-valve flow was achieved on each valve. The injector temperature recovery did not exceed the pre-firing temperatures, indicating there was none of the heat soak-back that would be associated with normal combustion. The Pc traces did not exhibit a slow pressure tail off; as a result, blocked Pc tubes were not suspected. The L2U paper cover was noted to be wet prior to launch.

Also during the RCS hot-fire, primary thruster L2L (S/N 234) was declared failed-leak at 089:06:11 G.m.t. (06:21:58 MET) by RCS RM, when the oxidizer injector temperature dropped below the 30 °F leak detection limit. The leak began after the second nominal hot-fire pulse. The crew visually observed oxidizer spraying from the area, and isolated the left RCS manifold 2 at 089:06:16 G.m.t. (06:22:03 MET). The paper cover for L2L was also noted to be wet prior to launch. The manifold isolation valve was reopened at 090:06:29 G.m.t. (07:22:16 MET) in an attempt to recover the remaining thruster on that manifold. However, because primary thruster L2L continued to leak, the manifold was again isolated at 090:07:33 G.m.t. (07:23:20 MET) when the fuel injector temperature dropped below the flight rule limit of 40 °F. The manifold remained isolated for the remainder of the mission.

All entry stowage and deorbit preparations were completed in preparation for entry on the one-day-early landing day. The Ku-band antenna was stowed at 089:14:34 G.m.t. (07:06:21 MET). The payload bay doors were successfully closed at 090:09:08:57 G.m.t. (08:00:55:53 MET). The two landing opportunities were waved-off due to unacceptable weather conditions at the KSC Shuttle Landing Facility (SLF). The payload bay doors were subsequently reopened for on-orbit activities at 090:14:37:47 G.m.t. (08:06:24:43 MET) during the ensuing deorbit preparation backout.

During payload bay door (PLB) re-opening after the wave off, both PLB centerline latch 9-12 release indications failed to indicate release after single-motor run time. The release indication is normally obtained when the latch is in the full-open position. The backup flight system (BFS) logic terminated the auto sequence when the release indications were not obtained within the 40-second single-motor run time. The crew reported that the 9-12 latch gang appeared to be fully open as viewed from the Spacehab overhead view port. The crew manually commanded the latch to open and saw no latch movement and still the release indication did not come on. Because the latches appeared to be open, the crew completed door opening in manual mode. At 090:15:22 G.m.t. (008:07:09 MET), the centerline 9-12 release 2 indication recovered with no crew action. The release 1 indication began toggling between on and off beginning at 090:16:03 G.m.t. (008:07:50 MET), and at 090:16:14 G.m.t. (008:08:01 MET) stabilized with the release indication on. The previous two flights of OV-104 (STS-71 and -74) had nominal latch indications during door openings and closures. The condition did not impact further door operations.

While reconfiguring from the payload bay door problem, the BFS went stand-alone because the primary avionics software system (PASS) redundant set was reconfigured, and remained stand-alone for approximately five minutes. After the crew entered an input/output (I/O) reset to reinitiate PASS tracking by BFS, the BFS began to track the PASS; however, the BFS unexpectedly remained on its internal time rather than synchronizing with the master timing unit (MTU). The phenomenon was explained as a condition that occurs when the BFS is left stand-alone for extended periods of time. This situation is recoverable with a BFS operational sequence (OPS)-0-to-OPS-3 transition.

Deorbit preparations were again performed prior to entry on the wave-off day, and the payload bay doors were closed with nominal indications for this landing attempt at 091:08:09:31 G.m.t. (08:23:56:27 MET).

Prior to the deorbit maneuver on this first wave-off day, at 091:11:00 G.m.t. (09:02:47 MET), while configured to the B controller, the WSB 3 vent temperature decreased below the off-scale low value of 122 °F and remained there. After no cycling was observed for several minutes, the WSB 3 controller was reconfigured from B to A at 091:11:15 G.m.t. (09:03:02 MET). An increase in the vent temperature was observed shortly after this reconfiguration, indicating nominal heater cycling had been restored. At 091:11:43 G.m.t. (09:03:30 MET), the WSB 3B controller was reselected, and the nominal cycling continued. Normal operation continued in this configuration for the remainder of the mission.

The KSC landing opportunities on orbits 143 and 144 were waved off due to unacceptable weather conditions at the SLF. The deorbit maneuver was performed at 091:12:23:08.1 G.m.t. (09:04:10:04.1 MET) on orbit 144 for a landing at Edwards Air Force Base (EAFB) concrete runway 22, and the maneuver was 200.4 seconds in duration with a ΔV of 356 ft/sec. Entry interface (400,000 ft) occurred at 091:12:57:33.3 G.m.t. (09:04:44:29.3 MET).

Entry was completed satisfactorily, and main landing gear touchdown occurred on EAFB concrete runway 22 at 091:13:28:56.8 G.m.t. (09:05:15:52.8 MET) on March 31, 1996. The Orbiter drag chute was deployed at 091:13:29:00.4 G.m.t., and the nose gear touchdown occurred 7.4 seconds later. The drag chute was jettisoned at 091:13:29:31.4 G.m.t., with wheels-stop occurring at 091:13:29:52.0 G.m.t. The rollout was normal in all respects. The flight duration was 9 days 5 hours 15 minutes and 53 seconds. APU 3 was shut down within 34 seconds following wheels-stop, and the remaining two APUs were shut down approximately 15 minutes after landing.

LESSONS LEARNED AND RECOMMENDATIONS FOR SPACE STATION APPLICATION

The Spacehab soft stowage system provided versatility that proved to be invaluable for transition of cargo between the Orbiter and Mir. Using the system enabled the crew to complete all planned transfer activities and pack the Spacehab module at their discretion with minimal direction from the ground controllers.

The lessons learned concerning the operation of the RCS are as follows:

1. Marginal heater power on the RCS vernier thrusters may result in injector temperatures below the 130 °F operational limit during extended, non-active periods at low Beta angles. Evaluation of the Mir cases resulted in a flight rule to allow restricted vernier thruster operation at temperatures below 130 °F, based on extensive ground data monitoring. A re-evaluation of this condition will be required for an International Space Station Alpha (ISSA) docked mission based on the predicted thermal environment, ground monitoring capability, and flight crew workaround capabilities.

2. RCS vernier utilization (firing time) during STS-76 was higher than that experienced on STS-74 and STS-71. The following table summarizes the data for the six vernier thrusters.

COMPARISON OF VERNIER THRUSTER DATA

Thruster no.	Firings	Firing time, seconds	Thermal cycles	Flight duration, hours
F5L	2920	5552.44	138	-
F5R	2906	7546.68	202	-
L5D	4027	7210.73	174	-
L5L	1794	3183.80	50	-
R5D	4131	8227.78	192	-
R5R	2459	3458.98	56	-
STS-76 Totals	18,237	35,180.44	812	216.75
STS-74 Totals	16,372	30,436	733	197
STS-71 Totals	19,907	32,327	840	223

The number of firings fell well within the 500,000 cycle certification life. The firing time on the aft down-firing thrusters was very minimal when compared to the 125,000-second certified limit (approximately 16.2-mission equivalent). Also, high duty-cycles during the attitude-hold operations requires evaluation to determine if the 1000-cycle/hour limit was exceeded. Evaluation of the STS-71, STS-74, and STS-76 data to assess the long-term effects on the hardware is continuing.

Concerns from the certified life standpoint exist with the chamber/nozzle damage that would require chamber replacement. Coating damage is primarily driven by thermal cycles. While all vernier thruster usage parameters vary depending on mission profile and duration, average vernier thruster mission thermal cycles based on the evaluation of 63 previous mission are:

Thruster F5L and F5R:	42 thermal cycles/mission
Thruster L5D and R5D:	105 thermal cycles/mission
Thruster L5L and R5R	47 thermal cycles/mission

With thermal cycles on the order of 1.3 to 3 times higher than the nominal mission average, the chamber wear-out rate would be expected to increase if future Mir and ISSA docked missions result in similar usage. This poses a significant spares risk to the program and requires evaluation by engineering and logistics personnel. If vernier usage can be optimized (minimized) by improved digital autopilot (DAP) models or primary RCS thruster usage, the vernier usage may be significantly reduced from that seen on the three Mir docking missions thus far, assuming future missions of similar duration.

3. Thermal issues continue to be a concern for future ISSA missions, where cold vernier thrusters and hot primary thrusters are expected. These thermal concerns are under investigation by thermal personnel at Johnson Space Center (JSC).

Lessons learned and recommendations as a result of the first EVA while docked with the Mir are as follows:

1. The universal foot restraint (UFR) should be further evaluated for use in future EVA missions, including ISSA assembly and maintenance operations. Consideration should be given to modifying the small United States (U. S) boot to the same height at the toe bar interface as the large U. S. boot. This modification will allow one toe-bar setting for all boots.

2. Either the multi-use tether (MUT) or the rigid tether (RT) should be declared as the prime device for moving items in the size range of the MEEP during EVAs. Crew comments should heavily influence which device is declared prime.

3. The crew comments from the STS-72 and STS-76 crewmembers should be used in the selection of the most desirable hook designs.

4. An on-orbit test should be conducted of the UFR, MUT, and common tethers with the Russian ORLAN suit to verify common hardware compatibility.

The flight control system implications to Space Station are as follows:

1. The capability of controlling and stabilizing Space Station payloads extended over the Orbiter nose using the vernier RCS was successfully demonstrated.

2. Improved control performance with the new minimum angle thruster selection for Space Station-sized payloads was successfully demonstrated.

3. The capability to update the Mir inertial platform basis using Orbiter attitude data was successfully demonstrated.

PAYLOADS

The Spacehab module was a single-module configuration, similar to that flown on previous Spacehab missions. STS-76 delivered a U. S. Astronaut to Mir, demonstrated the feasibility of EVA for transferring and installing small items on the Mir, provided an opportunity to evaluate rigid tether prototypes when transferring a large unit (MEEP) to the Mir, demonstrated changeout of science hardware such as the Mir incubator controller, returned two key Mir components (KURS radars) for refurbishment, and served as a pathfinder for the upcoming logistics/science resupply missions. All Spacehab subsystems operated nominally throughout the mission.

Equipment and other items carried in the Spacehab module for STS-76 were categorized into five types, of which a total of 4,787 lb transferred to Mir. The types are discussed in the following paragraphs.

a. Russian logistics - The Russian logistics were carried in a double rack that was dedicated to the Russian equipment, which was made up of a gyrodyne to replace a used gyrodyne, and an individual equipment and seat liner (IESL) kit for use by Mission Specialist Shannon Lucid should return to Earth in the Soyuz capsule be required. Approximately 1900 lb of Russian items were stowed in the Spacehab soft stowage system for transfer to the Mir. The logistics transfer to the Mir consisted of 2562 lb of Russian experiment equipment, 614.4 lb of food, 42.2 lb of nitrogen and 61.6 lb of oxygen, plus the gyrodyne, Russian storage batteries, film and IESL kit, as well as the water that is discussed in a later paragraph. The total weight of all items transferred to the Mir was 4,787 lb. Six items that were designated for transfer from Mir to Shuttle were not found on Mir and not transferred to the Orbiter. One was for the Public Affairs Office and five were science clean-up items that represent no loss of science.

b. EVA tools - The EVA tools and support equipment was carried in several soft bags. Included in these bags were EVA tools, waist tethers, and a 35 mm camera and accessories required to support the various Development Test Objectives (DTOs) and Detailed Supplementary Objectives (DSOs).

c. RME - The RME hardware was carried in soft stowage bags and consisted of the items discussed in the following two subparagraphs.

1. Mir Electric Field Characterization (MEFC) hardware - The MEFC experiment collected data on the external and internal radio interference in the 400 Mhz to 18 Ghz frequency band while being operated on the Orbiter flight deck. The experiment hardware consisted of a radio frequency spectrum analyzer and power cable, an Orbiter window antenna, and a payload general support computer (PGSC).

2. MEEP attachment brackets - The MEEP experiment was deployed during the EVA with the attachment brackets clamped on Mir handrails. The MEEP will continue

to collect samples of orbital and micrometeoroid debris until the experiment is retrieved on a later mission (STS-86).

d. American logistics - Fifteen full water bags, weighing 1506.6 lb, were supplied through the Shuttle's water system to the Mir station. In addition, new film was traded for film already shot on the Mir. The docking module light and video camera that was retrieved during the EVA was also returned.

e. Science and Technology experiments - The science and technology equipment and supplies transferred the Mir Glovebox Stowage (MGBX), which was carried in soft stowage bags to replenish hardware for the MGBX located in the Mir. The equipment included a combustion experiments parts box, a passive accelerometer, a protein crystal growth experiment, and the protein crystal growth thermal enclosure system ancillary. Other science transferred to the Mir included the Queen's University Experiment in Liquid Diffusion (QUELD), and the High Temperature Liquid Phase Sintering (LPS) experiment.

The ESA's Biorack experiment was also carried for use in the Orbiter and was not to be transferred to the Mir. The Biorack shared a double rack in the Spacehab with the Life Sciences Laboratory Equipment (LSLE) Refrigerator/Freezer. The equipment included in the Biorack consisted of incubator units, a glovebox, a power switching unit, an external power data panel, and a soft stowage locker. The Biorack unit also made use of three middeck lockers which contained a passive thermal control unit (PCTU).

A total of 11 experiments were flown of which three were from the U. S., three from France, three from Germany, one from Switzerland and one from the Netherlands.

The LSLE refrigerator/freezer and the commercial refrigerator incubator module (CRIM) performed nominally. The ESA Biorack experienced a data downlink problem during activation, and the problem was traced to the software in a ground computer that processed all the data. All data were collected onboard; consequently no data were lost. Ten of the eleven preplanned Biorack investigations were completed successfully. In preparation for landing one day early, Spacehab and Biorack personnel minimized the loss of the science from the eleventh investigation to 10 percent.

KIDSAT PROJECT

The KIDSAT is a three-year pilot project that will fly once a year on the Shuttle. STS-76 was the first flight of this Project. The middle school students, who participate in this project, configure their own payload of digital video and a camera for flight on the Shuttle, command the camera from their classrooms, and download their images of Earth in near-real-time. Approximately 300 photographs were taken during the mission using the onboard electronic still camera (ESC). These photographs were downlinked via the Ku-Band Communication Adapter (KCA). Over 90 percent of the planned photographs were taken. Some of the missed photographs were caused by the failure of the onboard PGSC Thinkpad. The Thinkpad unexpectedly halted on orbit 22 and all orbit 23 photo opportunities were missed. After Atlantis undocked from the Mir, atmospheric conditions adversely affected 60 percent of the photographs attempted during the following orbit. Most of the remaining pictures were of good quality.

SHUTTLE AMATEUR RADIO EXPERIMENT

Five schools were chosen for contacts via the Shuttle Amateur Radio Experiment (SAREX); however, no school contacts were made and only four personal contacts were made. This condition resulted from the crew being unavailable because of the shortened mission. Two of the personal contacts were successful and two were fair, probably as a result of the inertial attitude and blockage from the combined Shuttle/Mir vehicles. After the decision was made to return a day early, the school contacts scheduled for flight day 9 were delayed until a later mission. Two of the four remaining contacts scheduled for flight day 8 were notified to prepare for the contacts; however, the contacts subsequently had to be canceled because of crew workload.

RISK MITIGATION EXPERIMENTS

RME 1301 Mated Shuttle and Mir Structural Dynamics Test - This RME was scheduled on an opportunity basis; however, since the Priroda module had not yet docked with the Mir, this RME was performed.

RME 1302 Mir Electric Fields Characteristics - This spectral analyzer failed to initialize. The crew was instructed to recycle through the activation steps of the analyzer, but this was not successful. The experiment was stowed for entry with no data obtained. The PGSC data cable was subsequently transferred to the Mir for use in developing a 25-pin-to-9-pin converter cable to connect the radiogram system to the bubble jet ink printer onboard Mir.

RME 1304 Mir Environmental Effects Payload - All four experiments were deployed in the correct location and orientation on the Mir docking module during the EVA. The MEEP hardware had no anomalous operations. The installation of the handrail clamps and experiment containers was completed in a satisfactory manner.

RME 1306 Mir Wireless Network Experiment - The Mir Wireless Network was a success and the data were collected in a timely manner. The Mir Wireless Network was transported from the Mir stowage location to the Shuttle for the first operational data collection. One full data set was collected at the initial middeck location and a partial set at the flight-deck location. The Mir Wireless Network was then transported back to the Mir where the initial full data set was collected as planned in the Spektr module. A partial set was also collected at another location within the Spektr module.

RME 1310 Shuttle/Mir Alignment Stability - The Mir star tracker alignment was performed at 084:10:23 G.m.t. (002:02:10 MET) and the onboard attitude was updated. The attitude knowledge was based on the Mir precise star tracker measurements.

NASA concurred that the star tracker correction corresponded to the errors indicated in the Shuttle attitude error downlist of approximately 0.6 deg. No further maneuver of star tracker align was required, and attitude data were collected during the five sleep periods when the two vehicles were docked.

RME 1315 Trapped Ions in Space Environment - The Trapped Ions in Space Environment (TRIS) was located in a Get Away Special (GAS) canister and was activated on flight day 1 after the payload bay doors were open. The experiment continued to operate and collect data through deactivated at 090:04:13 G.m.t. (007:20:00 MET). The data have been given to the sponsor for evaluation, and the results will be published in separate documentation.

VEHICLE PERFORMANCE

The data review shows that all vehicle subsystems performed nominally and no problems were noted that impacted the successful completion of the mission.

SOLID ROCKET BOOSTERS

Analysis of the flight data and assessment of the postflight condition of the recovered Solid Rocket Booster (SRB) hardware indicates nominal performance of the SRB and its subsystems. No SRB in-flight anomalies were identified. The SRB prelaunch countdown was normal, and no SRB Launch Commit Criteria (LCC) or Operations and Maintenance Requirements and Specifications Document (OMRSD) violations occurred.

Both SRBs were successfully separated from the External Tank (ET) at T+125.885 seconds, and visual reports from the recovery area indicated that all deceleration subsystems performed as designed. Following day break, the SRBs were recovered, towed to Cape Canaveral, and transferred to KSC for inspection, disassembly and refurbishment.

REUSABLE SOLID ROCKET MOTORS

Analysis of the data indicates that the Reusable Solid Rocket Motor (RSRM) flight performance was well within the allowable performance envelopes, and was typical of the performance observed on previous flights. The countdown was nominal, and no LCC or OMRSD violations occurred. The maximum trace shape variation of pressure versus time was calculated to be 0.63 percent at 62 seconds (left RSRM), and 0.47 percent at 72.5 seconds (right RSRM). Both values were well within the 3.2-percent allowable limit.

Power up and operation of all igniter and field joint heaters was satisfactory. All RSRM temperatures were maintained within acceptable limits throughout the countdown. The RSRM propellant mean bulk temperature (PMBT) was 61 °F at liftoff.

The aft skirt purge operated for a total of 22 hours 2 minutes. During the successful countdown, the aft skirt purge was activated to maintain the nozzle/case temperatures above the minimum LCC temperature. During the LCC time frame, the nozzle/case joint temperatures ranged from 72 °F to 82 °F.

The postflight assessment showed that all J-joints (igniter and field) performed as designed. However, gas paths were observed through the polysulfide on both nozzle-to-case joints.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 61 °F		Right motor, 61 °F	
	Predict	Actual	Predicted	Actual
Impulse gates				
I-20, 10^6 lbf-sec	65.03	64.71	65.19	64.65
I-60, 10^6 lbf-sec	173.64	173.97	173.97	173.68
I-AT, 10^6 lbf-sec	296.97	296.84	296.84	296.40
Vacuum Isp, lbf-sec/lbm	268.4	268.3	268.4	268.8
Burn rate, in/sec @ 60 °F at 625 psia	0.3686	0.3689	0.3693	0.3693
Burn rate, in/sec @ 62 °F at 625 psia	0.3689	0.3692	0.3696	0.3696
Event times, seconds[a]				
Ignition interval	0.232	N/A	0.232	N/A
Web time[b]	110.7	110.7	110.4	110.5
50 psia cue time	120.5	120.8	120.2	121.0
Action time[b]	122.6	123.4	122.3	123.0
Separation command	125.4	125:9	125.4	125.9
PMBT, °F	61	61	61	61
Maximum ignition rise rate, psia/10 ms	90.4	N/A	90.4	N/A
Decay time, seconds (59.4 psia to 85 K)	2.8	3.3	2.8	3.2
Tailoff Imbalance Impulse differential, Klbf-sec	Predicted		Actual	
	N/A		247.1	

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).

EXTERNAL TANK

The ET subsystem performance was satisfactory, and all flight objectives were satisfied. The ET propellant loading and flight operations met all objectives and requirements. All ET electrical equipment and instrumentation operated satisfactorily. ET purge and heater operations were nominal. No LCC or OMRSD violations occurred.

No unexpected ice/frost formations were observed by the ice/frost team during the countdown, nor was any frost observed in the acreage areas of the ET. Normal amounts of ice/frost were present on the LH_2 and LO_2 feed-lines, the pressurization line brackets and along the LH_2 protuberance air load (PAL) ramps. All observations were acceptable based on approved documentation (NSTS 08303). The ice/frost team also reported that no anomalous thermal protection subsystem (TPS) conditions existed;

however, two vertical strut TPS cracks were noted, and these were typical of conditions observed on previous launches.

After SRB separation, the ET range safety system (RSS) signal strength frequently dropped below the minimum requirement of -85 dBm when being tracked from the Bermuda site. The lowest observed ET RSS signal strength after handover to the Bermuda site was -100 dBm. The observed value did not exceed the command sensitivity limit and would not have affected system operation. A post-ascent investigation showed that the flight hardware was not at fault, but that the tracking site had an antenna problem that resulted in low transmitted power.

The ET pressurization system functioned properly throughout engine start and flight operations. The minimum LO_2 ullage pressure experienced during the ullage pressure slump was 13.4 psid.

ET separation was confirmed and ET entry and breakup occurred within the preflight predicted impact area and was approximately 29 nautical miles uprange from the preflight predicted impact point.

SPACE SHUTTLE MAIN ENGINE

All Space Shuttle main engine (SSME) parameters were normal throughout the prelaunch countdown and were typical of conditions observed on previous missions. No OMRSD violations occurred. Engine ready was achieved at the proper time, all LCC were met, and engine start and thrust buildup were nominal.

One in-flight anomaly was identified in that the fuel preburner chamber channel A igniter failed to indicate on at engine start on SSME 2 (Flight Problem STS-76-E-1). This is the first occurrence of an igniter failing to indicate on at engine start. The lack of a spark indication may be real or may be a failure in the monitoring circuit. Troubleshooting is continuing in an effort to isolate the cause of the anomaly. Checkout tests have not duplicated the anomaly on channel A; however, the fuel preburner chamber channel B igniter has failed to spark during tests.

Flight data indicate that the SSME performance during mainstage, throttling, shutdown and propellant dump operations was nominal with no in-flight anomalies or significant SSME problems noted. The high pressure oxidizer turbopump (HPOTP) and high pressure fuel turbopump (HPFTP) temperatures were well within the specification throughout engine operation. Space Shuttle main engine cutoff (MECO) occurred at 512.56 seconds after liftoff.

At 120 seconds after MECO, the main oxidizer valve was unable to open for the normal propellant dump sequence. The engine hydraulic system had been isolated from the vehicle since approximately 50 seconds after engine shutdown to troubleshoot the APU 3 hydraulic leak discussed in the Orbiter subsystems portion of this report. The oxidizer valve not opening was expected since no hydraulic pressure was present in the engine.

As a result, a pneumatic shutdown was commanded by the engine controller to verify that all valves were closed. The engine controller and software performed satisfactorily in light of the anomalous Orbiter hydraulic leak condition.

SHUTTLE RANGE SAFETY SYSTEM

The Shuttle Range Safety System (SRSS) closed-loop testing was completed as scheduled during the launch countdown. All SRSS safe and arm (S&A) devices were armed and system inhibits turned off at the appropriate (planned) times. All SRSS measurements indicated that the system operated as designed throughout the countdown and flight, with the exception of the ET range safety system (RSS) signal strength, which fell below the 2.1 Vdc lower limit at approximately T + 7 minutes and remained low until ET separation (approximately 2 minutes).

As planned, the SRB S&A devices were safed, and SRB system power was turned off prior to SRB separation. The ET system remained active until ET separation from the Orbiter.

ORBITER SUBSYSTEMS PERFORMANCE

Main Propulsion Subsystem

Ascent main propulsion subsystem (MPS) performance was completely nominal. Data indicate that both (LO_2 and LH_2) pressurization systems performed nominally, and all net positive suction pressure (NPSP) requirements were met throughout the flight.

Throughout the countdown period, no significant hazardous gas concentrations were detected. The maximum hydrogen concentration level in the Orbiter aft compartment (which occurred shortly after start of fast-fill) was approximately 175 ppm. This value compares favorably with previous data from this vehicle. No LCC or OMRSD violations occurred during the preflight period.

The LO_2 and LH_2 loading was performed as planned with no stop flows or reverts. A comparison of the calculated propellant loads at the end of replenish versus the inventory (planned) loads shows a loading accuracy of 0.01 percent for LH_2 and 0.08 percent for LO_2.

STS-76 was the first flight of the GH_2 pressurization systems modifications where all prescribed modifications were completed. This modification involved rotating the flow control valves (FCVs), rerouting the lines from the engine interface to the FCV manifold, and incorporating filter housings and filters in all three engine legs plus the prepressurization line for each engine. The performance of all four filter elements was within the expected band determined from analysis. The GH_2 system leaked at a rate of 54.8 scim versus the allowable leakage of 15 scim. This leakage did not impact the flight. Postflight turnaround activities will ensure that the leak is eliminated or that at least the leak rate is reduced to an allowable level.

All three FCVs performed nominally with the system 1 FCV experiencing no cycles, system 2 experiencing nine cycles, and system 3 experiencing 36 cycles. All three valves were replaced during STS-76 turnaround operations.

Reaction Control Subsystem

The reaction control subsystem (RCS) performed satisfactorily during all firings and major activities of the STS-76 mission. The RCS lessons learned from the STS-76 mission are discussed in the Lessons Learned section of this report. The RCS successfully supported all docking requirements as well as DTO performance throughout the mission. Three in-flight anomalies were identified during the RCS hot-fire test late in the mission. Three thrusters were deselected, one because of a leak and the other two because of low chamber pressure (Pc), and all three thrusters remained deselected for the remainder of the mission.

Propellant consumption by the RCS was 4,406.1 lbm from the RCS tanks and an additional 1896.0 lbm from the OMS during interconnect operations.

The RCS supported Mir undocking with a low-Z maneuver at 089:01:08:03.4 G.m.t. (06:16:54:59.0 MET). The final separation maneuver utilizing two RCS thrusters was performed at 089:02:08 G.m.t. (06:17:55 MET) and lasted 12.5 seconds. Thruster firings were nominal.

During the RCS hot-fire, primary thrusters L2U and R4R were deselected by RM as failed-off because of low Pc (Flight Problems STS-76-V-03 and -04). This was the first attempted firing of these thrusters this flight. The maximum Pc reached was 13 psia and 10 psia, for L2U and R4R, respectively. Nominal Pc is 150 psia. The injector temperatures both dropped due to evaporative cooling, indicating that partial pilot-valve flow was achieved on each valve. The injector temperature recovery did not exceed the pre-firing temperatures, indicating that the heat soak-back that would be associated with normal combustion did not occur. The Pc traces did not exhibit a slow pressure tail off; as a result, blocked Pc tubes are not suspected. The L2U paper cover was noted to be wet prior to launch.

Also during the RCS hot-fire, primary thruster L2L (S/N 234) was declared failed-leak at 089:06:11 G.m.t. (06:21:58 MET) by RCS RM, when the oxidizer injector temperature dropped below the 30 °F leak detection limit (Flight Problem STS-76-V-02). The leak began after the second nominal hot-fire pulse. The crew visually observed oxidizer spraying from the area, and isolated left RCS manifold 2 at 089:06:16 G.m.t. (06:22:03 MET). The paper cover for L2L was also noted to be wet prior to launch. The manifold isolation valve was reopened at 090:06:29 G.m.t. (07:22:16 MET). However, primary thruster L2L continued to leak and the manifold isolation valve was again closed at 090:07:33 G.m.t. (07:23:20 MET) when the fuel injector temperature dropped below the flight rule limit of 40 °F. The manifold remained isolated for the remainder of the mission.

Orbital Maneuvering Subsystem

The orbital maneuvering subsystem (OMS) performed satisfactorily throughout the mission. The left-hand fuel gaging system failed to indicate the forward total quantity level after the OMS 2 maneuver. However, during the OMS 5 maneuver, the gaging system began indicating the correct level and did so for the remainder of the flight. This gaging system has exhibited similar indications on two previous flights of this vehicle.

Propellant consumption during the seven OMS maneuvers plus the interconnect operations was 18,923.1 lbm of which 2069.9 lbm (15.95 percent) were consumed by the RCS during interconnect operations. The seven maneuvers performed are shown in the following table.

OMS FIRINGS

OMS firing	Engine	Ignition time, G.m.t./MET	Firing duration, seconds	ΔV, ft/sec
OMS-2	Both	082:08:55:26.0 G.m.t. 00:00:42:22.0 MET	47.8	76
OMS-3	Both	082:11:55:29.8 G.m.t. 00:03:42:25.8 MET	42.8	69
OMS-4	Right	082:23:49:04.2 G.m.t. 00:15:36:00.2 MET	9.8	8
OMS-5	Both	083:09:24:26.8 G.m.t. 01:01:11:22.8 MET	57.2	93
OMS-6	Both	083:22:16:37.6 G.m.t. 01:14:03:33.6 MET	85.4	141
OMS-7	Left	083:23:51:38.2 G.m.t. 01:15:38:34.2 MET	11.0	9
Deorbit	Both	091:12:23:08.1 G.m.t. 09:04:10:04.1 MET	200.4	356

Power Reactant Storage and Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem performance was nominal throughout the mission, and no in-flight anomalies were identified from the data analysis. The PRSD supplied the fuel cells 2,438 lbm of oxygen and 307 lbm of hydrogen. In addition, 167 lbm of oxygen was supplied to the environmental control and life support system (ECLSS), and 61 lbm of that total was supplied to the Mir Space Station. The Orbiter landed with 1,297 lbm of oxygen and 143 lbm of hydrogen remaining, and this was sufficient for an 89-hour mission extension at average power levels (125-hour extension at extension-day power levels of 11.1 kW).

Fuel Cell Powerplant Subsystem

Performance of the fuel cell powerplant (FCP) subsystem was nominal throughout the mission with no in-flight anomalies identified. The fuel cell average electrical power level and load were 15.9 kW and 523 amperes, respectively. The fuel cells produced 3,525 kWh of electrical energy and 2,745 lbm of potable water while using 2,438 lbm of oxygen and 307 lbm of hydrogen.

Four fuel cell purges were performed, and the fuel cell purge system operated nominally in both the automatic and manual modes. The actual fuel cell voltages at the end of the mission were 0.10 Volt above the predicted value for fuel cell 1, and 0.20 Volt above the predicted level for fuel cells 2 and 3.

Auxiliary Power Unit Subsystem

The auxiliary power unit (APU) subsystem performance was nominal throughout the STS-76 mission, and no in-flight anomalies were recorded. The APU run times and fuel consumption for the mission are shown in the following table.

APU RUN TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (S/N 208)		APU 2 (S/N 406)		APU 3 (S/N 310)	
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	25:51	63	26:00	62	30:08	58
FCS checkout[a]						
Entry[b, c]	59:26	128	86:03	140	07:40	12
Total[b]	85:17	191	112:03	234	37:48	70

[a] The FCS checkout was performed without operating the APUs.
[b] APUs 1 and 2 ran for approximately 15 minutes 20 seconds after landing. APU 3 ran for 1 minute 30 seconds after landing.
[c] Totals include 08 minutes 02 seconds of high-speed run time for APU 1, and 08 minutes 01 second of high-speed run time for APU 2.

During the ascent phase, a hydraulic leak from system 3 was noted. Analysis of the hydraulic system 3 leak data showed a significant decrease in the hydraulic system 3 reservoir quantity of approximately 1 percent/minute of run time. The quantity decreased from 63 percent to 54 percent with a slight increase to 56 percent prior to APU shutdown. As a result of the system 3 hydraulic leak during ascent, the decision was made not to run an APU for FCS checkout. The checkout was instead performed using the hydraulic system 1 circulation pump, and this verified essential flight control capabilities for entry. Also, APU 3 was not started until terminal area energy management (TAEM), was operated in low-pressure mode, and the APU was shut down shortly after wheels stop on the runway.

Hydraulics/Water Spray Boiler Subsystem

The hydraulics/water spray boiler (WSB) subsystem met all requirements placed on it during the mission. Four in-flight anomalies occurred and these are discussed in the following paragraphs.

During the ascent phase, a hydraulic leak from system 3 was noted (Flight Problem STS-76-V-01). The hydraulic system 3 leak data indicated a significant decrease in the hydraulic system 3 reservoir quantity of approximately 1 percent/minute of run time. The quantity decreased from 63 percent to 54 percent with a slight increase to 56 percent prior to APU shutdown. The thrust vector control (TVC) isolation valve for this system was closed in an attempt to halt the leak; however, the reservoir quantity continued to decrease. APU 3 was taken to the low-pressure mode shortly after valve closure. APUs 1 and 2 were shut down while APU 3 was left running in the low-pressure mode for an additional four minutes. No significant quantity decrease was noted during low-pressure operation. The APU was shut down. Approximately 48 hours later, the hydraulic system 3 reservoir quantity showed a slight decrease to 44.0 percent. A comparison of plots of quantity versus temperature for each hydraulic system showed a similar quantity decrease rate on each system, which indicated that system 3 was not leaking while shut down.

The hydraulic system data were presented to the MMT for a final determination of the manner in which the mission was to be completed. The decision was made to continue the mission to the planned landing time on March 31, 1996, with some tightening of the landing constraints concerning crosswinds, cloud coverage and landing-site selection.

The Russian Mission Control Center personnel requested that the aft compartment vent doors be closed to preclude contamination by any free hydraulic fluid that may exist in the aft compartment. Port vent doors 8 and 9 were closed at 084:00:25 G.m.t. (01:16:12 MET), and starboard vent doors 8 and 9 were closed three minutes later.

Revised limits for the control of hydraulic system 3 circulation pump were uplinked to the Orbiter at 084:12:47 G.m.t. (02:04:34 MET). These new limits controlled circulation pump operations with lower-than-normal temperatures to minimize the frequency of pump use.

Several circulation pump runs were performed either manually or automatically over the course of the mission, and based on the data, none resulted in further hydraulic fluid leakage.

As a result of the system 3 hydraulic leak during ascent, the decision was made not to run an APU for FCS checkout. The checkout was instead performed using the hydraulic system 1 circulation pump and this verified essential flight control capabilities for entry. The circulation pump was started at 089:04:53:29 G.m.t. (06:20:40:25 MET) and ran for 9 minutes 24 seconds. Performance was as expected.

During FCS checkout, it was noted that hydraulic system 2 and 3 pressures (reservoir and circulation pump) exhibited slight dips while exercising the flight control system. This pressure response was most likely caused by minimal inter-system leakage due to switching-valve action. Normal circulation-pump pressure (approximately 250 psia) was attained on system. However, as expected, during the high-flow demand periods of the checkout, the fixed-displacement pump could not maintain 250 psia. Drops in pressure occurred to as low as 103 psia. This, in turn, caused switching valve movement. Analysis of data revealed that a period of under-cooling occurred on WSB system 3 during the ascent APU run (Flight Problem STS-76-V-05). When the APU lubrication-oil temperature reached 307 °F, controller B was selected, and 31 seconds later cooling was observed. This condition did not impact APU or hydraulic system operations.

During ascent, hydraulic system 2 experienced two periods of over-cooling to 195 °F and 202 °F (Flight Problem STS-76-V-06). Both over-cooling periods occurred while operating on the A controller. APU 2 was shut down during the second over-cooling period and the lubrication oil temperature had reached 193 °F. A similar problem occurred on the last flight of this vehicle.

At 091:11:00 G.m.t. (09:02:47 MET), prior to the deorbit maneuver, the WSB 3 vent temperature 2 went off-scale low (122 °F) (Flight Problem STS-76-V-07). Nominally, the heater cycles at approximately 145 °F. The system was operating on the B controller, and the signature indicates that the B heater failed off. The system was switched to the WSB 3 A controller at 091:11:16 G.m.t. (09:03:03 MET), and a rise in the vent temperature was observed a short time later. About 30 minutes later and after a nominal heater cycle on the A controller, the system was switched back to the B controller. Nominal cycling of the B vent heater was observed for the remainder of the flight.

Hydraulic performance during entry was nominal for the modified entry flight plan developed because of the system 3 leak during ascent. APU 2 was activated five minutes prior to deorbit maneuver ignition, and APU 1 was started 13 minutes prior to entry interface. APU 3 was started at TAEM and remained in low pressure until shutdown (approximately 34 seconds after wheels stop). No unusual behavior or unexpected operation was noted during descent and landing.

Electrical Power Distribution and Control Subsystem

The electrical power distribution and control (EPDC) subsystem performed satisfactorily during all phases of the STS-76 mission. The data review and analysis did not show any abnormal or anomalous behavior.

Environmental Control and Life Support Subsystem

The environmental control and life support subsystem (ECLSS) performed nominally throughout the mission.

The atmospheric revitalization pressure control system (ARPCS) performed normally. The Orbiter and Mir docking system interface was checked by pressurizing the vestibule and performing a subsequent leak check. After the mating interface was confirmed to have no leaks, the Orbiter and Mir volume pressures were equalized to a pressure of 14.23 psia and the Mir/Shuttle transfer hatches were opened.

In preparation for the EVA, the vestibule was depressurized and the external airlock/tunnel-adapter hatch was closed. The Orbiter cabin was depressurized to 10.2 psia and repressurized to 14.7 psia during the EVA. Following the EVA, the Orbiter/Mir volume was pressurized to 14.23 psia. Using the Shuttle repressurization configuration, the entire Orbiter/Mir pressure was increased to 14.62 psia and then to 15.54 psia using the oxygen transfer system. This was the first use of the oxygen transfer system, which includes a 7.7 lb/hr flow orifice connected to a launch/entry suit (LES) hose that allowed a continuous flow of oxygen with minimal crew interaction.

Total consumables transferred to the Mir during the docked phase were 42.2 lb of nitrogen and 61.6 lb of oxygen. The nitrogen was used for Mir pressurization, and the oxygen was used for metabolic consumption during docked operation and for raising the total pressure and partial oxygen pressure (PPO_2) to 15.4 psia and 3.94 psia, respectively. Vestibule repressurization and depressurization were nominal.

The supply water and waste management systems performed normally. Supply water was managed through the use of the FES and water transfer to the Mir. The supply water dump line temperature was maintained within satisfactory limits by using the line heater.

The crew observed gas bubbles in the water after galley activation. After performing the galley-purge procedure, the crew reported an acceptable level of bubbles in the hot water and no bubbles in the cold water.

The hardware used for the STS-76 Mir water transfer performed nominally. Fifteen contingency water containers (CWCs) were filled with a total of approximately 1506 lb of Orbiter supply water that was transferred to the Mir during the flight. The CWCs were filled in an average of 46.5 minutes at a rate of 2.16 lb/min. The iodine and iodide was removed from the water as the CWCs were filled. All of the CWCs had silver biocide added and eight of the CWCs had minerals added to allow the Mir crew to use that water for drinking water. Samples were taken from each CWC during the flight and from the iodine removal system after each CWC was filled. All of these samples were retrieved postflight, and an analysis has shown no iodine or iodide in the water. Postflight, an additional CWC was filled using the same transfer hardware, and this CWC will be used for a long-term stowage test. Samples taken from this CWC also indicate that all iodide and iodine in the Shuttle water was removed by the iodine removal system, and no bacterial growth was present.

During the fill of the seventh water-transfer CWC, the crew experienced problems with the operation of the syringe used for mineral injection (Flight Problem STS-76-F-02). The minerals were successfully injected; however, during a second flush of the syringe, the crewmember could not exert enough force to push the plunger down and re-inject the water into the CWC. The mineral syringe was removed, and the silver biocide syringe was used successfully. During a subsequent CWC fill, a spare mineral syringe was used successfully. The inoperable syringe was labeled so that it could be evaluated after landing.

The waste water was gathered at approximately the predicted rate. Three waste water dumps were performed at an average dump rate of 2.03 percent/minute (3.35 lb/min). The waste water dump line, vacuum vent line, and vacuum vent nozzle temperatures were maintained within acceptable limits.

The waste collection system performed normally throughout the mission.

Airlock Support System

The airlock depressurization valve was used to depressurize the cabin from 14.47 psia to 10.43 psia, and the airlock from 10.2 psia to a vacuum for the EVA. All hardware performed nominally during the EVA.

After docking with the 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 outputs throughout the flight.

Smoke Detection and Fire Suppression Subsystems

The smoke detection system (SDS) showed no indications of smoke during the entire flight. Use of the fire suppression system was not required.

Avionics and Software Support Subsystem

The integrated guidance, navigation, and control system performed satisfactorily throughout the mission.

The flight control system performance during docked operations was nominal, with no dynamic interaction stability considerations observed. The Shuttle controlled the mated stack with vernier RCS for the entire mated phase, except for a single 90-minute period when the Mir was given control of the stack. The Mir assumed control to perform an alignment of the inertial basis using the backup Mir star tracker. Shuttle control was maintained with 5-degree and 1-degree vernier RCS deadbands. A review of the propellant consumption during the periods of inertial hold indicated that the preflight estimates matched the flight consumption within approximately 5 percent.

No flight control anomalies were observed, but degraded FCS performance was noted in the presence of the depressurization vent force during the depressurization of the crew cabin for the EVA. Tighter-than-desired one-sided limit cycles were observed during the initial period of the vent disturbance while the Shuttle estimate of the disturbance acceleration converged on the actual value. However, degraded performance in the presence of these types of disturbances can be expected with the reduced filter gains and firing inhibit enabled.

Analysis of the Shuttle downlist during the Mir control period indicated that the Mir attitude control system (ACS) performed nominally. Prior to the selection of Mir control, the Shuttle attitude quaternion was transmitted to the Russians and uplinked to the Mir to provide a coarse alignment. Following receipt of these data and near the end of the Mir control period, a precise alignment was completed using the Mir star tracker. Ideally, zero error should exist in the Shuttle attitude error as both inertial platforms had been aligned and the Mir gyrodynes provide precise control; however, the error still read approximately 0.4, 0.1, and 0.2 degree in Shuttle roll, pitch, and yaw, respectively. This error would indicate a structural misalignment between the two vehicles of approximately 0.5 degree.

As a result of the system 3 hydraulic leak during ascent, the decision was made not to run an APU for FCS checkout. The checkout was instead performed using the hydraulic system 1 circulation pump. The circulation pump was started at 089:04:53:29 G.m.t. (06:20:40:25 MET) and ran for 9 minutes 24 seconds. This was the first time that this option had been exercised during the Shuttle Program because of an anomaly, and performance was nominal.

During payload bay (PLB) door re-opening after the planned-landing-day wave off, both PLB door centerline latch 9-12 release indications failed to indicate release after single-motor run time. The release indication is normally obtained when the latch is in the full-open position. The BFS logic terminated the auto sequence when the release indications were not obtained within the 40-second single-motor run time. While reconfiguring from the payload bay door problem, the backup flight system (BFS) went stand-alone because the primary avionics software system (PASS) redundant set was reconfigured, and remained stand-alone for approximately five minutes. After the crew entered input/output (I/O) reset to reinitiate PASS tracking by BFS, the BFS began to track the PASS; however, the BFS remained on its internal time rather than synchronizing with the master timing unit (MTU). The phenomenon was explained as an expected condition that occurs when the BFS is left stand-alone for extended periods of time. This situation was recoverable with a BFS operational sequence (OPS)-0-to-OPS-3 transition.

Entry was accomplished with hydraulic systems 1 and 2. System 3 was operated in low pressure from TAEM through rollout and systems APU 1 and 2 were operated at high speed during this period. Control during the period from TAEM to landing was nominal.

Displays and Controls Subsystem

The displays and controls subsystem performed nominally throughout the mission, and no in-flight anomalies were identified.

Communications and Tracking Subsystems

The communications and tracking subsystems performed nominally, and no in-flight anomalies were identified. Ku-band antenna deployment was satisfactory, and Ku-band operation in the radar and communications modes was nominal.

The on-orbit S-band Tracking and Data Relay Satellite (TDRS) operation was nominal with some incidents of radio frequency interference (RFI). Data analysis showed no hardware problems. The RFI did not operationally impact on-orbit operations.

Difficulties were experienced communicating with the Mir. Transmissions from Mir were heard onboard the Orbiter, but Orbiter transmissions were not heard on Mir. The crew performed troubleshooting procedures with the VHF radio prior to undocking. These procedures were unsuccessful in restoring the VHF link between the Orbiter and Mir. Shortly after the crew terminated the troubleshooting procedures, the Mir communications system was reconfigured, allowing successful two-way communications between Moscow and Mir. The assessment was that the VHF problems were due to the Mir communications configuration as no hardware nor Orbiter problems have been identified that would cause this problem.

The Ku-band radar acquired Mir at 083:23:09 G.m.t. (01:13:56 MET) at a range of 137,861 feet (approximately 23 nmi.). Mir was tracked to a range of 330 feet at 084:01:50 G.m.t. (01:17:37 MET), at which time the Ku-band was configured to the communications mode for downlink of docking video. The trajectory control sensors (TCSs) 1 and 2 were activated at 083:23:58 G.m.t. (01:15:45 MET) and 084:01:22 G.m.t. (01:17:09 MET), respectively and performed satisfactorily.

The two TCS units were activated at 089:00:15 G.m.t. (06:16:02 MET) to support Mir undocking, and TCS 2 began tracking the target eight minutes later. TCS 1 did not respond as expected, and a power cycle and re-execution of startup procedures were performed. TCS 1 subsequently began tracking the target at 089:00:53 G.m.t. (06:16:40 MET). Both sensors tracked until the reflectors went out of the field of view at a range of approximately 500 feet. The sensors reacquired the reflector at least twice during the fly-around and separation, and the last measured distance was 1232.1 feet.

Operational Instrumentation/Modular Auxiliary Data System

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

Structures and Mechanical Subsystems

The structures and mechanical subsystems performed nominally throughout the mission. No in-flight anomalies were identified from the data; however, one problem did occur after the first wave-off of landing. The drag chute performance was nominal. The table on the following page presents the significant landing parameters.

All ET/Orbiter separation devices functioned properly. No debris was found on the runway below the ET/Orbiter umbilical cavities, nor was any debris found on the runway as a result of the landing.

LANDING AND BRAKING PARAMETERS

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	2384	197.0	~ 2.7	N/A
Nose gear touchdown	5482	144.8	N/A	~4.2

Brake initiation speed	116.0 knots
Brake-on time	36.3 seconds
Rollout distance	8,295 feet
Rollout time	55.0 seconds
Runway	22 (Concrete) Edwards AFB
Orbiter weight at landing	211,893 lb

Brake sensor location	Peak pressure, psia	Brake assembly	Energy, million ft-lb
Left-hand inboard 1	960	Left-hand outboard	17.02
Left-hand inboard 3	936	Left-hand inboard	22.34
Left-hand outboard 2	888	Right-hand inboard	15.64
Left-hand outboard 4	828	Right-hand outboard	15.67
Right-hand inboard 1	744		
Right-hand inboard 3	840		
Right-hand outboard 2	780		
Right-hand outboard 4	756		

During PLB door re-opening after the wave off, both PLB centerline latch 9-12 release indications failed to indicate release after single-motor run time. The release indication is normally obtained when the latch is in the full-open position. The BFS logic terminated the auto sequence when the release indications were not obtained within the 40-second single-motor run time. The crew reported that the 9-12 latch gang appeared to be fully open as viewed from the Spacehab overhead view port. The crew manually commanded the latch to open and saw no latch movement and still the release indication did not come on. Because the latches appeared to be open, the crew completed door opening in manual mode. At 090:15:22 G.m.t. (008:07:09 MET), the centerline 9-12 release 2 indication recovered with no crew action. The release 1 indication began toggling between on and off beginning at 090:16:03 G.m.t. (008:07:50 MET), and at 090:16:14 G.m.t. (008:08:01 MET) stabilized with the release indication on. The condition did not impact further door operations.

Following wheels stop, the tires were observed to be in good condition. Also, the drag chute functioned nominally. All drag chute hardware except the mortar cover was recovered and none showed any obvious signs of abnormal wear.

Orbiter Docking System

The Orbiter docking system (ODS) performance was nominal and no in-flight anomalies were identified. During extension of the docking ring from the initial position to the final position at 083:09:46:25 G.m.t. (01:01:33:21 MET), the display power on heater 2 did not indicate on. This same problem had surfaced during ground turnaround activities at KSC, and troubleshooting revealed that only the indication was faulty and power was being applied to the heaters and display. The ODS was powered up for docking at 084:01:54:49 G.m.t. (01:16:41:45 MET), and 34 seconds later the heater 2 display power-on indication came on and remained on for the remainder of the docking sequence until power was removed from the ODS.

The ODS avionics hardware performed nominally throughout initial contact, capture, damping, associated docking-ring drives, and structural-hooks closure with capture latch release. Capture was nominal and occurred at 084:02:34:02 G.m.t. (01:18:20:58 MET) and was followed by activation of the electromagnetic dampers (brakes) for 30 seconds. Data showed that the dampers remained on for 60 seconds even though the power was cut off by the automatic sequence at 30 seconds. This condition was unexpected, but is explained by the design of the clutch that activates the dampers. If any residual torque is acting on the dampers when damper power is removed, the high energy dampers may remain engaged. This condition was present during the docking with the Mir and was caused by high energy damper 3 remaining engaged because of the relative motion present at that time. The crew interrupted the automatic docking sequence by removing power 78 seconds after docking to allow further damping, and this in turn caused the Orbiter to develop increased post-capture rotation relative to the Mir (>7 deg). The ring-aligned signal came on even though a considerable angular misalignment still existed. Damping was completed after about 9 minutes and 19 seconds at which time the crew reinitiated the automatic docking sequence to drive the docking ring to the final position. The structural hooks were activated and were closed within 2.5 minutes. Docking was completed at 084:02:50:09.9 G.m.t. (01:18:37:05.9 MET). The ODS was powered down at 084:02:52:42 G.m.t. (01:18:39:38 MET).

The ODS performed satisfactorily during the undocking operations. The ODS was powered up for undocking with the Mir at 089:00:37:38 G.m.t. (06:16:24:34 MET), and the heater 2 power on indication remained on for the 39 minutes the ODS was powered for undocking. Undocking was completed at 089:01:08:03.4 G.m.t. (06:16:54:59.4 MET).

Integrated Aerodynamics, Heating and Thermal Interfaces

The prelaunch thermal interface purges were nominal.

The ascent and entry aerodynamics were nominal. There were no programmed test inputs for this flight.

The ascent aerodynamic and plume heating was nominal. Likewise, the entry aerodynamic heating to the SSME nozzles was nominal.

Thermal Control Subsystem

The thermal performance of the OV-104 vehicle thermal control subsystem (TCS) on this mission was nominal during all phases. All subsystem temperatures were maintained within acceptable limits. No heater failures or instrumentation anomalies were noted. The beta angle ranged from approximately -12.9 degrees at orbital insertion to +31.9 degrees at entry interface (EI). The orbital inclination was 51.6 degrees, and the orbital altitude ranged from 172 to 216 nautical miles during the mission.

During the on-orbit phase of the mission, thermal analyses were performed to evaluate changes to the planned attitude timeline (ATL). ATL changes resulted from, among other things, a one-day launch delay due to weather. Ten revisions to the planned ATL, including an early-return mission ATL, were assessed. Also considered were a 275-second duration vernier thruster firing during the docked phase and minimizing the operation of hydraulic circulation pump 3.

In the ATL versions, the OMS oxidizer high-point bleed line (HPBL) quick disconnect temperature was predicted to approach the +20 °F minimum limit during the nose-sun type attitudes as well as during the port-side sun attitudes. Also, during the first docked day attitude, a bending effect "anytime return" temperature limit was predicted to approach the upper (violation) limit. However, both concerns were affected by the Mir presence (shading and insulating effects). The OMS HPBL quick disconnect temperature remained well above the predicted level because of the one-day launch delay change to the Sun clock and the cone angles for the nose-sun type attitudes. The new Sun angle warmed the starboard sidewall structural temperature above the preflight prediction. The warm sidewall, coupled with the better-than-expected heater duty cycle resulted in HPBL quick disconnect temperatures well above the predicted level. Also, the Mir presence influenced the best estimate trajectory (BET) predicted temperatures by insulating the sill longerons from their view of space.

Aerothermodynamics

The Orbiter entry aerothermodynamics were as expected for the STS-76 mission. The acreage heating and local heating were nominal. The boundary layer transition was also nominal.

Thermal Protection Subsystem and Windows

The TPS performed satisfactorily. Based on structural temperature response data (temperature rise), the entry heating was above average for this vehicle. Structural temperature rises on the lower surface exceeded previous maximums for this vehicle in most cases. The largest exceedance was 5 degrees; however, all of the temperatures were well within the flight experience of the Orbiter fleet.

Boundary layer transition from laminar flow to turbulent flow was symmetric and occurred at 1170 seconds after entry interface at the aft centerline of the vehicle and within 10 seconds on the aft right-hand and left-hand sides of the vehicle. .
The postflight inspection of the TPS identified 69 damage sites (hits) of which 15 had a major dimension of 1 inch or greater. This total does not reflect the numerous hits on the base heat shield attributed to the flame arrestment sparkler system. A comparison of these numbers to statistics from 57 previous missions of similar configuration indicates that overall debris damage was below average, which is 90. Also the number of hits on the lower surface with a major dimension of one inch or greater was 5, which is below the average value of 14. The distribution of the hits on the Orbiter is shown in the following table.

TPS DAMAGE SITES

Orbiter Surfaces	Hits > 1 Inch	Total Hits
Lower Surface	5	32
Upper Surface	5	19
Right Side	2	8
Left Side	0	1
Right OMS Pod	1	3
Left OMS Pod	2	6
Total	15	69

The X-33 advanced TPS demonstrations flown on the upper body flap (FRCI-12/TUFI) tiles, base heat shield (AETB-8TUFI/RCG) tiles, and aft fuselage sidewall (TABI) blankets showed no signs of damage or degradation as a result of the flight.

Tile damage sites on the lower surface were generally located aft of the midpoint of the vehicle and approximately equally distributed about the vehicle centerline. A cluster of seven hits was noted forward of the main landing gear wells and slightly right of the vehicle centerline. The nose landing gear door (NLGD) thermal barriers were in good condition. A right-hand NLGD aft edge tile had a large damaged area on the lip

(2.5 inches by 0.5 inch), which will probably require replacement. The typical debris impact damage in the areas aft of the umbilical doors was not present after this flight. Damage in this area is generally attributed to impact by the umbilical purge barrier flapping against the tiles or impact by ET separation ice debris. Analysis of the STS-76 liftoff films showed that the purge barrier was torn away and released much earlier than usual, and this condition probably accounted for the lesser amount of damage observed. No lower surface damage was attributed to the wheels or tires.

The main landing gear door (MLGD) thermal barriers were in good condition. Two thermal-barrier outer-cover ends were protruding on the left-hand MLGD. The right-hand MLGD had two breached thermal barriers and four protruding outer cover ends. A tile on the right-hand elevon-elevon gap had minor edge slumping.

Tile damage on the base heat shield was normal. The engine dome-mounted heat shield (DMHS) closeout blankets were in good condition with the exception of torn and missing blanket material at the 6 to 8 o'clock position of SSME 1.

Three tile damage sites were found on the vertical tail stinger lower surface as well as a chipped tile edge immediately below the drag chute opening. Damage to these areas most likely occurred as a result of the drag chute deployment.

Light hazing was observed on windows 3 and 4 with streaks on windows 2, 3, and 4. Surface wipes were taken of all windows for laboratory analysis. Typical damage resulting from impacts by RCS paper cover/room temperature vulcanizing (RTV) material was observed on the perimeter tiles of windows 2, 3, 4, and 5.

MIR RENDEZVOUS OPERATIONS

The performance of the on-orbit rendezvous navigation and guidance for the fly-around and for the rendezvous was nominal, and there are no concerns under investigation.

MIR RENDEZVOUS

The Mir rendezvous operations were initiated at 082:11:55:29.8 G.m.t. (00:03:42:25.8 MET) when the OMS was used to perform the NC1 (OMS-3) Mir-rendezvous maneuver. This was a 42.8-second dual-engine, straight-feed firing. The ΔV was 69 ft/sec, and this placed the vehicle in a 159 by 123 nmi. orbit. The NC2 (OMS-4) Mir-rendezvous maneuver occurred at 082:23:49:04.2 G.m.t. (00:15:36:00.2 MET) using the right OMS engine configured for straight feed. The maneuver was 9.8 seconds in duration with a resulting ΔV of approximately 8 ft/sec, raising the orbit to 158.8 by 126.4 nmi. A 57.2-second dual-engine straight-feed NC3 (OMS-5) Mir-rendezvous maneuver occurred at 083:09:24:26.8 G.m.t. (01:01:11:22.8 MET) with a ΔV of 93 ft/sec and a resulting orbit of 210 by 127 nmi. OMS performance was nominal during all three of these maneuvers.

The NC4 (OMS-6) maneuver was performed in support of the Mir rendezvous. The dual-engine NC4 firing was executed at 083:22:16:37.6 G.m.t. (01:14:03:33.6 MET) and was 85.4 seconds in duration with a resultant ΔV of 141 ft/sec. The postfiring residuals were below the 0.20 ft/sec trim limit. The apogee and perigee were raised to 214 nmi and 203 nmi, respectively, and the closing rate with the Mir was decreased. Following the OMS-6 maneuver, a successful gimbal check was performed on both gimbal drives.

The left orbital maneuvering engine (OME) was used for the terminal phase initiation (TI) maneuver (OMS-7) at 083:23:51:38.2 G.m.t. (01:15:38:34.2 MET) that was executed using the onboard solution. The firing duration was 11 seconds and the resulting ΔV was 9.0 ft/sec.

The first rendezvous sensor pass used the star tracker for state vector updates. The pass lasted approximately 22 minutes, and 175 marks were incorporated with no marks rejected. The navigation-computed angular residuals (errors) never exceeded 0.3 deg and the ratios (error/maximum allowable error) also never exceeded 0.3. The Orbiter filter state vector was updated 875 ft and 1.1 ft/sec root sum square (RSS) by the end of the pass.

During the star tracker pass, the first onboard rendezvous guidance maneuver solution for the corrective combination (NCC) maneuver was computed. The final NCC maneuver solution was very close to the ground-computed maneuver solution. The onboard maneuver solution was performed with the RCS at the computed time of 083:22:53:56 G.m.t. (01:14:40:52 MET).

Following the NCC maneuver, the rendezvous navigation was configured for a rendezous radar (RR) pass. The Ku-band was configured for general purpose computer (GPC)-commanded, passive target-track of the Mir. Initial RR lock-on occurred at a range of approximately 140,000 ft and a closing range-rate of 83 ft/sec. After the RR was selected as the source for Orbiter state vector updates, the residuals and ratios were acceptable (both less than 0.1). During the RR pass, approximately 150 marks were accepted with none rejected. At the end of the pass, all of the ratios were less than 0.01 and the relative state vector was updated by approximately 1350 ft and 1.5 ft/sec.

After the transition back to major mode (MM) 201, the RR pass was reinitiated. The error in the relative state vector induced by the TI maneuver (RR more sensitive than IMUs) was removed after only a few marks. Shortly thereafter, a filter-to-propagated state vector transfer was performed to ensure that the back-up state vector was also updated.

Between the TI maneuver and Mir-intercept, the midcourse correction (MCC) maneuvers (one through four) were executed to correct dispersions in the relative trajectory and to ensure that the target was intercepted in daylight. All the MCC maneuvers are nominally zero and are usually less than 2.0 ft/sec. The onboard MCC 1 maneuver solution (< 1.0 ft/sec) was used as the basis to perform the RCS maneuver at 084:00:13:50 G.m.t. (01:16:00:46 MET).

The time of ignition (TIG) for the second MCC maneuver varies as a function of the elevation angle between the local horizontal of the Orbiter and the line-of-sight to the target at the TIG. The desired elevation angle of 28.09 degrees is used to ensure that the target is illuminated during proximity operations. The nominal variation between the planned and actual TIG is +7 to -3 minutes, and for this rendezvous the MCC 2 TIG slip was +4 minutes 35 seconds. The final onboard solution was used for the RCS maneuver at 084:00:45:49 G.m.t. (01:16:32:45 MET).

The last two MCC maneuver solutions (3 and 4) were nominal with differential velocities (ΔVs) of less than 0.5 ft/sec, and the maneuvers were performed 10 and 20 minutes after the TIG of the MCC 2 maneuver, respectively.

During the time period between the TI maneuver and reaching a range to the Mir of less than 100 ft, all RR range and range-rate navigation marks were accepted up to a separation distance of approximately 600 ft. As the range to the Mir decreased, the RR residuals and ratios became noisier, especially the angular residuals, and this lead to the RR angle marks being inhibited at 470 marks. The RCS thruster firings during proximity operations to establish braking gates, as well as the increasing angular size of the Mir (beam wander), contributed to the noisy RR data.

The final rendezvous was completed nominally with radius vector axis (R-bar) crossing occurring at approximately 084:01:10 G.m.t. (01:17:35 MET) with docking occurring approximately 50 minutes later.

MIR FLY-AROUND ACTIVITIES

Following the successful undocking and at a range of approximately two feet, a small +Z separation firing was performed to initiate the separation. After the range became greater than 100 ft, rendezvous navigation and system management (SM) antenna software were configured for RR target track. Automatic navigation mark incorporation was enabled after the RR acquired the Mir with the first mark being incorporated at a range of 190 ft. The initial sensor residuals were small, and this indicated a solid RR lock-on to the Mir.

After the range to the Mir reached 475 ft, a tail-forward attitude for the fly-around, which would be conducted at twice the orbital rate, was established.

Prior to the minus velocity vector axis (-Vbar) crossing and after 91 RR navigation marks had been incorporated, 11 angular (azimuth) marks were rejected in succession. The azimuth error showed a dramatic increase from approximately 1.0 degree to 7.0 degrees. The range and range rate data were good, but the angular data error had increased at a time when the covariance matrix was converged. It is currently theorized that the size of the Mir and the changing aspect angle to the Mir caused the rejected marks. Once the covariance matrix was reinitialized by the crew, the azimuth angle mark incorporation began again automatically. Reinitializing the covariance matrix loosened the edit criterion and allowed uninterrupted navigation mark incorporation for the next 10 minutes (75 more marks) with no further rejects.

The fly-around was discontinued by performing the final separation maneuver at the R-bar crossing. The separation maneuver was a 3.0 ft/sec retrograde firing, performed manually with the RCS thrusters. The rendezvous navigation was disabled shortly afterwards.

EXTRAVEHICULAR ACTIVITY

The first EVA while docked with the Mir Space Station was satisfactorily performed during the STS-76 mission and had a duration of 6 hours and 2 minutes. All objectives of the EVA were accomplished and the EVA required only 30 minutes longer than planned. The average metabolic rates for this EVA were calculated from primary oxygen usage and were 705 Btu/hr for the EV 1 crewmember (Godwin) and 755 Btu/hr for the EV2 crewmember (Clifford). The EMUs performed well during the EVA with only one in-flight anomaly.

Extravehicular mobility unit (EMU) checkout began at approximately 083:05:13 G.m.t. (00:21:00 MET). Both EMUs performed nominally during the checkout and were ready to support the EVA on flight day six. The EMUs had several thermal conditioning improvements to ensure crew comfort in the unique Shuttle/Mir environment. The improvements included the capability to shut off the cooling water in case the EV crewmember became too cool, battery-powered electric heaters for the finger-tips, and other thermal clothing.

During EMU donning, no biomedical data were received from the EV2 crewmember (Flight Problem STS-76-F-03). The problem was suspected to be in the biomedical signal conditioner. The conditioner was replaced with the biomedical signal conditioner from the medical kit. Since the medical kit unit was not calibrated for the EV2 crewmember, the signal amplitude was off-scale resulting in an inability to compile and analyze trends in the data. At 087:10:21 G.m.t. (05:02:08 MET), during the EVA, EV2 experienced a loss of the electrocardiogram (ECG) signal; however, the signal was regained 12 minutes later. The signal was lost again at 087:12:19 G.m.t. (05:04:06 MET), just prior to airlock ingress, and the signal was intermittent for the remainder of the EVA.

In preparation for the planned EVA, depressurization of the Orbiter docking system (ODS) vestibule was performed at 086:11:45 G.m.t. (04:03:32 MET). Depressurization of the cabin to 10.4 psia was subsequently completed at 086:12:40 G.m.t. (04:04:27 MET). The airlock depressurization was initiated at 87:06:15 G.m.t. (04:22:02 MET). The EVA was initiated at 087:06:36 G.m.t. (04:22:23 MET). The cabin was repressurized to 14.7 psia at 87:07:10 G.m.t. (04:22:57 MET).

The EVA tasks consisted of installing four Mir Environmental Effects Payload (MEEP) clamps on the Mir docking module, removal and return of a docking camera, and transfer of four MEEP experiments from their stowage location in the payload bay to mounting points on the Mir docking module. Additional objectives included performing an evaluation of the universal foot restraint, a multi-use tether, a rigid tether, common waist tethers, and 55-foot tethers. All of these items were designed to interface with the Russian ORLAN space suit as well as the U. S. EMU.

The crew noted a white paint residue on the EMU gloves after translating on the Mir docking module handrails. The crew also reported that the bayonet fitting was not properly oriented, preventing stowage of the large cable cutter on the modified mini-workstation along with the MEEP clamps.

The universal foot restraint (UFR) performed satisfactorily, although some minor problems with the toe bar were reported. One crewmember experienced unintentional egress from the UFR on two occasions. The toe bar setting was a compromise to accommodate both shoe types for this flight, so the unintentional egress was not unexpected.

The common safety tethers performed nominally. Likewise, the common waist tethers with improved hooks also performed satisfactorily. The common waist tethers were used in a simulated Mir translation activity using the Russian hand-over-hand method, which was described as a slow method of translation because of the high number of hook install/remove cycles.

Both crewmembers used the multi-use tether (MUT) and the rigid tether (RT), and good stability was provided while using these tethers.

Following the flight, an inspection of the EMU revealed cuts in the EMU gloves that were to the depth of the pressure layer. An investigation board was organized to determine the cause of these cuts and to prescribe the corrective action to prevent the cuts in the future.

FLIGHT CREW EQUIPMENT/GOVERNMENT FURNISHED EQUIPMENT

The Government furnished equipment/flight crew equipment (GFE/FCE) performed nominally.

The crew reported that a camcorder in the Spacehab had experienced a cassette eject failure. An in-flight maintenance (IFM) procedure to clear the tape from the camcorder was available, but this camcorder was not required. There were four additional camcorders onboard available for use, two of which were scheduled to remain on Mir.

The crew was unable to locate a camera bayonet bracket that was to be used during EVA. It was determined that this hardware had been inadvertently omitted from the hardware shipment to KSC for stowage in the Spacehab module. A workaround was developed that enabled the camera to be used for the EVA operations.

CARGO INTEGRATION

The cargo integration hardware performance was nominal throughout the mission. No in-flight anomalies were identified.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DEVELOPMENT TEST OBJECTIVES

DTO 310D -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 MADS recorder postflight and were given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DTO 307D - Entry Structural Capability - The DTO is data-only, with the data being recorded on the MADS recorder, which is not dumped during the flight. The data were dumped postflight 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) (No maneuvers) - No hand-held photography of the ET was obtained because of equipment difficulty. No +X translation maneuver was performed.

Two rolls of umbilical well camera 16 mm film (5 mm and 10 mm lens) were obtained from the LH_2 umbilical. Good coverage of the left-hand SRB separation was acquired. The views of the ET separation were unusable because of the night-time conditions. Numerous light colored pieces of debris (probably insulation) and dark debris (probably charred insulation) were seen throughout the SRB film sequence. Typical ablation and charring of the LH_2 umbilical electrical cable tray and the -Y ET/SRB vertical strut was also seen. These events are typical of those seen on previous mission umbilical well film and are not considered anomalous.

The 16 mm film has good to dark exposure and good focus. Timing data were not present on the 16 mm films.

DTO 648 - Electronic Still Camera Test, (Configuration 2), Color ESC-II With Downlink - Photographs were made of the joint docked operations and downlinked in real time. The quality of the downlinked images was excellent.

DTO 671 - EVA Hardware for Future Scheduled EVA Missions (Test 12) - The common foot restraint, common safety tethers, body/equipment tethers and thermal comfort in the docked Mir environment were evaluated during the flight day 6 EVA, which deployed the MEEPs and recovered the Docking Module (DM) camera and light as well as evaluating the various pieces of EVA hardware. The crew comments on the EVA hardware are found in the Extravehicular Activity Section of this report.

DTO 700-5 - Trajectory Control Sensors (Sensors Mounted on ODS, Pulse Mode Test only) - The trajectory control sensors (TCSs) were used extensively during the rendezvous and were a valuable source of data for the rendezvous operations. The evaluation of the TCS operations was completed and the publication of the results will be in separate documentation.

DTO 700-10 - Orbiter Space Vision System Video Taping - The docking module target and Mir configuration data were recorded for postflight model development in support of future Orbiter Space Vision System flight software.

DTO 700-13 - Signal Attenuation Effects of ET During Ascent - Data were collected for this DTO during ascent. These data have been given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

DTO 805 - Crosswind Landing Performance - Weather conditions on landing day were not conducive to performing this DTO.

DTO 1118 - Photographic and Video Survey of Mir Space Station - All photographic surveys of the Mir during rendezvous and separation were completed. Other photographic surveys were also accomplished during docking from both the Shuttle middeck and the Spacehab. Additional photographs of the Kvant Russian EVA location were requested by the Russians and were accomplished.

DTO 1210 - EVA Operations Procedures/Training - This DTO was completed in its entirety with the completion of the postflight weightless Environment Training Facility (WETF) session that corresponded to the length of the EVA. The evaluation of this EVA will be published in a separate report.

DETAILED SUPPLEMENTARY OBJECTIVES

DSO 331 - LES and Sustained Weightlessness on Egress Locomotion - Data were recorded during entry and continued to be taken postflight with a treadmill session. The data were given to the sponsor for evaluation. The results of that evaluation will be reported in separate documentation.

DSO 483 - Back Pain Pattern in Microgravity - Data were recorded in-flight and were also recorded from a postflight back exam and debriefing. These data were given to the sponsor for evaluation, and the results of the evaluation will be reported in separate documentation.

DSO 487 - Immunological Assessment of Crewmembers - Data were collected for this DSO during the preflight and postflight assessments of the crewmembers. These data were given to the sponsor for evaluation, and the results of the evaluation will be reported in separate documentation.

DSO 489 - EVA Dosimetry Evaluation - Data for this DSO were recorded during the EVA, and these data have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DSO 901 - Documentary Television - Video data were recorded of significant events throughout the flight.
DSO 902 - Documentary Motion Picture Photography - Motion pictures were taken of the significant events that occurred during the flight.

DSO 903 - Documentary Still Photography - Still photographs were taken of the significant events that occurred during the flight.

PHOTOGRAPHY AND TELEVISION ANALYSES

LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSES

Twenty four videos of the launch were screened and no anomalies or significant items were noted. In addition, eighteen 35 mm films and twenty-four 16 mm films were screened. The only significant item noted was a bolt hang-up on left-hand SRB hold-down post M-5 at liftoff. Slight holddown post shoe movement was also visible prior to bolt release.

ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSES

No requests for screening of onboard photography or video were made of the JSC team.

LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSES

Six videos of the landing were screened. The only significant item was that the main landing gear door opening and gear deployment did not occur synchronously. The starboard main gear door opened 0.333 second after the port side main gear door. No other significant conditions were noted.

TABLE I.- STS-76 MISSION 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	082:08:08:14.726 082:08:08:16.296 082:08:08:17.691
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	082:08:12:36.129 082:08:12:36.289 082:08:12.36.449 082:08:12:36.609
Main Propulsion System Start[a]	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	082:08:12:57.439 082:08:12:57.582 082:08:12:57.664
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	082:08:13:03.999
Throttle up to 104 Percent Thrust[a]	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	082:08:13:08.064 082:08:13:08.064 082:08:13:08.102
Throttle down to 67 Percent Thrust[a]	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	082:08:13:34.304 082:08:13:34.305 082:08:13:34.343
Maximum Dynamic Pressure (q)	Derived ascent dynamic pressure	082:08:13:55.7
Throttle up to 104 Percent[a]	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	082:08:14:04.865 082:08:14:04.865 082:08:14:04.903
Both SRM's Chamber Pressure at 50 psi[a]	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	082:08:15:04.799 082:08:15:04:839
End SRM [a] Action[a]	LH SRM chamber pressure mid-range select RH SRM chamber pressure mid-range select	082:08:15:07.609 082:08:15:07.689
SRB Physical Separation[a]	LH rate APU turbine speed - LOS RH rate APU turbine speed - LOS	082:08:15:09.879 082:08:15:09.879
SRB Separation Command	SRB separation command flag	082:08:15:10
Throttle Down for 3g Acceleration[a]	ME-3 command accepted ME-1 command accepted ME-2 command accepted	082:08:20:32.674 082:08:20:32.709 082:08:20:32.747
3g Acceleration	Total load factor	082:08:20:36 5
Throttle Down to 67 Percent Thrust[a]	ME-3 command accepted ME-1 command accepted ME-2 command accepted	082:08:21:30.595 082:08:21:30.630 082:08:21:30.667
SSME Shutdown[a]	ME-3 command accepted ME-1 command accepted ME-2 command accepted	082:08:21:36.555 082:08:21:36.590 082:08:21:36.627
MECO	MECO command flag MECO confirm flag	082:08:21:36.8 082:08:21:37.3
ET Separation	ET separation command flag	082:08:21:56

[a]MSFC supplied data

TABLE I.- STS-76 MISSION EVENTS
(Continued)

Event	Description	Actual time, G.m.t.
APU Deactivation	APU-1 GG chamber pressure APU 2 GG chamber pressure APU 3 GG chamber pressure	082:08:34:05.980 082:08:34:16.334 082:08:38:26.269
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	082:08:55:26.0 082:08:55:26.0
OMS-2 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	082:08:56:13.8 082:08:56:13.8
Payload Bay Doors (PLBDs) Open	PLBD right open 1 PLBD left open 1	082:09:46:50 082:09:48:09
Radiator Deployment	Port radiator deployment 1	082:10:42:42
OMS-3 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	082:11:55:29.8 082:11:55:29.9
OMS-3 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	082:11:56:12.6 082:11:56:12.6
Radiator Latch	Port radiator latch no.7-12 latch 2	083:23:14:04
OMS-4 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	N/A 082:23:49:04.2
OMS-4 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	N/A 082:23:49:14:0
OMS-5 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	083:09:24:26.8 083:09:24:26.9
OMS-5 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	083:09:25:24.0 083:09:25:24.0
OMS-6 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	083:22:16:37.6 083:22:16:37.6
OMS-6 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	083:22:18:03.0 083:22:18:03.1
OMS-7 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	083:23:51:38.2 N/A
OMS-7 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	083:23:51:49.2 N/A
Docking Complete	Docking ring final position	084:02:50:09.9
Extravehicular Activity Start	EMU battery power on	087:06:34
Extravehicular Activity Stop	Initiation of airlock repressurization	087:12:36
Initiation of Undocking	Actuation of hooks no. 1 drive	089:01:05:46.1
Undocking complete	Undock complete	089:01:08:03.4
Flight Control System Checkout APU Start APU Stop	 APU-1 GG chamber pressure APU-1 GG chamber pressure	 N/A N/A
Flight Control System Checkout Circulation Pump Start Circulation Pump Stop	 Hyd. Sys. 1 Circ. Pump Pressure Hyd. Sys. 1 Circ. Pump Pressure	 089:04:53:29.3 089:05:02:53.3
Payload Bay Doors Close 1	PLBD left close 1 PLBD right close 1	090:09:06:48 090:09:08:57

TABLE I.- STS-75 MISSION EVENTS (Concluded)

Event	Description	Actual time, G.m.t.
Payload Bay Doors Reopen	PLBD right open 1 PLBD left open 1	090:14:34:41 090:14:37:47
Payload Bay Doors Close 2	PLBD left close 1 PLBD right close 1	091:08:07:53 091:08:09:31
APU Activation for Entry	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	091:12:18:16.687 091:12:44:45.681 091:13:22:47.346
Deorbit Burn Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	091:12:23:08.1 091:12:23:08.2
Deorbit Burn Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	091:12:26:28.4 091:12:26:28.5
Entry Interface (400K feet)	Current orbital altitude above	091:12:57:33.3
Blackout end	Data locked (high sample rate)	No blackout
Terminal Area Energy Mgmt.	Major mode change (305)	091:13:22:46.9
Main Landing Gear Contact	LH main landing gear tire pressure 1 RH main landing gear tire pressure 2	091:13:28:56.7 091:13:28:56.7
Main Landing Gear Weight on Wheels	RH main landing gear weight on wheels LH main landing gear weight on wheels	091:13:28:56.8 091:13:28:56.8
Drag Chute Deployment	Drag chute deploy 1 CP Volts	091:13:29:00.4
Nose Landing Gear Weight on Wheels	NLG no weight on wheels	091:13:29:07.8
Nose Landing Gear Contact	NLG 1 RH tire pressure 1	091:13:29:08.4
Drag Chute Jettison	Drag chute jettison 1 CP Volts	091:13:29:31.4
Wheel Stop	Velocity with respect to runway	091:13:29:52.0
APU Deactivation	APU-3 GG chamber pressure APU-1 GG chamber pressure APU-2 GG chamber pressure	091:13:30:26.157 091:13:44:12.321 091:13:44:19.806

TABLE II.- ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-76-V-01	Hydraulic System 3 External Leak	82:08:08 00 G.m.t. Prelaunch CAR 76RF01 IPR 79V-0004	Hydraulic system 3 experienced an external leak of hydraulic fluid throughout the ascent run. The leak rate was approximately 1 percent/minute, and a total of 20 percent of the hydraulic fluid in system 3 was lost. The SSME thrust vector control (TVC) isolation valve was closed in an unsuccessful attempt to isolate the leak. The APU was taken to low pressure and the leak rate decreased significantly. Hydraulic system 3 fluid level remained steady after APU shutdown, and system 3 circulation pump runs did not affect the system 3 reservoir quantity. The management of the APU/hydraulic systems during FCS checkout and entry was established. APU 2 was started prior to the deorbit maneuver, and APU 1 was started at EI -13 minutes. Systems 1 and 2 were taken to normal pressure at EI -6 minutes and to high speed for the period from TAEM to wheels stop. APU 3 was started at TAEM and remained in low pressure throughout entry because it was not needed, and APU 3 was shut down at wheels stop. Prior to starting APU 3 at TAEM, the hydraulic system 3 quantity had increased from 41.6 percent to 44 percent at landing, and this indicates that the leak was minimized by leaving the APU in low pressure. At wheels stop, APUs 1 and 2 were taken back to normal speed. All weather placards for the loss of a single APU were observed. KSC: Hydraulic fluid was found in the aft compartment. The highest amount of mist was found in the rear portion of the right-hand side towards the top of the aft compartment. Some puddling of fluid was noted along the center floor area aft of avionics bay 6. The total quantity aspirated is small, about a quart or less. The fluid splattered as a mist around the inside of vent door 8 and 9 on the left-hand side. No data were taken on the right-hand side. External inspections found signs of hydraulic fluid in a film form around the SSME 1 and 3 dome-mounted heat shields. The heaviest concentration was on SSME 3 between the 8 and 12 o'clock position. None of the vent doors on either side of the vehicle showed any signs of hydraulic fluid. No leaks were found in the return pressure line. The hydraulic system supply was attached to the flex hose, and at 950 psi system pressure a leak was discovered at the flex-hose to elbow joint. The B nut was subjected to 95 ft/lb with no movement. An X-ray of the joint was taken, and the hose/elbow assembly was removed and sent to Rockwell-Downey for failure analysis. Initial observations of the X-rays found indications of misalignment. The assembly had a blowing leak at 600 psia, and when the assembly

TABLE II.- ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
			was dismantled the mating surfaces had crescent-shaped deformations. KSC installed a new hose, which will be leak checked at 3000 psi. Also, a request is in work to hot-fire the APU at the pad.
STS-76-V-02	RCS Primary Thruster L2L Failed Leak	089:06:11 G.m.t. 06:21:58 MET CAR 76RF05 PR LP03-0508	During the RCS hot-fire, RM software declared primary RCS thruster L2L failed-leak on the second firing of the thruster when the oxidizer injector temperature dropped below the 30 °F leak detect limit. The thruster had fired twice during the hot-fire procedure with nominal results. The leak was visually confirmed by the crew. Left RCS manifold 2 was isolated. KSC: Remove and replace the thruster.
STS-76-V-03	Primary RCS Thruster L2U Failed OFF	089:06:08 G.m.t. 06:21:55 MET CAR 76RF06 IPR LP03-0509	During the RCS hot-fire, RM deselected RCS primary thruster L2U as failed off due to low chamber pressure (Pc). The maximum Pc achieved on the firing was 13 psia, whereas nominal Pc is 150 psia. This was the first attempted firing of this thruster on this flight. Oxidizer and fuel injector temperatures dropped due to evaporative cooling, indicating at least partial flow. Subsequent injector temperature response indicated none of the heat soak back normally associated with nominal combustion. KSC: The thruster will be removed and replaced during replacement of thruster L2D/L2L on the same manifold.
STS-76-V-04	Primary RCS Thruster R4R Failed Off	089:06:31 G.m.t. 06:22:18 MET CAR 76RF07 IPR RP04-0526	During the RCS hot-fire, RM software declared primary RCS thruster R4R failed off due to low chamber pressure. The maximum Pc achieved on this firing was 10 psia, whereas normal Pc is 150 psia. This was the first attempted firing of this thruster this flight. Oxidizer and fuel injector temperatures dropped due to evaporative cooling, indicating at least partial flow. Subsequent injector temperature response indicated none of the heat soak back normally associated with nominal combustion. KSC: Plans are to replace thruster R4R and R4D/R4U on the same manifold.
STS-76-V-05	WSB 3 Undercool	082:08:21 G.m.t. 00:00:08 MET CAR 76RF03 PR Hyd-0687	The water spray boiler (WSB) for APU/hydraulic system 3 experienced an under-cooling condition during ascent. When the APU lubrication oil reached 307 °F, WSB 3 controller B was selected. The WSB should control the APU lubrication oil temperature at approximately 250 °F. Thirty-one seconds after selecting the B controller, cooling was observed. After an expected over-cooling condition at 243 °F, the lubrication oil achieved a steady-state temperature of 255 °F. The signature was similar to that seen when there is a freeze-up of the WSB lubrication oil spray bar.

TABLE II.- ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
			KSC: Controller A will be removed and replaced. An acceptance test procedure (ATP) will be performed on the controller. The vendor is shipping a replacement controller.
STS-76-V-06	WSB 2 Overcools (No Ferry Impact)	082:08:28 G.m.t. 00:00:15 MET CAR 76RF04 IPR 79V-0018	The WSB for APU hydraulic system 2 experienced two over-cooling conditions during ascent while operating on the A controller. In the initial over-cooling condition, the APU 2 lubrication oil temperature dropped to 195 °F before recovering to nominal temperatures at approximately 250 °F. The APU was shut down during the second over-cooling condition (over-cooling was not the cause of the shut down). At the time of APU 2 shut down, the lubrication oil temperature was 193 °F. The over-cooling condition did not impact APU or hydraulic system operations. KSC/Palmdale: WSB over-cooling testing was scheduled for mid-April at Palmdale. The test results will determine the corrective act ion to be taken on the controller.
STS-76-V-07	WSB 3 Vent Heater Dropout On B Controller	091:11:00 G.m.t. 09:02:47 MET CAR 76RF09 IPR 79V-0017	At 091:11:00 G.m.t. (09:02:47 MET) just prior to the deorbit maneuver, the WSB 3 vent temperature number 2 went off scale low (122 °F). Nominally, the heater should have cycled on at approximately 145 °F. The system was operating on the B controller at the time, and this signature indicated that the B heater had failed off. The system was switched to the WSB 3A controller at 091:11:16 G.m.t. (09:03:03 MET), and a rise in vent temperature was observed a short time later. To better characterize the problem, after about 30 minutes and a nominal heater cycle on the A controller, the system was switched back to the B controller. Nominal cycling of the B vent heater was observed for the remainder of the flight. KSC: Troubleshooting will be performed on the B controller and heater string.

TABLE III.- GOVERNMENT FURNISHED EQUIPMENT PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-76-F-01	Camcorder Tape Eject Failure	086:13:18 G.m.t. 04:05:05 MET	The crew reported that the tape cassette in one of the camcorders was jammed and could not be ejected. An IFM procedure for removal of the tape cassette was available; however, there are other camcorders available onboard. There are five camcorders onboard, two of which will be left with the Mir-21 crew. The crew fixed the jam in-flight, shortly after the stuck condition was reported. The IFM was not required for the most part. The tape cover/door on the cassette was stuck open. The crewmember that performed the fix didn't think it was a camera mechanism problem.
STS-76-F-02	Inorperable Mineral Injection Syringe	085:02:59 G.m.t. 02:18:46 MET	During the filling of the seventh water transfer CWC, the crew experienced problems with the operation of the syringe used for mineral injection. They were able to inject the minerals; however, during the second flush of the syringe, they were unable to apply enough force to push the plunger down and re-inject water back into the CWC. The mineral syringe was removed from the injection port and a silver biocide syringe was used successfully. During a subsequent CWC fill, a spare mineral syringe was used successfully. The problem appears to be isolated to the mineral syringe used during the seventh CWC fill. The syringe that was inoperable was labeled for evaluation postflight.
STS-76-F-03	Loss of ECG Signal on EV2	087:02:43 G.m.t. 04:18:30 MET	During EMU suit donning, no biomedical data were received from EV2. The problem was suspected to be the biomedical signal conditioner. The conditioner was replaced with the signal conditioner from the medical kit. Since the medical kit unit was not calibrated for the EV2 crewmember (as was the original signal conditioner), the signal amplitude was off-scale resulting in the inability to compile or analyze trends in the data. At 087:10:21 G.m.t. (05:02:08 MET), during the EVA, EV2 experienced a loss of ECG signal downlink. The signal was regained 12 minutes later. The signal was lost again at 087:12:19 G.m.t.(05:04:06 MET), just prior to airlock ingress and was intermittent for the rest of the EVA.

TABLE IV.- MSFC PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-76-E-01	Main Engine 2 Fuel Preburner Channel A Igniter Did Not Indicate ON at Engine Start	T-6 seconds	During the postflight data review, it was noted that the Main Engine (ME) -2 Fuel Preburner (FPB) channel A igniter did not indicate ON at engine start. This is the first known occurrence in the SSME program of an igniter failing to indicate ON at engine start, and the condition is considered a Crit 3 failure. The channel B igniter did energize and the engine started normally. There are two igniters located in each preburner and in the main combustion chamber (six per total engine) for redundancy. The worst case failure of both igniters failing to spark at engine start would be in the fuel preburner chamber, and this is a Crit 1 condition. If this were to occur, the engine would safely shut down on the pad due to a high pressure fuel pump minimum speed violation (4500 rpm minimum required from 1.24 to 1.28 seconds). The single igniter mean time before failure (MTBF) is 3856 hot-fire tests with a 90 percent confidence. The dual failure vehicle MTBF is greater than 1,000,000 flights with a 90 percent confidence. The failure could be located in the igniter, harness or controller.

<u>DOCUMENT SOURCES</u>

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 Quick Look Report
7. MER Problem Tracking List
8. MER Event Times
9. Subsystem Manager Reports/Inputs
10. MOD Systems Anomaly List
11. MSFC Flash Report
12. MSFC Event Times
13. MSFC Interim Report
14. Crew Debriefing comments
15. 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)
APU	auxiliary power unit
ARPCS	atmospheric revitalization pressure control system
ATL	attitude timeline
BET	best estimate trajectory
BFS	backup flight system
Btu/hr	British thermal unit per hour
CRIM	commercial refrigerator incubator module
CWC	contingency water container
DAP	digital autopilot
dBm	decibel per meter
DM	Docking Module
DMHS	dome-mounted heat shield
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
ΔV	differential velocity
EAFB	Edwards Air Force Base
ECG	electrocardiogram
ECLSS	Environmental Control and Life Support System
EI	entry interface
EMU	extravehicular mobility unit
EPDC	electrical power distribution and control subsystem
ESA	European Space Agency
ESC	electronic still camera
ET	External Tank
EVA	extravehicular activity
FCE	flight crew equipment
FCP	fuel cell powerplant
FCS	flight control system
FCV	flow control valve
ft/sec	feet per second
g	gravity
GAS	Get Away Special
GFE	Government furnished equipment
GH_2	gaseous helium
Ghz	gigahertz
G.m.t.	Greenwich mean time
GPC	general purpose computer
HPBL	high-point bleed line
HPFTP	high pressure fuel turbopump
HPOTP	high pressure oxidizer turbopump
IESL	individual equipment and seat liner
IFA	in-flight anomaly

IFM	in-flight maintenance
I/O	input/output device
Isp	specific impulse
ISSA	International Space Station Alpha
JSC	Johnson Space Center
KCA	Ku-band communication adapter
KIDSAT	Middle school student participation experiment
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt/hour
lbm	pound mass
LCC	Launch Commit Criteria
LES	launch/entry suit
LH_2	liquid hydrogen
LMES	Lockheed Martin Engineering and Science
LO_2	liquid oxygen
LPS	Liquid Phase Sintering
LSLE	Life Science Laboratory Equipment Refrigerator/Freezer
MADS	modular auxiliary data system
MCC	midcourse correction maneuvers
MECO	main engine cutoff
MEEP	Mir Environmental Effects Payload
MEFC	Mir Electric Field Characterization
MET	mission elapsed time
MGBX	middeck glovebox
Mhz	megahertz
MM	major mode
MMT	Mission Management Team
MPS	main propulsion system
MTU	master timing unit
MUT	multi-use tether
NASA	National Aeronautics and Space Administration
NC1-4	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)
ODS	Orbiter docking system
OI	operational instrumentation
OME	orbital maneuvering engine
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OPS	operations
ORLAN	Russian space suit
PAL	protuberance air load
PASS	primary avionics software system
Pc	chamber pressure
PCTU	passive thermal control unit
PGSC	payload general support computer

PLB	payload bay
PMBT	propellant mean bulk temperature
ppm	parts per million
PPO_2	partial pressure oxygen
PRSD	power reactant storage and distribution
psia	pound per square inch absolute
psid	pound per square inch differential
QUELD	Queen's University Experiment in Liquid Diffusion
Rbar	radius vector axis
RCS	reaction control subsystem
RFI	radio frequency interference
RM	Redundancy Management
RME	Risk Mitigation Experiment
RR	rendezvous radar
RSB	rudder speedbrake
RSRM	Reusable Solid Rocket Motor
RSS	Range Safety System/room sum square
RT	rigid tether
RTV	room temperature vulcanizing (material)
S&A	safe and arm
SAREX	Shuttle Amateur Radio Experiment
SDS	smoke detection system
SLF	Shuttle Landing Facility
SM	systems management
S/N	serial number
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSME	Space Shuttle main engine
STS	Space Transportation System
TAEM	terminal area energy management
TCS	thermal control subsystem/trajectory control sensors
TDRS	Tracking and Data Relay Satellite
TI	terminal phase initiation
TIG	time of ignition
TPS	thermal protection system/subsystem
TRIS	Trapped Ions in Space Environment
TVC	thrust vector control
UFR	universal foot restraint
U. S.	United States
-Vbar	minus velocity vector axis
VHF	very high frequency
WETF	Weightless Environment Training Facility
WSB	water spray boiler