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STS-81 SPACE SHUTTLE MISSION REPORT

March 1997

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

NOTE

The STS-81 Space Shuttle Mission Report was prepared from inputs received from the Space Shuttle Operations Engineering Office as well as other organizations. The following personnel may be contacted should questions arise concerning the technical content of this document.

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SPACE SHUTTLE

MISSION REPORT

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INTRODUCTION

STS-81 was the fifth of nine planned missions to dock with the Russian Mir Space Station and the fourth crewmember transfer mission. Astronaut John Blaha, who was on the Mir since September 19, 1996, was replaced by Astronaut Jerry Linenger. The double Spacehab module was carried for the second time, and it housed experiments that were performed by the crew and logistics equipment (in excess of 6,000 lb) that was transferred to the Mir. After transfer of equipment to the Mir, space was provided for return items from the Mir.

The STS-81 Space Shuttle Program Mission Report summarizes the activities such as rendezvous and docking and experiment operations. This report also discusses the Orbiter, External Tank (ET), Solid Rocket Booster (SRB), Reusable Solid Rocket Motor (RSRM), and the Space Shuttle main engine (SSME) performance during this eighty-first mission of the Space Shuttle Program. STS-81 was the fifty-sixth flight since the return to flight and the eighteenth flight of the Atlantis (OV-104). In addition to the Orbiter, the flight vehicle consisted of an ET that was designated ET-83; three Phase II SSMEs that were designated as serial numbers 2041, 2034, and 2042 in positions 1, 2, and 3, respectively; and two SRBs that were designated BI-082. The two RSRMs were designated RSRM-54 with one installed in each SRB. The individual RSRMs were designated as 360T054A for the left SRB, and 360T054B for the right SRB.

The STS-81 Space Shuttle Program Mission Report fulfills the Space Shuttle Program requirement as documented in NSTS 07700, Volume VII, Appendix E. The requirement is that each organizational element supporting the Program will report the results of their hardware and software evaluation and mission performance plus identify all related in-flight anomalies.

The primary objectives of this flight were to perform the fifth rendezvous and docking with the Russian Mir Space Station and perform a logistics resupply and the exchange of a Mir Astronaut. A double Spacehab module carried science experiments and hardware (including the Biorack facility consisting of two incubators, a glovebox, and two refrigerators as well as a refrigerator/freezer), the Space Acceleration Measurements System (SAMS), Risk Mitigation Experiments (RMEs) and Russian logistics in support of the Phase 1 Program requirements.

The secondary objectives of this flight included the performance of the KidSat Payload activities, and the Cosmic Radiation Effects and Activation Monitor (CREAM) activities; and, as a payload of opportunity when the objectives could be met without impacting the flight, the performance of the Midcourse Space Experiment (MSX).

The STS-81 flight was planned as a 10-day plus 2-contingency-day flight. The two contingency days were available for bad weather avoidance for landing or other Orbiter contingency operations. The sequence of events for the STS-81 mission are shown in Table I, and the Orbiter In-Flight Anomaly List is shown in Table II. The Government Furnished equipment/flight crew equipment (GFE/FCE) Problem Tracking List is shown in Table III.

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

The seven-person crew for STS-81 consisted of eight persons because of the crewmember exchange that occurred. The crewmembers were Michael A. Baker, Capt., U.S. Navy, Commander; Brent Jett, CDR, U.S. Navy, Pilot; Peter J. K. Wisoff, Civilian, Ph.D., Mission Specialist 1; John M. Grunsfeld, Civilian, Ph.D., Mission Specialist 2; Marsha S. Ivins, Civilian, Mission Specialist 3; and Jerry Linenger, Capt. Medical Corps, U.S. Navy, Mission Specialist 4 (Ascent) and John E. Blaha, Col. USAF Retired, Mission Specialist 4 (Descent). STS-81 was the sixth flight for Mission Specialist 4 (Descent), the fourth flight for the Commander and Mission Specialist 3, the third flight for the Mission Specialist 1, and the second flight for the Pilot, Mission Specialist 2, and Mission Specialist 4 (Ascent).

MISSION SUMMARY

Liftoff of the STS-81 flight occurred on-time at 12:09:27:22.984 G.m.t. (4:27:23 a.m. e.s.t. on January 12, 1997) following a countdown with no unscheduled holds. The ascent trajectory was nominal, and no orbital maneuvering subsystem (OMS) 1 maneuver was required. An evaluation of vehicle performance during ascent was made using vehicle acceleration and preflight propulsion prediction data. From these data, the average flight-derived engine specific impulse (I_{sp}) determined for the time period between SRB separation and start of 3-g throttling was 453.59 seconds as compared to the Main Propulsion System(MPS) tag value of 453.18 seconds.

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

The OMS 2 maneuver was initiated at 12:10:10:23.8 G.m.t. [00:00:43:00.9 mission elapsed time (MET)]. The maneuver was 47 seconds in duration and a differential velocity (ΔV) of 75.5 ft/sec was imparted to the vehicle.

The payload bay doors were fully open at 12:11:06:53 G.m.t. (00:01:39:26 MET). The door opening was nominal and performed in dual-motor time.

The crew reported that the aft-port latch on the lithium hydroxide (LiOH) stowage door was difficult to open (Flight Problem STS-81-V-01). They were unable to open the latch by hand and a tool was used. The plan was to leave this latch open until entry day. A loads analysis was performed and it showed that the LiOH door with the recumbent seat installed could withstand a 20g crash load with the aft-port latch open.

Fifteen contingency water containers (CWCs) were evacuated in preparation for transfer of water to the Mir. The procedure was begun at 013:02:03 G.m.t. (00:16:35 MET) and completed at 013:03:27 G.m.t. (00:17:59 MET). This procedure was utilized on STS-81 as a result of reports that gas was in the CWCs filled during STS-79.

The rendezvous with the Mir was performed nominally. The Mir approach timing and alignment thruster firings were nominal, and a mechanism roll alignment maneuver of about 1 degree was performed. Post contact thrusting was nominal and full-firing duration occurred. Docking loads were nominal.

The Orbiter docking system (ODS) avionics hardware performed nominally throughout the docking sequence. The ODS was powered up at 015:03:19:25 G.m.t. (02:17:52:03 MET). Capture occurred nominally at 015:03:54:50 G.m.t. (02:18:27:28 MET). The capture latches were activated at 015:04:02:36 G.m.t. (02:18:35:14 MET), and the docking ring proceeded to the "Final" position that ended the automated docking sequence with a successful Orbiter/Mir docking, which was completed at 015:04:02:43 G.m.t. (02:18:35:21 MET).

Vestibule pressurization occurred at 015:04:29 G.m.t. (02:19:01 MET), cabin pressure equalization with Mir was begun at 015:05:32 G.m.t. (02:20:04 MET), and hatch opening occurred at 015:05:57 G.m.t. (02:20:29 MET).

At approximately 015:14:42 G.m.t. (03:05:15 MET), excessive drift rates and drift-rate trending were observed on the inertial measurement unit (IMU) 3 X- and Y-axes (Flight Problem STS-81-V-02). The performance signature was similar to that seen previously, and the cause has been inadequate or contaminated lubrication in the vertical (x-y axis) gyro. To preserve IMU 3 for use during entry and landing, the crew switched the IMU to standby at 017:14:33 G.m.t. (05:05:05 MET). This action was expected to maintain the X- and Y-axis gyro drift rate at about its pre-shutdown value. The IMU was switched to operate on entry day at 022:06:21 G.m.t. (09:20:54 MET), and the IMU performed satisfactorily throughout entry and landing.

The fuel cell 1 calculated performance (differential voltage) started degrading at a faster-than-normal rate at 017:01:01 G.m.t. (04:15:33 MET) (Flight Problem STS-81-V-03). The degradation rate shifted from a nominal value of approximately 0.008 V/hr to a rate of 0.018 V/hr. As a result, the third on-orbit purge was performed on all three fuel cells at 017:14:39 G.m.t. (05:05:11 MET). Fuel cell 1 recovered some of its performance after this third purge, but it still appeared to be lower-than-normal. Consequently, an additional (manual) purge of only fuel cell 1 was performed at 017:14:52 G.m.t. (05:05:24 MET). This additional purge did not appear to change the performance level of fuel cell 1. As a precaution, main busses A and B were tied prior to the upcoming sleep period.

A comparison of the fuel cell 1 voltage to the main bus A voltage indicated that the fuel cell 1 voltage was reading 0.1 to 0.5 V low, which was determined to be the cause of the erroneous calculated degradation rate. When main bus A voltage was plotted against the fuel cell 1 predicted performance, the performance appeared nominal. The fuel cell 1 voltage continued throughout the flight to read lower than normal and the reading remained erratic. The main bus A voltage and other parameters continued to verify that fuel cell 1 was healthy, which indicated that the erratic fuel cell 1 voltage indication was an instrumentation problem. Main busses A and B were untied at 019:01:58 G.m.t.

(06:16:30 MET) after it was determined that the drop in fuel cell 1 performance was due to instrumentation and not a problem with the fuel cell.

The STS-4 payload general support computer (PGSC) was used for both Development Test Objective (DTO) 700-12 [Global Positioning System/Inertial Navigation System (GPS/INS)] and RME 1318 (TVIS). The crew reported that the STS-4 PGSC did not recognize the GPS/INS flash-card in the lower slot of that machine (Flight Problem STS-81-F-03). Suspecting a problem with the STS-4 PGSC, the crew checked for TVIS data that was recorded earlier in the flight and did not find any data. The cause of these problems will require postflight evaluation to determine if the PGSC was at fault. As a result of the TVIS data not being found, RME 1318 was re-accomplished later in the flight, and the data were recorded and downlinked to the ground controllers and sponsor for evaluation.

During docked operations with the Mir, sixteen CWCs were filled and transferred. The total water transfer was 1608 lb.

Orbiter/Mir hatch closure was completed at 019:12:46 G.m.t. (07:03:19 MET). All activities and operations associated with the hatch closure were nominal.

The undocking, fly-around, and separation from the Mir were accomplished nominally, beginning at approximately 020:02:13 G.m.t. (07:16:45 MET). The ODS performed nominally during undocking operations. The ODS was powered up at 020:01:46 G.m.t. (07:16:18 MET) and powered down at 020:02:24 G.m.t. (07:16:56 MET).

A time executed command (TEC) was uplinked at 020:01:39 G.m.t. (07:16:11 MET) (Flight Problem STS-81-V-05). The TEC failed to toggle the Ku-band extravehicular activity (EVA) protect mode bit in the Ku-band/S-band control word at its scheduled time of 020:02:20 G.m.t. (07:16:52 MET). The command had been sent to disable the EVA protect mode. This problem appears to be the result of an incomplete implementation of Ku-band crew member protection flight software change, which added a Ku-band EVA protect mode capability to the flight software (FSW). Using this feature, the ground can define a protected "area" for an EVA crewman (or for the Mir as was the case during this mission) using Orbiter pitch and roll angles. If the Ku-Band antenna points into this protected area while the mode is enabled, the FSW turns off the Ku-band traveling wave tube (TWT), thus preventing the Ku-band antenna from radiating while in the protected area. The command was subsequently sent not using a TEC and the EVA protect mode was disabled.

The flight control system (FCS) checkout was performed using APU 3. The APU and hydraulics subsystems performed nominally during the checkout. APU 3 was started at 21:05:34:39 G.m.t. (08:20:07:17 MET) and ran for 3 minutes 54 seconds. The fuel consumption during this run was 14 lb. No water spray boiler operation occurred because of the short APU run time. FCS performance was nominal.

Primary reaction control system (RCS) thruster F3F failed off at 21:06:28:28 G.m.t. (08:21:01:06 MET) on the first attempted firing during the RCS hot-fire (Flight Problem STS-81-V-06). The maximum chamber pressure achieved was 16.3 psia. The pressure signature, along with the fuel/oxidizer injector temperature profile, was typical of an oxidizer-valve failing to open completely because of iron-nitrate contamination. This was the sixth flight of this thruster in the F3F position and the thruster had accumulated 10 pulses for a total firing time of 5 seconds since being installed. The thruster was leak-free and remained deselected for the remainder of the flight. All other thrusters functioned nominally during the hot-fire.

The payload bay doors were closed at 022:09:01:41 G.m.t. (09:23:34:18 MET) in preparation for landing. The first landing opportunity at the KSC Shuttle Landing Facility (SLF) was waved off because of forecast and observed unacceptable cloud cover. The dual-engine deorbit maneuver for the second landing opportunity at the KSC SLF was performed on orbit 160 at 022:13:17:33.2 G.m.t. (10:03:50:10.2 MET). The maneuver was 202.5 seconds in duration with a ΔV of 355.8 ft/sec.

Entry was completed satisfactorily, and main landing gear touchdown occurred on concrete runway 33 at 022:14:22:46 G.m.t. (10:04:55:23 MET) on January 22, 1997. The Orbiter drag chute was deployed at 022:14:22:46.3 G.m.t. and the nose gear touchdown occurred 9.7 seconds later. The drag chute was jettisoned at 022:14:23:25.5 G.m.t. with wheels stop occurring at 022:14:23:51 G.m.t. The rollout was normal in all respects. The flight duration was 10 days 04 hours 55 minutes and 23 seconds. The APUs were shut down 20 minutes 26 seconds after landing.

Approximately 14 minutes after wheels stop, the APU 3 gas generator chamber pressure measurement shifted downward about 200 psi (Flight Problem STS-81-V-07). The cause of this shift was determined to be a failure within the transducer.

PAYLOADS AND EXPERIMENTS

Valuable scientific data were returned from the Shuttle-Mir Science Program in the areas of advanced technology, Earth sciences, fundamental biology, human life sciences, microgravity and space sciences. These investigations provided valuable information about space flight and long-term exposure to the microgravity environment. In addition, the commercially initiated research and technology evaluated new technologies and techniques using the Mir Space Station as a test bed.

SPACEHAB SCIENCE AND SYSTEMS

The Spacehab systems operated flawlessly throughout the mission. Spacehab tear-down was late on flight day 10 with closeout occurring prior to the deorbit preparation activities.

A two-hour time period on flight day 9 provided a validation of the Spacehab 32 kbps data stream capability of the Spacehab. The use of this system is planned for future flights.

Biorack

All eleven of the Biorack experiments were completed. The preliminary science-gain assessment for the 11 experiments is:

a. FO-01 Fungus - 90 percent - Reduced time due to flight day 4 docking;
b. FO-02 Cress - 80 percent - Reduced time due to flight day 4 docking;
c. FO-03 Chara - <100 percent - Reduced time due to flight day 4 docking;
d. FO-04 Dosimetry - > 90 percent - Meter 6 loss after PGSC crash/reboot;
e. FO-05 Biofilm - 100 percent
f. FO-06 Isozyme - 100 percent
g. FO-07 Osteogene - > 90 percent - Reduced time due to flight day 4 docking;
h. FO-08 Sperm - 100 percent
i. FO-09 Preplastid - >100 percent
j. FO-010 Aggs - 100 percent
k. FO-011 Gravity - >100 percent

Other problems reported with the Biorack involved a fixative leak in FO-02 Cress operations. Leak cleanup procedures were reviewed by the Surgeon and implemented by the crew without incident.

The PGSC experienced six lock-ups during the course of the mission. The symptom was a single-event upset resulting in a parity bit error. The suspected cause was a combination of cosmic radiation and a PGSC memory intensive application such as Biorack. Following the lock-ups, the data from the Meter 6, Dosimetry Telescope (DOSTEL) investigation became static. Data recovery was accomplished by reseating the data connector. After the sixth lock-up, the Meter 6 data was switched to Incubator A position which was not connected to the PGSC, and Meter 6 data were no longer downlinked but stored on internal memory.

Commercial Generic Bioprocessing Apparatus

Two Commercial Generic Bioprocessing Apparatus (CGBA) units were maintained in the powered configuration and placed in the Spacehab for return to Earth. The units operated nominally.

Biotechnology System

Two Biotechnology Systems (BTS) units were maintained in the powered state when returned from the Mir to Earth. All operations continued to be nominal during the return.

MIDDECK SCIENCE AND PAYLOADS

Surface Sampler Kit/Microbial Air Sampler

Air and surface samples were collected for this experiment. These were returned to Earth for postflight analysis. The results of the analysis will be published in separate documentation.

Cosmic Radiation Effects and Activation Monitor

The active monitor and passive foil detectors of the Cosmic Radiation Effects and Activation Monitor (CREAM) experiment were initially deployed at the nominally planned stations. The active monitor location was changed four times. The final active monitor was located in the Shuttle airlock.

During deactivation, the crew reported that the green power light emitting diode (LED) was off. Orbiter power problems were eliminated since other payloads tied to the same power bus were operating nominally. Power cycling the unit failed to light the LED. No data loss occurred because of the LED anomaly.

The CREAM recorded heavy ions that penetrate the structure as a function of location, time, and orbital attitude. The results of this experiment will be used in updating environmental models, understanding the effects on the human body, and in the design of structures and electronics.

RISK MITIGATION EXPERIMENTS

RME 1302 - Electric Fields High Inclination/Mir

The set-up and activation of this RME on the Mir was performed in accordance with the scheduled time-line, and data collection lasted for approximately 15 hours. An alternate power cable was used to power the spectrum analyzer when the cable that was called out in the procedures could not be located. Data were also collected on the Orbiter during flight day 9, after which the RME was deactivated and stowed.

RME 1303-1 - Enhanced Dynamics Load Sensor

The transfer of Enhanced Dynamics Load Sensor (EDLS) replacement hardware was nominal. Photographs were taken of the EDLS foot restraints with an astronaut in place to document placement and evaluate if the video angles will be available to complete the Mir EDLS experiment.

RME 1303-2 - Mir Auxiliary Sensor Unit for Mir Structural Dynamics Experiment

The Mir Auxiliary Sensor Unit for Mir Structural Dynamics Experiment (MISDE) hardware was transferred to the Mir.

RME 1303-3 - Water Experiment Kit

Water Experiment Kit (WEK) 2 was transferred to the Mir, and WEK 1 was returned from the Mir. WEK 2 will be used during the next phase of the Mir mission and returned to Earth on a subsequent mission.

RME 1307 - Optical Properties Monitor

The Optical Properties Monitor (OPM) system hardware was successfully transferred to the Mir Krystall module for storage until deployment during an EVA later in the Mir operations. The OPM will be used to collect environmental data from around the Mir.

RME 1317 - MISDE Joint Operations

The MISDE joint operations during the docked phase were successfully performed. These operations included a Mir thruster firing, Mir treadmill crew exercise, Orbiter RCS thruster firing, intravehicular crew push-off activities, and day/night/day transitions. Negotiations prior to the Mir thruster firing test resulted in a request to align the Kvant-2 module solar array parallel to the Kvant-2 long axis. Also a request to repeat the Mir thruster firing test to capture Mir accelerometer data was initially accepted, but the test was not performed because of the Shuttle crew workload.

RME 1318 - Treadmill Vibration Isolation and Stabilization System

The Treadmill Vibration Isolation and Stabilization System (TVIS) was successfully completed and the required data were obtained. However, in completing this RME, some problems were encountered and these are discussed in the following paragraphs.

During the initial setup of the TVIS, it was noted that a mismatch existed between the Orbiter power cables and the treadmill electronics box power input connectors. Since the pin locations in a TVIS connector did not correspond to the appropriate pin locations in the Orbiter power cable, the IFM procedure provided instructions for the installation of jumper wires between the power cable and the TVIS connector, as well as the direction for securing the jumpers and the cable to prevent inadvertent disconnection. This IFM was completed and power was provided to the TVIS.

A number of real-time operations were also completed to enhance system operation and these included:

a. Adjustment of retaining pin on the RME frame for a more secure fit;
b. Relocation of a write-protect switch on the treadmill CCM cards to allow data storage; and
c. Update of a TVIS configuration file default values to allow PGSC PCMCIA card data storage.

The initial results indicate more oscillations than expected at walking speeds. The recorded data included treadmill exercise data, TVIS force transmission data, and TVIS camera target video motion data that was used for postflight evaluation.

During an attempt to downlink the data recorded during the initial TVIS session, it was discovered that no data were recorded on the PGSC PCMCIA card that was used to store data. A further investigation concluded that the PGSC (STS 4) used during the TVIS operation had malfunctioned. As a result, a plan was developed and approved by the Mission Management Team (MMT) that the crew would repeat the TVIS operations immediately after undocking and still maintain the landing on the nominal timeline.

The TVIS hardware was subsequently unstowed and assembled for the second TVIS operation on three test subjects. PGSC STS 5 recorded the data during the second TVIS operation. Also, TVIS software changes were made to move configuration files into the correct directory to avoid a problem encountered during the first TVIS run. The TVIS operations were completed and the data were downlinked via the Orbiter Communications Adapter (OCA) and confirmed as being good-quality data.

A noise that was believed to be a gyro causing the stabilizer springs to resonate was determined to be of no impact to the test. The TVIS hardware demonstrated a stable platform with a minor pitch oscillation associated with fore-aft shifting of the runner on the running surface. Preliminary analysis of the downlinked data show that a force of less than 1 lb was imparted during the steady-state walking/running. With the gyroscope not functioning, the TVIS provided, as expected, a larger roll disturbance which had a magnitude that was dependent on the running style and lateral displacement of the foot falls from the treadmill center-line.

RME 1324 - Volatile Organic Analyzer

The Volatile Organic Analyzer (VOA) was powered at 12:14:45 G.m.t (00:05:18 MET) and system bake-out proceeded as planned for the seven-hour period. As the crew proceeded with the warm-up of the instrument, the VOA display did illuminate. Power profiles during the bake-out indicated the system was operating nominally until a current drop was observed. Power was removed from the system, and discussions were held with the hardware developer that confirmed that a suspected 3-ampere fuse had blown. The fuse was inaccessible and also there was no spare onboard the vehicle. A decision was made to declare the hardware failed and no attempt at further troubleshooting was made.

The VOA is currently scheduled to fly on STS-84, as International Space Station hardware, to test the Orbiter and Mir air quality.

RME 1325 - Water Quality Monitor

The total organic carbon (TOC) supply kit and analyzer were deployed in the Spacehab. Control analysis of all standards to evaluate the performance of the International Space Station prototype hardware was successfully completed. The results were within the preflight predictions, thus demonstrating efficient Water Quality Monitor operation. Additionally, three Mir water samples were collected and will be analyzed during the postflight analysis operations.

CREW MEDICAL RESTRAINT SYSTEM

The crew medical restraint system (CMRS) was deployed and the first subject was secured in 56 seconds using one medical officer. The deployment and restraint required two minutes and this more than satisfied the requirement. The crew reported no problems with the procedures and setup.

SPACE STATION CREW MIDDECK INTERFACE FUNCTIONALITY

The Space Station Crew Middeck Interface Functionality (SSCIF) was connected to the 1553 PGSCs for data collection during overnight periods while docked. The data collected are being analyzed during postflight operations to determine the extent of radiation upsets that occurred during operations.

KIDSAT PROJECT

The KidSat payload operations were very successful. The preflight plan was to take 287 photographs with the Electronic Still Camera (ESC); however, excellent coordination between all parties involved in the KidSat operations resulted in 525 photographs being taken. A total of 304 of the photographs were taken prior to docking and 221 after docking.

Three error messages were received and these indicated no communication between the ESC and the OCA. The first instance occurred early in the mission when the AC utility power was off. The power was restored, but the images were noisy. The second and third instances occurred about 4 hours later, when after the second message the KidSat software was restarted and this caused the third message. A checkout procedure was uplinked to the crew and after two attempts of the procedure, success was achieved and the KidSat software was restarted. The procedure required disconnection of the Global Positioning System interface, rebooting of the OCA, and restarting the software. KidSat reported 24 Mb of lost memory storage on the PCMCIA card, and this condition may have been caused by the GPS interface. A backup PCMCIA card was successfully used for the remainder of the mission.

MIDCOURSE SPACE EXPERIMENT

The Midcourse Space Experiment (MSX) was unable to acquire any data takes as there were no conjunctions between the MSX and the Orbiter.

SPACE ACCELERATION MEASUREMENTS SYSTEM

The Space Acceleration Measurements Experiment (SAMS) hardware was a part of the resupply hardware to the Mir. The hardware was transferred as planned.

VEHICLE PERFORMANCE

SOLID ROCKET BOOSTERS

All Solid Rocket Booster (SRB) subsystems performed nominally and no in-flight anomalies were identified. Analysis of the flight data and assessment of the postflight condition of the recovered hardware indicate subsystem performance was nominal.

The SRB prelaunch countdown was normal, and no SRB Launch Commit Criteria (LCC) or Operational Maintenance Requirements and Specification Document (OMRSD) violations occurred. For this flight, the high-pressure heated ground purge in the SRB aft skirt was used to maintain the case/nozzle joint temperatures within the required LCC limits.

Both SRBs were successfully separated from the External Tank (ET) at liftoff plus 125.723 seconds. The right SRB main parachute no. 3 failed during entry because of its entanglement of the canopy ribbons with the vent line. This problem did not impact entry and water impact operations. The SRBs were retrieved and towed back to shore, and returned to Kennedy Space Center (KSC) for disassembly and refurbishment.

REUSABLE SOLID ROCKET MOTORS

The Reusable Solid Rocket Motors (RSRMs) performed satisfactorily, and all parameters were well within the allowable performance envelopes and typical of the performance observed on previous missions. There were no LCC violations nor were any in-flight anomalies identified.

All RSRM temperatures were maintained within acceptable limits throughout the countdown. The RSRM propellant mean bulk temperature (PMBT) was 63 °F at liftoff.

Motor performance parameters were within contract end item (CEI) specification limits. One out-of-family condition was noted on the pressure trace shape variation during the 0- to 55-second time period, but the variation was well within limits. The calculated PMBT was 63 °F at the time of launch. The maximum trace shape variation of pressure versus time during the 62-80 second time period was calculated to be 0.32 percent for the left motor and 1.45 percent for the right motor. These values were well within the 3.2 percent allowable limits.

The RSRM propulsion parameters are shown in the following table.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 63 °F		Right motor, 63 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10^6 lbf-sec	65.14	64.35	65.02	64.27
I-60, 10^6 lbf-sec	173.85	173.53	173.57	173.97
I-AT, 10^6 lbf-sec	296.78	296.55	296.60	297.22
Vacuum Isp, lbf-sec/lbm	268.4	268.2	268.4	269.0
Burn rate, in/sec @ 60 °F at 625 psia	0.3687	0.3682	0.3685	0.3684
Burn rate, in/sec @ 63 °F at 625 psia	0.3695	0.3690	0.3693	0.3692
Event times, seconds[a]				
Ignition interval	0.232	N/A	0.232	N/A
Web time[b]	110.5	110.7	110.6	110.3
50 psia cue time	120.3	120.7	120.4	120.5
Action time[b]	122.4	122.9	122.5	123.2
Separation command	125.3	125.6	125.3	125.6
PMBT, °F	63	63	63	63
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	2.9	2.8	3.5
Tailoff Imbalance Impulse differential, Klbf-sec	Predicted		Actual	
	N/A		286.9	

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).

Field joint heaters operated for 12 hours 49 minutes during the launch countdown. Power was applied to the heating elements an average of 31 percent of the time to maintain the field joints in their normal operating range.

Igniter joint heaters operated 17 hours 47 minutes during the countdown. Power was applied to the heating elements 68 percent of the time to maintain the joints within the normal operating range.

The aft skirt purge operated for a total of 27 hours 42 minutes. During the countdown, the aft skirt purge was used to maintain the nozzle/case joint temperatures above the minimum LCC temperature. During the LCC time frame, the nozzle/case joint sensor temperatures ranged from 80 to 85 °F and 77 to 80 °F for the left and right motors, respectively. The calculated flex bearing mean bulk temperature was 79 °F.

EXTERNAL TANK

All External Tank (ET) objectives and requirements associated with propellant loading and flight operations were met, and no in-flight anomalies were identified. All ET electrical equipment and instrumentation operated satisfactorily. The ET purge and heater operations were monitored and all performed properly. No ET LCC or OMRSD violations were identified.

No unexpected ice/frost formations were observed on the ET during the countdown. Also, no ice or frost were observed on the acreage areas of the ET. Normal quantities of ice or frost were present on the liquid oxygen (LO_2) and liquid hydrogen (LH_2) feedlines, the pressurization line brackets, and along the LH_2 protuberance airload (PAL) ramps. All observations were acceptable per NSTS 08303. In addition, the Ice/Frost Red Team reported that no anomalous conditions existed.

The ET pressurization system functioned properly throughout engine start and flight. The minimum LO_2 ullage pressure experienced during the period of the ullage pressure slump was 13.8 psid, which was well within the experience base.

The ET separation was performed satisfactorily, and the ET entry and breakup were within 8 nmi. of the preflight predicted impact print.

SPACE SHUTTLE MAIN ENGINES

All Space Shuttle main engine (SSME) parameters were normal throughout the prelaunch countdown and were typical of prelaunch parameters observed on previous flights. Engine ready was achieved at the proper time; all LCC were met; and engine start and thrust buildup were normal. No in-flight anomalies were identified.

Flight data indicate that the SSME performance during mainstage, throttling, shutdown, and propellant dump operations was normal. Cutoff times for SSMEs 1, 2, and 3 were 518.13, 518.25, and 518.37 seconds, respectively. The I_{sp} was rated as 453.59 seconds based on trajectory data. Controller and software performance were nominal.

The high pressure oxidizer turbopump (HPOTP) and high pressure fuel turbopump (HPFTP) temperatures were well within specification throughout engine operation. There were no failures, and no significant SSME problems were identified.

SHUTTLE RANGE SAFETY SYSTEM

The Shuttle Range Safety System (SRSS) closed-loop testing was completed as scheduled during the countdown. All SRSS safe and arm (S&A) devices were armed and system inhibits were turned off at the appropriate times. All SRSS measurements indicated that the system operated as expected throughout the launch countdown and flight.

As planned, the SRB S&A devices were safed, and the SRB system power was turned off prior to SRB separation. The ET system has been deleted.

ORBITER SUBSYSTEM PERFORMANCE

Main Propulsion System

The overall performance of the main propulsion system (MPS) was nominal. No LCC or OMRSD violations occurred, nor were any in-flight anomalies identified.

All events and sequences were performed nominally. The aft hazardous gas concentration during loading were nominal. Throughout the period of preflight operations, no significant hazardous gas concentrations were detected. The maximum hydrogen concentration level in the Orbiter aft compartment (occurred shortly after start of fast-fill) was approximately 130 ppm, which compares favorably with previous data for this vehicle.

LH_2 propellant 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 resulted in a loading accuracy of -0.01 percent for LH_2 and +0.02 percent for LO_2. The total LH_2 load was 231,307 lbm, and the total LH_2 load was 1,388,502 lbm.

Data from the ascent phase indicate that the LO_2 and LH_2 pressurization and feed systems performed as planned, and all net positive suction pressure (NPSP) requirements were met throughout the flight. The minimum LO_2 ullage pressure experienced during the period of ullage-pressure slump was 13.8 psia. The GO_2 fixed-orifice pressurization system performed as predicted. Reconstructed data from the engine as well as MPS parameters matched the actual ET ullage pressure measurements.

All three flow control valves (FCVs) performed nominally. The engine 1 FCV had 44 cycles, which was the most of any of the three systems.

Helium system performance for the SSME and pneumatic helium systems was nominal. Entry helium usage was 59.6 lbm, which is within the requirements. All other parameters were also nominal.

Reaction Control Subsystem

The reaction control subsystem (RCS) performed nominally with the exception of primary RCS thruster F3F, which failed off (Flight Problem STS-81-V-06) during the hot-fire test following the FCS checkout. This anomaly is discussed further in a later paragraph.

A total of 4510.9 lbm of propellants were consumed from the RCS tanks during the mission. In addition, 2410.9 lbm of propellants were consumed from the OMS tanks during the mission.

The RCS maneuvers performed to rendezvous with the Mir are shown in the following table.

RCS RENDEZVOUS MANEUVERS

Maneuver	G.m.t./MET	ΔV, ft/sec
NC-3	013:11:37:23 G.m.t. 01:02:10:01 MET	2.9
NC-4	014:02:35:21 G.m.t. 01:17:07:59 MET	3.3
NH	015:00:16:12 G.m.t. 02:14:48:50 MET	1.3
MC-1	015:01:36:06 G.m.t. 02:16:08:44 MET	0.7
MC-2	015:02:06:16 G.m.t. 02:16:38:54 MET	0.7
MC-3	015:02:16:00 G.m.t. 02:16:48:38 MET	0.2
+X Separation	020:04:02:00 G.m.t. 07:18:34:38 MET	3.0

Primary RCS thruster F3F failed off at 021:06:28:28 G.m.t. (08:21:01:06 MET) on the first attempted firing during the RCS hot-fire (Flight Problem STS-81-V-06). The maximum chamber pressure achieved was 16.3 psia. The pressure signature, along with the fuel/oxidizer injector-temperature profile, was typical of an oxidizer-valve failing to open completely because of iron-nitrate contamination. This was the sixth flight of this thruster in the F3F position and the thruster had accumulated 10 pulses for a total firing time of 5 seconds since being installed. The thruster was leak-free and remained deselected for the remainder of the flight. All other thrusters functioned nominally during the hot-fire. Thruster F3F as well as the other three thrusters (F3L, F3U, and F3D) on the same manifold were removed and replaced during postflight turnaround activities.

During the NC-3 +X RCS maneuver that was performed at 013:11:37:23 G.m.t. (01:02:10:00 MET) transients were observed in the thruster R3A chamber pressure trace; however, these were attributed to operating in the left-OMS interconnect configuration, and were not abnormal.

Orbital Maneuvering Subsystem

The OMS performed nominally throughout the mission with no in-flight anomalies identified. The OMS 1 maneuver was not performed because of the nominal direct-ascent trajectory flown. The following table lists the pertinent information concerning the OMS maneuvers.

OMS MANEUVERS

OMS firing	Engine	Ignition time, G.m.t./MET	Firing duration, seconds	ΔV, ft/sec
OMS 2	Both	012:10:10:23.3 G.m.t. 00:00:43:00.3 MET	47.6	75
OMS 3	Both	012:13:03:03.3 G.m.t. 00:03:35:40.3 MET	51.4	82
OMS 4 NC-2	Right	013:01:02:27.8 G.m.t. 00:15:35:04.8 MET	10.0	8.0
OMS-5	Both	014:09:10:44.1 G.m.t. 01:23:43:21.1 MET	58.5	94
OMS-6 NC-6	Both	014:23:41:15.6 G.m.t. 02:14:13:52.6 MET	63.3	103
OMS-7 TI	Left	015:01:13:54.1 G.m.t. 02:15:46:31.1 MET	12.0	9.5
OMS-8 Orbit adjust	Both	020:13:53:53.2 G.m.t. 08:04:26:30.2 MET	25.6	42.7
Deorbit	Both	022:13:17:33.2 G.m.t. 10:03:50:10.2 MET	202.6	355.8

All prelaunch operations were nominal. Systems temperatures and pressures were within expected ranges and system valves operated as commanded.

OMS propellant consumption during the mission was 20,204.7 lbm of which 12,606.5 lbm was oxidizer and 7598.2 lbm was fuel. There were two periods of interconnect operation (one left and one right), during which 2420.9 lbm (20.73 percent) of the OMS propellants were consumed by the RCS.

Evaluation of the inlet pressures, chamber pressures and regeneration jacket temperatures for both orbital maneuvering engines (OMEs) showed nominal performance. The OMS firing times and propellant consumption were consistent with predictions, and this also verified proper operations.

Following the OMS 2, OMS 3 and OMS 4 maneuvers, the left-hand fuel-tank total-quantity gauging system failed to indicate the forward total quantity level. However, during the OMS 5 maneuver, the gauging system began indicating the correct level after regaining the forward probe signal and remained active for the remainder of the mission. This fuel-tank gauging system has exhibited similar behavior on STS-71, STS-76, and STS-79. On STS-74, nominal performance was not regained following the OMS 5 maneuver. An intermittent condition is suspected in the system associated with the totalizer/forward probe.

Power Reactant Storage and Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem performance was nominal throughout the STS-81 mission. The PRSD subsystem supplied the fuel cells with 2671 lbm of oxygen and 336 lbm of hydrogen for the production of 3862 kWh of electrical energy. In addition, the environmental control and life support system (ECLSS) was supplied with 152 lbm of oxygen, which includes 57.7 lbm furnished to the Mir Space Station. A three-day mission extension was possible at the average power level with the reactants remaining at landing.

The PRSD subsystem hydrogen (H_2) manifold 1 isolation valve was opened and gave a false indication at 017:01:11:48 G.m.t. (04:15:44:25 MET). The H_2 manifold 1 isolation valve indication briefly showed open then indicated closed. System parameters confirmed that the valve had in fact opened and remained open. The valve indication had been proper the previous three days. The valve had a similar false-closed indication on the previous flight of this vehicle, STS-79, as well as on STS-74 and STS-71. Corrective action for the condition has been deferred to the next OV-104 OMDP. When the H_2 manifold 1 isolation valves were opened at 019:23:54 G.m.t. (07:14:26 MET) the valve indicated open after having falsely indicated closed for all but 2 hours of the previous three days.

Fuel Cell Powerplant Subsystem

Performance of the fuel cell powerplant (FCP) subsystem was satisfactory during this fifth mission to the Mir. The average electrical power level and load was 15.8 kW and 518 amperes. The fuel cells produced 3,007 lb of potable water and 3,862 kWh of electrical energy from 2671 lbm of oxygen and 336 lbm of hydrogen. Six satisfactory purges of the fuel cells were performed using both the automatic and manual modes. The actual fuel cell voltages at the end of the mission were 0.1 volt above predicted for fuel cell 1, and 0.2 volt above predicted for fuel cells 2 and 3. The overall thermal performance of the fuel cell water relief, water line and reactant purge systems was also nominal. Two in-flight anomalies occurred during the mission and these are discussed in following paragraphs.

The fuel cell 1 calculated performance (differential voltage) started degrading at a faster-than-normal rate after a PRSD cryogenic reconfiguration to PRSD tank 5 at 017:01:01 G.m.t. (04:15:33 MET) (Flight Problem STS-81-V-03). The degradation rate shifted from a nominal value of approximately 0.008 volt/hr to a rate of 0.018 volt/hr. At 17:07:22 G.m.t. (04:21:54 MET), the performance shifted downward 0.14 volt when the PRSD tanks were reconfigured from tank set 5 to tank set 4. Evaluation of the data indicated that the apparent performance degradation was not related to the PRSD events. The third on-orbit purge was performed on all three fuel cells at 017:14:40 G.m.t. (05:05:12 MET) as it had been 48 hours since the last purge and the fuel cell 1 calculated performance degradation was 0.28 volt, whereas fuel cells 2 and 3 had only degraded 0.1 volt. Fuel cell 1 recovered some of its performance after this third purge, but it still appeared to be lower-than-normal. Consequently, an additional (manual) purge of only fuel cell 1 was performed at 017:14:52 G.m.t. (05:05:24 MET). This additional purge did not appear to change the performance level of fuel cell 1. As a precaution, main busses A and B were tied prior to the upcoming sleep period.

A plot of the fuel cell 1 voltage and the main bus A voltage indicated that the fuel cell 1 voltage shifted downward 0.1 to 0.5 volt at the same time that the performance curve shifted. A plot of these two measurements showed that the measurements were tracking each other until the shift. The main bus A voltage and other parameters continued to verify that fuel cell 1 was healthy, and supported the theory that the erratic fuel cell 1 voltage indication was the cause of the indicated performance degradation and it was not a fuel cell problem. Main busses A and B were untied at 019:01:58 G.m.t. (06:16:30 MET). Postflight troubleshooting could not isolate the problem. Card 1 in the mid 1 dedicated signal conditioner (DSC) was removed and replaced.

All three channels of the fuel cell 2 cell performance monitor (CPM) remained at the self-test value of 48-50 mV for 3.5 minutes for six consecutive self-test cycles that began at 020:08:06:14 G.m.t. (07:12:38:51 MET), after which it operated nominally for the remainder of the mission (Flight Problem STS-81-V-04). The nominal self-test duration is 2 seconds every 7.5 minutes. Substack differential-voltage values were nominal between self-test operations, indicating that fuel cell performance was acceptable. This is the third consecutive flight that this fuel cell (S/N 120) has experienced an anomaly with the CPM, the other two flights being STS-73 and STS-75. Self-test operations returned to normal, and remained so for the remainder of the flight. The CPM on fuel cell 2 was removed and replaced during postflight turnaround activities.

At approximately 020:13:57 G.m.t. (08:04:30 MET), the fuel cell 3 alternate water line temperature increased to 122 °F. A review of the data revealed that the fuel cell 1 and 2 alternate water line temperatures had small increases in temperature at the same time that the fuel cell 3 alternate water line temperature began increasing. The OMS maneuver performed at 020:13:53:53 G.m.t. (08:04:26:31 MET) cracked all three alternate water line check valves and apparently the fuel cell 3 check valve failed to reseat properly. The fuel cell 3 alternate water line temperature started to decrease 8 hours prior to landing, from 120 to 100 °F over a 2-hour period. The temperature then increased to 124 °F. Two hours prior to landing, it again began decreasing and returned to a nominal value of about 87 °F just prior to landing, which indicates the leak had stopped. There was no mission impact and no postflight actions were performed.

Auxiliary Power Unit Subsystem

The auxiliary power unit (APU) subsystem performance was nominal throughout the STS-81 mission, except for the in-flight anomaly that occurred after landing and that is discussed in a later paragraph. The run times and fuel consumption for the APUs on this flight are summarized in the following table.

APU RUN TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (a) (b) (S/N 407)		APU 2 (a) (S/N 412)		APU 3 (a) (S/N 311)	
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	20:16	49	20:21	50	20:25	52
FCS checkout					03:55	11
Entry[a]	64:36	115	90:35	162	64:44	119
Total	84:52	164	110:56	212	89:04	182

[a] APUs were shut down 20 minutes 26 seconds after landing.
[b] APU 3 was used for the FCS checkout.

The FCS checkout was performed using APU 3. The APU and hydraulics subsystems performed nominally during the checkout. APU 3 was started at 21:05:34:44 G.m.t. (08:20:07:22 MET) and ran for 3 minutes 55 seconds. No water spray boiler operation occurred because of the short APU run time. FCS performance was nominal.

The APU 2 fuel pump/line/gas generator valve module (GGVM) system A thermostat narrowed its set points after four cycles, resulting in the APU 2 bypass line temperature band decreasing from 40 °F to 5 °F. This thermostat is located on a fuel line that is attached to the APU. Previous experience has shown that a thermostat located at this position will eventually fail once it begins to indicate a narrowing of its set point range. Generally, this "narrowing" is a first step followed by more erratic operation of the thermostat prior to failure. The thermostat was replaced during the turnaround activity following the flight.

When the APU 2 gas generator (GG) bed heater was switched from system A to system B, the GG injector temperature deadband decreased from approximately 85 °F to 12 °F. All APUs exhibit such change to a varying degree because of the asymmetrical placement of the heaters relative to the injector thermocouple. Although the APU 2 band is narrower than most APUs, it has been consistently narrow on its six flights that began with STS-50.

Approximately 15 minutes after wheels stop, the APU 3 gas generator chamber pressure measurement shifted downward about 200 psi (Flight Problem STS-81-V-07). Data review indicated that the shift was most likely caused by a bias shift in the chamber pressure transducer. This would make the fourth transducer that has exhibited this performance in the past 18 months. This transducer provides the best indication of proper APU performance and is, thereby, mandatory for launch in the LCC. KSC ground testing of the transducer and signal conditioner confirmed that the pressure transducer had shifted. The APU has been removed and replaced.

Hydraulics/Water Spray Boiler Subsystems

Overall performance of the hydraulics/water spray boiler (WSB) subsystem during STS-81 was nominal with no in-flight anomalies identified.

During ascent, the APU 3 lubrication oil temperature reached 272 °F before WSB spray cooling began. During entry, the APU 3 lubrication oil temperature reached 265 °F before spraying cooling began. The two APU 3 under-cooling conditions did not violate the specification (no greater than 275 °F at spray start) and had no affect mission operations. However, spray cooling should be observed at approximately 255 °F. Ground checkout of WSB 3 was not required.

Development Test Objective (DTO) 416 was performed following ascent. A more complete discussion of this DTO was placed in the Development Test Objective/Detailed Test Objective section of this report.

APU/hydraulic system 3 was used to perform the FCS checkout. The APU ran 3 minutes and 55 seconds, which was not long enough for WSB spray cooling to begin as the lubrication oil temperature of APU 3 only reached 199 °F.

Hydraulic performance during entry was nominal. WSB 1 exhibited a 24.4 °F over-cooling at the start of spray cooling. This condition, likewise, did not affect entry flight operations. Ground checkout of WSB 1 was not required.

Postlanding, a regulator outlet pressure transducer dropout was observed on WSB 3. Previous flights of this vehicle have exhibited similar behavior by this transducer. Currently, no spare transducers are available; however, a new design is being developed to replace the existing transducer. The next flight of OV-104 will be flown as-is with this transducer.

Electrical Power Distribution and Control Subsystem

The electrical power distribution and control (EPDC) subsystem performed nominally throughout the STS-81 mission. The data review revealed no abnormal condition.

The heater indication problem with the ODS is discussed in detail in the Structures and Mechanical Subsystem section of this report.

Pressure Control Subsystem

The pressure control subsystem (PCS) performed normally throughout the duration of the STS-81 mission. After docking with the Mir, vestibule pressurization occurred at 015:04:29 G.m.t. (02:19:01 MET) using Mir consumables. Cabin pressure equalization with Mir was begun at 015:05:32 G.m.t. (02:20:04 MET) when the airlock upper-hatch equalization valves were opened, and the Mir and Orbiter total pressure was equalized at 14.39 psia.

The hatch opening occurred at 015:05:57 G.m.t. (02:20:29 MET), and the entire Mir/Orbiter volume pressure was raised to 14.62 psia using the Orbiter PCS. The total consumables transferred to the Mir during the docked phase was 42.1 lb of nitrogen and 57.7 lb of oxygen. Prior to undocking, the pressure of the combined vehicles was raised to 15.34 psia and the partial pressure of oxygen was 3.98 psia.

Atmospheric Revitalization Subsystem

The atmospheric revitalization system (ARS) performed nominally during the STS-81 mission. The maximum cabin environmental conditions during the on-orbit phase showed an air temperature of 80.6 °F, a cabin humidity of 52.3 percent, and a partial pressure of carbon dioxide of 5.64 mmHg. All of these conditions were acceptable and within limits.

An increase in inertial measurement unit (IMU) fan differential pressure above 4.5 inches of water occurred three times while the Orbiter was docked with the Mir and the crew was sleeping. The differential pressure peaked at 4.68 and 4.73 inches of water during the first two occurrences of increased pressure. A differential pressure of 4.96 inches of water was noted during the third period of increased differential pressure when the cabin pressure was 15.1 psia. The normal operating limit is 4.95 inches of water and the closer that the fan operates to that level, the shorter the life of the bearings. A review of the data from previous docking missions also showed higher levels of fan differential pressure while docked with the crew sleeping and the cabin pressure above nominal levels. The avionics specification requires 144 lb/hr air flow and with three IMUs operating and the fan differential pressure at 4.95 or above, the cooling would be marginal. Some increase in IMU temperatures would be noted. Only two IMUs were operating during this period of elevated differential pressure. On future docking missions, this higher level of differential pressure may occur when docked and operating at elevated cabin pressure.

Active Thermal Control Subsystem

The active thermal control subsystem (ATCS) performed normally throughout the mission. Supply water was managed through the use of the flash evaporator system (FES).

Supply and Waste Water Subsystem

The supply and waste water subsystem (SWWS) performed normally throughout the mission.

Supply water was managed through the use of the FES, the water dump system, and water transfer to the Mir Space Station. One nozzle dump of supply water was performed at an average dump rate of 1.76 percent/minute (2.9 lb/min). The supply water dump line temperature was maintained between 64 and 96 °F throughout the mission with the operation of the line heater.

Prior to undocking from the Mir, sixteen CWCs were filled and transferred. The total water transfer was 1608 lb. Eight of the CWCs had only silver biocide added and the remaining eight had both silver biocide and minerals added.

Waste water was gathered at approximately the predicted rate. Three waste water dumps were performed at an average rate of 1.98 percent/minute (3.26 lb/min). The waste water dump line temperature was maintained between 55 and 76 °F throughout the mission. The vacuum vent line temperature was between 57 and 77 °F, with the vacuum vent nozzle between 125 and 194 °F.

Waste Collection Subsystem

The waste collection subsystem (WCS) performed normally throughout the mission.

Airlock Support Subsystem

Use of the airlock depressurization valve was not required because there were no planned or contingency EVAs performed. After docking with the Mir, the external airlock-to-vestibule hatch equalization valve was used to equalize the Mir and Space Shuttle habitable volume pressures. The active system parameters indicated nominal outputs throughout the flight.

Smoke Detection and Fire Suppression Subsystem

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

Flight Data Systems

The performance of the flight data systems was nominal throughout the mission.

Flight Software

The overall performance of the flight software (FSW) was satisfactory. One in-flight anomaly was identified and is discussed in the following paragraph. This anomaly did not impact the successful completion of the planned activities and the flight.

A TEC was uplinked at 020:01:39 G.m.t. (07:16:11 MET). The TEC failed to toggle the Ku-band extravehicular activity (EVA) protect mode bit in the Ku-band/S-band control word at its scheduled time of 020:02:20 G.m.t. (07:16:52 MET) (Flight Problem STS-81-V-05). The command had been sent to disable the EVA protect mode. This problem was the result of an incomplete implementation of the Ku-band crew member protection FSW change, which added a Ku-band EVA protect mode capability to the FSW. Using this feature, the ground can define a protected "area" for an EVA crewman (or for the Mir as was the case during this mission) using Orbiter pitch and roll angles. If the Ku-band antenna points into this protected area while the mode is enabled, the FSW turns off the Ku-band traveling wave tube (TWT), thus preventing the Ku-band antenna from radiating while in the protected area. The command was subsequently sent not using a TEC and the EVA protect mode was disabled. The reason for this incomplete implementation will be determined and a corrective action will be implemented.

Flight Control Subsystem

The performance of the flight control subsystem was satisfactory. One in-flight anomaly was identified and is discussed below. This anomaly did not impact the successful completion of the flight. Also discussed in this section is the performance of the flight control system during the joint phase of the flight.

The performance of two of the three inertial measurement units (IMUs) was satisfactory. However, IMU 3 (S/N 201) displayed anomalous performance and a discussion of this occurrence is contained in the following paragraph.

At approximately 016:04:27 G.m.t. (03:19:00 MET), the IMU 3 developed excessive drift rates and drift-rate trending in the X and Y axes (Flight Problem STS-81-V-02). The performance signature was similar to that seen previously, and the cause has been insufficient or contaminated lubrication in the vertical (x-y axis) gyro. The problem was most recently seen on STS-75 and failure analysis determined that the cause was insufficient lubrication of a vertical gyro spin bearing. To preserve IMU 3 for use during entry and landing, the crew switched the IMU to standby at 017:14:33 G.m.t. (05:05:05 MET). This action maintained the X- and Y-axis gyro drift rate at about its pre-shutdown value. The IMU was switched to operate on entry day at 022:06:21 G.m.t. (09:20:54 MET), and the IMU performed satisfactorily throughout entry and landing. The IMU has been removed and shipped to the vendor for failure analysis and repair.

On-orbit flight control system performance during the joint phase of flight was nominal. No dynamic interaction stability concerns were observed. The Orbiter controlled the mated stack using the vernier RCS thrusters during the entire mated phase, except for three periods of Mir control. Mir control performance was also nominal, with the exception of one period where the Mir failed to completely enter a passive mode following resumption of control by the Orbiter. During the mated phase, attitude quaternion data were periodically transferred to the Russian counterparts to allow updating of the Mir inertial base.

On flight day 4, about 16 minutes after docking with the Mir, the Orbiter assumed control of the mated stack, damped rates nominally, and maneuvered to the desired Mir attitude. Nominal Orbiter flight control system performance was observed.

On flight day 5, the Orbiter was moded to free drift, and the Mir assumed control of the mated stack. Shuttle quaternion data had been used to provide a coarse alignment of the Mir inertial base. At 016:07:36 G.m.t. (03:22:09 MET), the Mir performed a precise alignment with its star tracker. These operations were all performed nominally.

On flight day 6, the Mir Structural Dynamics Experiment (MISDE) (RME 1317) was completed. At 017:05:06 G.m.t. (04:19:39 MET), the Mir assumed control of the stack for 15 minutes to provide data from Mir control firings. At 017:06:40 G.m.t. (04:21:19 MET), a series of five open-loop vernier RCS thruster firings were commanded to provide data from Orbiter control firings. Control system performance from both of these tests was nominal, but it was later learned that the Mir accelerometers had not been enabled during the Mir control period.

Consequently, on flight day 7, the Mir control portion of the MISDE test was repeated. The Orbiter moded to free drift and the Mir assumed control of the stack. The Mir immediately began an attitude maneuver indicating a divergence from the planned attitude. The maneuver was terminated, the Mir was commanded to the passive mode, and the Orbiter assumed attitude control. Several hours after the Orbiter assumed control of the stack, it was observed that the Orbiter yaw axis was remaining quiescent with attitude errors close to zero degree for long periods of time. Discussions with the Russians revealed that the gyrodynes were still controlling and had not been placed in the passive mode. The Mir was again moded to passive and nominal Orbiter control behavior resumed. No adverse impacts on the Orbiter or the Mir systems were noted as a result of the late switching.

On flight day 9, the Orbiter undocked from the Mir, executed a fly-around maneuver, and performed a separation maneuver. All Orbiter flight control functions were performed nominally.

Displays and Controls

The crew reported that the lower right vertical lamp segment of the ones digit in the minute field of the mission timer on panel O3 was burned out. The timer continued to function; however, a slight degradation in readability was present. The crew reported during debriefing that the failed lamp began to function later in the mission. The problem was not observed during ground troubleshooting, and the timer will not be replaced.

When the payload bay floodlights were turned on at 022:08:36:00 G.m.t. (09:23:08:37 MET) for payload bay door closure, the forward port floodlight was arcing and did not come up to full brightness. The crew confirmed that the floodlight was not functioning and turned it off. The loss of this light did not impact door-closure operations. The floodlight has been replaced.

Communications and Tracking Subsystems

All communications and tracking hardware and systems operated nominally throughout the mission. One condition was noted that remotely affected the communications system, and this condition involved a TEC that was uplinked at 020:01:39 G.m.t. (07:16:11 MET). The TEC failed to toggle the Ku-band extravehicular activity (EVA) protect mode bit in the Ku-band/S-band control word at its scheduled time of 020:02:20 G.m.t. (07:16:52 MET). The command had been sent to disable the EVA protect mode in the Ku-band. Analysis of the condition revealed a problem in the flight software that is discussed in the Flight Software section of the report.

After closing the ODS hatch on the day prior to undocking, the crew reinstalled the ODS centerline closed circuit television (CCTV) camera and reported difficulty receiving video from the camera. They reported at that time that they had also experienced difficulty receiving video from the centerline camera when it was installed prior to Mir docking (Flight Problem STS-81-V-08). In-flight troubleshooting consisted of power cycles, verifying the camera installation and switching to the backup centerline camera. The crew reseated the ODS-to-Mir plug, power cycled the camera and centerline camera video was restored. Troubleshooting for this condition will be performed.

Operational Instrumentation/Modular Auxiliary Data System

The operational instrumentation (OI) and modular auxiliary data system (MADS) performed satisfactorily. No significant problems or in-flight anomalies were noted.

The heater indication problem with the ODS is discussed in detail in the Structures and Mechanical Subsystem section of this report.

Structures and Mechanical Subsystems

The structures and mechanical subsystems performed nominally throughout the mission. Likewise, the tires and brakes were found in good condition for a landing on the KSC concrete runway. The landing and braking data for the mission are shown in the table on the following page.

The crew reported that that the aft-port latch on the lithium hydroxide (LiOH) stowage door was difficult to open (Flight Problem STS-81-V-01). They were unable to open the latch by hand and a tool was used. The plan was to leave this latch open until entry day. A loads analysis was performed and it showed that the LiOH door with the recumbent seat installed could withstand a 20g crash load with the aft-port latch open. A troubleshooting procedure was developed that used foil tape to obtain a mold impression of latch-pin-to-hole alignment. On the day the Orbiter undocked from Mir, the crew reported that the trouble-shooting procedure had been performed, and the pin got stuck mid-way to the latched position. Further movement of the pin required such force that the crew was unable to stop the movement before puncturing the foil. The crew reported that there did not appear to be any problem with the pin alignment, but instead the problem appeared to be binding of the latch mechanism.

The ODS performed nominally throughout the three phases of docking: docking ring extension; docking, and undocking. The ODS was powered up for docking at 015:03:19:25 G.m.t. (02:17:52:03 MET). Capture occurred nominally at 015:03:54:50 G.m.t. (02:18:27:28 MET). The electromagnetic brakes activated 5 seconds later and remained active for the nominal 30 seconds. Twenty-seven seconds after the brakes were deactivated, the automated sequence began

LANDING AND BRAKING PARAMETERS

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	2945	194.4	1.0	N/A
Nose gear touchdown	6377	143.6	N/A	-5.6

Brake initiation speed	73.6 knots
Brake-on time	33.47 seconds
Rollout distance	9,417 feet
Rollout time	67.1 seconds
Runway	33 (Concrete) KSC
Orbiter weight at landing	214,915 lb

Brake sensor location	Peak pressure, psia	Brake assembly	Gross energy, million ft-lb
Left-hand inboard 1	600	Left-hand inboard	11.45
Left-hand inboard 3	613		
Left-hand outboard 2	468	Left-hand outboard	9.45
Left-hand outboard 4	576		
Right-hand inboard 1	576	Right-hand inboard	11.6
Right-hand inboard 3	669		
Right-hand outboard 2	624	Right-hand outboard	12.19
Right-hand outboard 4	576		

driving the docking ring toward the forward position. The crew stopped the automated sequence, thus allowing the relative motion between the two vehicle to damp out. When damping was complete and since the docking ring was aligned, the crew initiated a ring-in command, which began driving the docking ring towards the final position. At 15:04:00:00 G.m.t. (02:18:32:38 MET), the ball-screw linear advance reached 7 percent and the structural hooks were activated and began driving to the closed position. The structural hooks were closed and reached a linear advance of 92 percent at 015:04:02:09 G.m.t. (02:18:35:07 MET). The docking ring was then extended, and the capture latches were activated at 015:04:02:36 G.m.t. (02:18:35:14 MET) and were deactivated two seconds later. The docking ring then proceeded to the "Final" position and that ended the automated docking sequence with a successful Orbiter/Mir docking, which was completed at 015:04:02:51 G.m.t. (02:18:35:29 MET), after which the ODS was powered down.

The ODS was powered up for undocking from the Mir at 020:01:46:24 G.m.t. (07:16:09:01 MET), and the structural hooks were activated in the open direction at 020:02:13:03 G.m.t. (07:16:45:40 MET). The structural hooks traveled from 92 percent to 5 percent after which the hooks were deactivated at

020:02:15:24 G.m.t. (07:16:48:01 MET), and the undocking was completed. The ODS was powered down about 9 minutes later, having satisfactorily completed its functions.

A known condition which involved the on/off toggling of the heater 2/DCU power bus indication recurred when the ODS was powered for undocking. The indication toggled on and off four times, throughout the undocking phase which began at 020:02:08 G.m.t. (07:16:40 MET). This problem was discovered during turnaround operations of STS-76. Troubleshooting during that flow confirmed that the problem was with only the indication. The decision was made to fly-as-is unless another problem would require replacement of an item in the heater 2/DCU power indication string.

The payload bay doors were closed at 022:09:01:41 G.m.t. (09:23:34:18 MET) in preparation for landing.

Integrated Aerodynamic and Vehicle Heating and Thermal Interfaces

The ascent and entry aerodynamics and plume heating were nominal. The prelaunch thermal interface purges were nominal. The SSME nozzles were exposed to a higher level of entry aerodynamic heating than normal with the metal being blue-colored. As a result, a metal hardness test was performed and satisfactory results were obtained.

Thermal Control Subsystem

The thermal control subsystem (TCS) performed nominally throughout the STS-81 mission, and all subsystem temperatures were maintained within acceptable limits. A few instrumentation and minor heater problems occurred, none of which impacted the mission.

A new system B heater thermostat for the OMS oxidizer high point bleed line was installed prior to flight. This thermostat has a higher set-point range which precluded a violation of the quick disconnect (QD) low-certification thermal limit in certain docked attitudes.

Aerothermodynamics

Boundary layer transition was early (Mach 16 versus Mach 8) and asymmetric, and this condition was caused by protruding gap filler at 20 percent of the windward center-line. The acreage heating as well as the local heating was above nominal as a result of the early boundary layer transition.

Thermal Protection Subsystem and Windows

The TPS performed satisfactorily. Based on lower-surface structural temperature response data (temperature rise), entry heating was significantly higher than expected. Boundary layer transition from laminar flow to turbulent flow occurred earlier (Mach 16 versus Mach 8) than nominal. The transition occurred approximately 950 and 1000 seconds after entry interface at the aft most centerline measurements of the vehicle. There was also definite bondline temperature data showing that asymmetric transition occurred on the right-hand side of the vehicle, probably because of protruding gap filler at 20 percent of the windward centerline. There was no reported physical evidence that would have caused the asymmetric transition.

The postlanding inspection revealed a total of 100 impacts of which 15 had a major dimension of 1-inch or larger. This total did not include the numerous damage sites on the base heat shield that were attributed to the flame arrestment sparkler system. A comparison of these numbers to statistics from 65 previous missions of similar configuration indicates both the total number of damage sites as well as the number of damage sites having a major dimension of one inch or larger were less than average. 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	14	48
Upper Surface	0	31
Right Side	0	7
Left Side	0	7
Right OMS Pod	1	3
Left OMS Pod	0	4
Total	15	100

The largest lower surface damage site was located on the right inboard elevon and spanned two tiles. The damage site measured 8.0 inches long by 2.5 inches wide by 0.675 inch maximum depth. The depth of the damage site indicates a probable impact of ice.

Tile damage sites aft of the LH_2 ET/Orbiter umbilical were typical. The damage was most likely caused by impacts from umbilical ice or shredded pieces of umbilical purge barrier material that was flapping in the airstream.

No tile damage was noted that may have been caused by on-orbit debris or micrometeorites.

The SSME 2 and SSME 3 dome-mounted heat shield (DMHS) closeout blankets were in excellent condition. A torn/frayed area was noted at the 7:00-8:00 o'clock position on SSME 3, however. Tiles on the vertical stabilizer stinger were intact and undamaged with the exception of one small area near the hinge of the drag parachute door.

No ice adhered to the payload bay door. No unusual tile damage sites were noted on the leading edges of the vertical stabilizer and OMS pods.

GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

The Government furnished equipment (GFE)/flight crew equipment performed satisfactorily. Anomalies were noted, but only one of these impacted the flight.

Immediately prior to the crew sleep period following flight day 1, the crew reported that the video cable from CCTV monitor 1 to the TEAC recorder would not mate to the recorder (Flight Problem STS-81-F-01). The cable connector was not keyed for the locking pins on the recorder connector. An IFM procedure was developed to work-around the connector problem. However, the crew located another cable that was keyed properly for the recorder and used that cable. As a result, the IFM procedure was not required nor performed.

The STS-4 PGSC was used for both DTO 700-12 [Global Positioning System/Inertial Navigation System (GPS/INS)] and RME 1318 (TVIS). The crew reported that the STS-4 PGSC did not recognize the GPS/INS flash-card in the lower slot of that machine (Flight Problem STS-81-F-03). Suspecting a problem with the STS-4 PGSC, the crew checked for TVIS data that was recorded earlier in the flight and did not find any data. The cause of these problems will require postflight evaluation to determine if the PGSC was at fault. As a result of the TVIS data not being found, RME 1318 was re-accomplished later in the flight using the STS-5 PGSC, and the data were recorded and downlinked to the ground controllers and sponsor for evaluation. This anomaly required the rescheduling of the exercise operations, which impacted the flight, to obtain data for the postflight evaluation.

The crew connected a camcorder to panel O19 using video interface unit (VIU) serial number 1025 and attempted to route video of the flight deck from that camcorder to a CCTV monitor. The VIU supplied power to the camcorder, but no video was seen on the monitor (Flight Problem STS-81-F-04). A spare VIU was installed and a good picture was obtained on the monitor.

During a private medical conference, two-way audio was not present via the Proshare video-conference system (Flight Problem STS-81-V-02). Another air-to-ground audio link was used in place of the link through the Proshare system. Prior to the second medical conference, the crew verified that the configuration of the link having the Proshare system was correct, but the audio was still not functioning. The crew switched from the very lightweight headset (VLHS) and its cable adapter to a portable speakers/ICOM recorder microphone and reported that the audio functioned satisfactorily in the new configuration, which was used for the remainder of the flight. Troubleshooting of the VLHS/cable adapter will be performed post flight.

At 021:09:27 G.m.t. (09:00:00 MET), a smudge was noted on the center of the camera A lens (Flight Problem STS-81-F-05). This condition will be evaluated during postflight operations.

CARGO INTEGRATION

Integration hardware performance was nominal throughout the mission, and no significant issues or in-flight anomalies were identified.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DEVELOPMENT TEST OBJECTIVES

DTO 255 - Wraparound Digital Autopilot Flight Test Verification - The data were collected from a series of maneuvers that were performed during entry and the Terminal Area Energy Management (TAEM) phases of flight. The data have been given to the sponsor for postflight evaluation. The results of the evaluation will be published in separate documentation.

DTO 312 - External Tank Thermal Protection System Performance (Method 4) - Photography of the STS-81 ET after separation was acquired with a Nikon 35 mm camera using a 400 mm lens and a 2X extender. The OMS 2 attitude maneuver was performed early to assist the crew in acquiring the ET visually.

Twenty excellent quality views of the ET were acquired. The +Y/-Z axis of the ET was imaged, and timing data were on the film. The first picture was taken approximately 20 minutes after liftoff and the last was taken 64 seconds later.

Eight divots are clearly visible on or very near the LH_2/intertank closeout flange. Charring and multiple small 'popcorn' divots are visible on the ET aft dome. The normal SRB separation-motor burn scars and aerodynamic heating marks are visible on the ET thermal protection system (TPS). Measurements from the film show that the ET was 2.3 km from the Orbiter on the first ET picture. The ET separation rate was calculated to be 4.2 meters per second, and this is typical of separation rates from previous missions.

Film of the SRB separation from the umbilical well 16 mm cameras (5 mm lens and 10 mm lens) showed no anomalous conditions and a nominal separation. The film of ET separation from the two 16 mm cameras and the 35 mm camera was not usable as separation occurred in darkness and no imagery of the ET was visible.

DTO 416 - Water Spray Boiler Quick Restart Capability - Data were collected for this DTO after orbital insertion. This was the fourth of seven flights for this DTO. The results of the data gathered for this DTO will help verify WSB support of an orbit 2 deorbit or abort once around (AOA). The crew was to turn on the WSB vent heaters when the corresponding APU lubrication oil temperature reached 245 °F.

The opportunity was missed on system 1. The controller power was not turned on until after the lubrication oil temperature had dropped to 238 °F. The system 1 vent heater was activated approximately 11 minutes 35 seconds after APU shut down, and the vent temperature rose above 122 °F two hours and five minutes later. System 2 was activated approximately 12 minutes 9 seconds after APU shutdown, and the vent temperature rose above 122 °F one hour and 51 minutes later. System 3 was activated 11 minutes 36 seconds after APU shut down and the vent temperature rose above 122 °F fifty-seven minutes later.

DTO 700-10 - Orbiter Space Vision Systems Flight Video Taping - A total of 20 video data takes were recorded for the Orbiter Space Vision Systems (OSVS) DTO. These data were recorded during three crew-sleep periods and one crew-awake period. The data takes included views from all four payload bay cameras of target dots on the ODS, Docking Module, and Orbiter bulkheads.

This was the first flight of the targets being mounted on the Orbiter bulkheads, one above each of the cameras. The purpose of the targets was to provide a known reference in the camera field-of-view that allowed precise aiming of the camera to be determined in support of the feasibility evaluation of Space Vision System (SVS) as a rendezvous tool. Preliminary assessments of the real-time downlinked video indicated that all targets were trackable by the Mission Control Center (MCC) SVS unit. Postflight analysis of the video recorded onboard during rendezvous and separation will provide data for determining the performance of this aiming technique.

Downlinked video was also used to test SVS procedures and techniques that are being investigated in support of station assembly tasks. One of the procedures is the use of camera fields-of-view that are not one of the ten preflight calibrated settings; this technique, if viable, will allow a more robust capability in the station assembly task planning process. A second technique is the use of a single target to precisely aim a camera, in lieu of the entire target array. It is hoped that this technique will reduce target implementation requirements and provide a reliable method of aiming cameras for SVS rendezvous applications.

DTO 700-12 - Global Positioning System/Inertial Navigation System - The STS-81 flight represented the first flight of the DTO 700-12 Global Positioning System/Inertial Navigation System (GPS/INS) in space. The GPS/INS designated LN-100G and manufactured by Litton, was activated and commanded into a gyrocompass alignment to coincide with the Orbiter IMU alignment that occurred prior to launch. Automatic moding of the GPS/INS from the gyrocompass alignment to the navigation mode at SRB ignition, based on motion-sensor detection, performed as designed for the DTO. The PGSC locker assembly and data acquisition system successfully demonstrated for the first time the ability of experiments to record data during the high dynamics flight phases of ascent and entry. In addition to ascent and entry, five on-orbit data takes were successfully accomplished (flight days 1, 2, 6, 9, and 10) and these generated over 60 hours of data.

The reinitialization of the GPS/INS attitude using the Orbiter personal computer (PC) decommutated-attitude data was first attempted on flight day 2, and the GPS/INS was unable to receive its data. The GPS/INS was expecting Packet 1 data, which contains Orbiter state-vector data needed by GPS/INS to conduct GPS/INS attitude re-initialization. A change was made to the PC Decommutation (PCDecom) configuration after the GPS/INS software was designed, and PCDecom now provides the Orbiter state-vector data in Data Packet 15 instead of Data Packet 1. Once this was discovered, a PCDecom software configuration fix was uplinked, and another GPS/INS DTO attitude re-initialization attempt was made. This and all future attempts failed, because the GPS/INS PGSC was incorrectly configured to the PCDecom PGSC. This was verified postflight via testing in the Shuttle Mission Simulator (SMS). As documented preflight and during the flight, the RS-422 Y-cable should have been connected so that the command PGSC (source) connector was mated to the PCDecom PGSC communications (COM) Port 3. In the actual in-flight configuration, the RS-422 Y-cable source connector was mated to PCDecom PGSC Port 2. While attitude reinitialization was not demonstrated, the primary goals of the DTO were met.

A considerable amount of data were collected on this first flight of GPS/INS in low earth orbit. The INS-only performance during ascent was reasonable for strap-down inertial devices. The GPS/INS filter performed well through main engine cutoff (MECO) because of GPS measurement incorporation. However, during the on-orbit phase, the GPS/INS filter performance had degraded by flight day 2. Postflight tests of the flight GPS/INS by the vendor confirmed an approximate 0.05 deg/hr (10 sigma) and 0.03 deg/hr (6 sigma) drift on the Y gyro and Z gyro, respectively. The composite of the above drifts resulted in a 10 to 14 degree misalignment for the GPS/INS after 10 days, which contributed to the observed entry anomaly. The reasons for the large Y and Z gyro drift were that the GPS/INS filter was designed for the aircraft environment where a vehicle's heading can be placed at specific orientations during ground procedures to give the filter adequate data to calculate the gyro biases. Since the goal of the DTO was to test the unit in the environment as close as possible to Shuttle, the filter did not have any opportunities to accurately determine the Y and Z gyro biases during ground testing. Based on the STS-81 flight, ground calibration and alignment procedures have been developed to avoid similar accumulation of drift in the Y and Z gyros for future DTO flights. The DTO also determined that to avoid degraded on-orbit performance, the acceleration thresholds on this particular GPS/INS needed to be higher to avoid incorporation of noisy data into the filter.

These STS-81 GPS/INS lessons learned have already resulted in minor firmware and procedure modifications to the GPS/INS (Honeywell H764-G) manifested on STS-84. A final report of the STS-81 GPS/INS will be available April 1997.

DTO 700-13A - Signal Attenuation Effects of ET During Ascent - Data were obtained for this DTO, and these data have been given to the sponsor for evaluation. The results of the analysis will be published in separate documentation.

DTO 700-14 - Single String Global Positioning System - The DTO equipment was set up and the PGSC was powered. The initial data review indicated that the GPS receiver apparently became lost as a result of the NC2 rendezvous maneuver. A partial reinitialization was performed that resulted in the receiver tracking four satellites. The hardware operated nominally for the remainder of the flight. Data collection was adjusted to coincide with the DTO 700-12 data takes. This coincidental operation of these two receivers allows postflight data comparisons to be made that will enhance the results of both DTOs. The DTO was successfully completed with the power down and stowage of the PGSC, but the receiver continued to operate and downlist data through entry, once the backup flight system was activated.

DTO 805 - Crosswind Landing Performance - This DTO was assigned to the flight as a DTO-of-opportunity. The conditions at landing did not support this DTO; consequently no data were collected for the DTO.

DTO 840 - Hand-held LIDAR Procedure - The hand-held LIDAR (HHL) operated nominally during the docking operations. The data have been given to the sponsor for evaluation. The results of the analysis, which will determine the usefulness of this procedure versus other proximity aids, will be published in separate documentation.

DTO 1118 - Photographic and Video Survey of Mir Space Station - Photography and video during the docking, onboard the Mir, as well as during the undocking and flyaround of the Mir were successfully collected. The flight day 8 undocking activities also included photography of the payload disconnect assembly on the Docking Module hardware that has been exposed to the Mir environment.

DTO 1125 - Measurement of Dose as a Function of Shielding Thickness - Five spheres were successfully deployed on flight day 2 and stowed on flight day 10. The crew reported during the status checks that various spheres' spectrometer screens were frozen. A reboot of the system cleared up the failures and operations resumed. Postflight analysis will determine the amount of data collected and the success of this DTO. The results will be published in separate documentation.

DETAILED SUPPLEMENTARY OBJECTIVES

DSO 487 - Immunological Assessment of Crew Members - Preflight and postflight collection of the data for this DSO was performed. These data have been given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

PHOTOGRAPHY AND TELEVISION ANALYSIS

LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS

A total of twelve 16 mm films, eight 35 mm films and twenty-four launch videos were screened and analyzed. The usual events as well as the amount of debris were noted, and no anomalous conditions were noted.

ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS

No on-orbit photography or video data were analyzed as no anomalous conditions occurred that warranted this type of analysis.

LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSIS

A total of 11 videos of the landing were analyzed for significant events and anomalous conditions. All events appeared to occur nominally and no anomalous conditions were noted.

TABLE I.- STS-81SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
APU Activation	APU-3 GG chamber pressure APU-1GG chamber pressure APU-2GG chamber pressure	012:09:22:35.633 012:09:22:36.637 012:09:22:37.538
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	012:09:26:55.104 012:09:26:55.264 012:09:26:55.424 012:09:26:55.584
Main Propulsion System Start[a]	ME-2 Start command accepted ME-1 Start command accepted ME-3 Start command accepted	012:09:27:16.442 012:09:27:16.529 012:09:27:16.664
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	012:09:27:22.984
Throttle up to 104 Percent Thrust[a]	ME-2 Command accepted ME-1 Command accepted ME-3 Command accepted	012:09:27:27.209 012:09:27:27.224 012:09:27:27.243
Throttle down to 70 Percent Thrust[a]	ME-2 Command accepted ME-1 Command accepted ME-3 Command accepted	012:09:27:54.090 012:09:27:54.104 012:09:27:54.123
Maximum Dynamic Pressure (q)	Derived ascent dynamic pressure	012:09:28:16
Throttle up to 104 Percent[a]	ME-2 Command accepted ME-1 Command accepted ME-3 Command accepted	012:09:28:23.690 012:09:28:23.705 012:09:28:23.724
Both RSRM's Chamber Pressure at 50 psi[a]	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	012:09:29:23.394 012:09:29:23.434
End RSRM [a] Action[a] Time	LH SRM chamber pressure mid-range select RH SRM chamber pressure mid-range select	012:09:29:26.104 012:09:29:26.384
SRB Physical Separation[a]	LH rate APU turbine speed - LOS	012:09:29:28.704
SRB Separation Command	SRB separation command flag	012:09:29:29
Throttle Down for 3g Acceleration[a]	ME-2 command accepted ME-1 command accepted ME-3 command accepted	012:09:34:51.537 012:09:34:51.552 012:09:34:51.573
3g Acceleration	Total load factor	012:09:34:53.4
Throttle Down to 68 Percent Thrust[a]	ME-1 command accepted ME-3 command accepted ME-2 command accepted	012:09:35:48.513 012:09:35:48.534 012:09:35:48.539
SSME Shutdown[a]	ME-1 command accepted ME-2 command accepted ME-3 command accepted	012:09:35:54.793 012:09:35:54.814 012:09:35:54.819
MECO	MECO command flag MECO confirm flag	012:09:35:55 012:09:35:56
ET Separation	ET separation command flag	012:09:36:14

[a]MSFC supplied data

TABLE I.- STS-81 SEQUENCE OF 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	012:09:42:51.464 012:09:42:57.677 012:09:43:03.161
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	012:10:10:23.3 012:10:10:23.4
OMS-2 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	012:10:11:10.8 012:10:11:10.9
Payload Bay Doors (PLBDs) Open	PLBD right open 1 PLBD left open 1	012:11:05:35 012:11:06:53
OMS-3 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	N/A 013:01:02:27.8
OMS-3 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	N/A 013:01:02:38.0
OMS-4 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	013:13:03:03.4 013:13:03:03.4
OMS-4 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	013:13:03:55.1 013:13:03:55.2
OMS-5 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	014:09:10:44.1 014:09:10:44.2
OMS-5 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	014:09:11:42.5 014:09:11:42.6
OMS-6 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	014:23:41:15.6 014:23:41:15.7
OMS-6 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	014:23:42:18.8 014:23:42:18.9
OMS-7 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	015:01:13:54.1 N/A
OMS-7 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	015:01:14:06.1 N/A
Initial Mir Physical Contact	Docking ring contact	015:03:54:50
Docking - Complete	Docking ring final position	015:04:02:43
Initiation of Undocking	Actuation of hooks no. 1 drive	020:02:13:04
Undocking - Complete	Undock complete	020:02:15:24
OMS-8 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	020:13:53:53.2 020:13:53:53.3
OMS-8 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	020:13:54:18.5 020:13:54:18.6
Flight Control System Checkout APU-3 Start APU-3 Stop	 Gas generator chamber pressure Gas generator chamber pressure	 021:05:34:39.149 021:05:38.33.510
Payload Bay Doors Close	PLBD left close 1 PLBD right close 1	022:08:58:21 022:09:00:42

TABLE I.- STS-81 SEQUENCE OF EVENTS (Concluded)

Event	Description	Actual time, G.m.t.
APU Activation for Entry	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	022:13:12:32.856 022:13:38:26.763 022:13:38:27.660
Deorbit Burn Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	022:13:17:33.2 022:13:17:33.3
Deorbit Burn Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	022:13:20:55.7 022:13:20:55:8
Entry Interface (400K feet)	Current orbital altitude above	022:13:51:12
Blackout end	Data locked (high sample rate)	No blackout
Terminal Area Energy Mgmt.	Major mode change (305)	022:14:16:23
Main Landing Gear Contact	LH main landing gear tire pressure 1 RH main landing gear tire pressure 2	022:14:22:44 022:14:22:45
Main Landing Gear Weight on Wheels	LH main landing gear weight on wheels RH main landing gear weight on wheels	022:14:22:46 022:14:22:48
Drag Chute Deployment	Drag chute deploy 1 CP volts	022:14:22:46.3
Nose Landing Gear Contact	NLG LH tire pressure 1	022:14:22:55
Nose Landing Gear Weight On Wheels	NLG weight on wheels 1	022:14:22:56
Drag Chute Jettison	Drag chute jettison 1 CP Volts	022:14:23:25.5
Wheel Stop	Velocity with respect to runway	022:14:23:51
APU Deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	022:14:43.03.473 022:14:43:08.278 022:14:43:11.861

TABLE II.- STS-81 ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-81-V-01	LiOH Stowage Door Latch Difficult to Open	012:14:21 G.m.t. 00:04:53 MET CAR 81RF02 PR STR-4-19-4416	The crew reported that the aft-port latch on the LiOH stowage door was difficult to open. The latch could not be opened by hand and a tool was used to open it. The plan was to leave the latch open until entry day. A stress analysis was performed and it was determined that the maximum load that the LiOH door could withstand with the recumbent seat installed met the 20g crash load capability, even in the event that the latch could not be closed for entry. Both the STS-76 and STS-79 crews had trouble with this latch and work was done prior to STS-79. A procedure was developed that required the crew to inspect the latch and use foil tape to make mold impressions of the pin-to-hole alignment. The crew reported that when they performed the procedure, the pin got stuck midway to the latch position. The latch required such force to get it moving again that the crew was unable to keep it from puncturing the foil tape. There did not appear to be any problem with the pin fitting into the hole. The crew stated that it felt as if the pin was bent, causing it to bind. No problems were reported when the LiOH door was latched closed for entry day. KSC: Troubleshooting was performed and cycling of the latch revealed no binding. Mold impressions were made to determine the latch pin/latch hole alignment, the door was checked for flatness, the fittings and latch were inspected, and no problems were noted. KSC believes that the problem is the lateral tolerance in the piano hinge. This tolerance allows the door to rack from left to right approximately 0.010 inch. With the door racked full starboard, the aft-port latch does not bind; however, with the door racked fully to the port side, the aft-port latch binds hard, and the conditions is repeatable. The aft port fitting was removed and sent to the shop to machine approximately 0.020 inch from the hole. The LiOH door was removed for access and will be checked for flatness..
STS-81-V-02	IMU X- and Y- axis Excessive Drift	015:14:42 G.m.t. 003:05:15 MET CAR 81RF04 PR GNC-4-19-0140	At approximately 015:14:42 G.m.t. ((03:05:15 MET), IMU 3 (S/N 3) began exhibiting increasing X- and Y-axis drift rates and drift rate trending. The drift rates increased to the 8-10 σ (sigma) range (1σ is 0.006 deg/hr). The performance signature was similar to that seen previously (most recently STS-75), where the cause of the degradation has been determined to be inadequate or contaminated lubrication in the vertical (x-y axis) gyroscope. IMU 3 was taken to standby at 017:14:33 G.m.t.(05:05:15 MET) to preserve it for use during entry and landing. IMUs 1 and 2 performed nominally throughout the mission and IMU 3 was not

TABLE II.- STS-81 ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-81-V-02 (Continued)	IMU 3 X- and Y-axis Excessive Drift (Continued)	015:14:42 G.m.t. 03:05:15 MET CAR 1RF04 PR GNC-4-19-0140 (Continued)	considered to be failed. IMU 3 was taken to operate at 022:06:21 G.m.t. (09:20:54 MET) and as expected, its performance was similar to that seen prior to it being taken to standby. The unit supported entry. KSC: IMU 3 was removed on Jan. 29, 1997 and was returned to the vendor for failure analysis. The one spare IMU that is available is being held to support a launch contingency.
STS-81-V-03	Fuel Cell 1 Indicated Performance Degradation	017:01:01 G.m.t. 004:15:33 MET CAR 81RF05 IPR 84V-0003	The fuel cell 1 calculated performance (differential voltage) started degrading at a faster-than-normal rate at 017:01:01 G.m.t. (04:15:33 MET). The degradation rate shifted from a nominal rate of approximately 0.008 V/hr to a rate of 0.018 V/hr. The third on-orbit purge was performed on all three fuel cells at 017:14:39 G.m.t. (05:05:11 MET). Data indicate that fuel cell 1 recovered some of its performance after this third purge, but it still appeared lower-than-normal. Consequently, an additional (manual) purge of only fuel cell 1 was performed 13 minutes later. The additional purge did not appear to change the performance level of fuel cell 1. Since a fuel cell 1 problem could not be immediately ruled out, a main A and B bus tie was performed prior to the sleep period on flight day 6. A comparison of the fuel cell 1 voltage and the main bus A voltage indicated that the fuel cell 1 voltage was reading 0.1 to 0.5 V low, which would lead to an erroneous calculated degradation rate. When main bus A voltage was plotted against the fuel cell 1 predicted performance, the performance appeared normal. Therefore, it is believed that the indicated performance degradation was caused by an offset in the fuel cell 1 voltage measurement. All other fuel cell 1 parameters indicated nominal performance throughout the mission. The main A and B bus tie was broken at 019:01:58 G.m.t. (06:16:30 MET). KSC: Troubleshooting did not reveal anything abnormal. Card 1 in DSC mid number 1 was removed and replaced.
STS-81-V-04	Fuel Cell 2 Cell Performance Monitor Self-Test Duration Erratic	020:08:06 G.m.t. 007:22:39 MET CAR 81RF07 PR FCP-4-19-0226	The fuel cell 2 (S/N 120) cell performance monitor (CPM) experienced several self-test cycles that lasted up to 3.5 minutes, whereas nominal self-test duration is about 2 seconds. CPM self-tests occur every seven minutes. Substack differential voltage values were nominal between self-test operations, indicating the fuel cell performance was acceptable. CPM self-test operations returned to normal after the anomalous cycles, and the condition did not impact fuel cell operations. KSC: The CPM was removed and replaced.

TABLE II.- STS-81 ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-81-V-05	Time Execute Command (TEC) Failed to Disable Ku-Band EVA Protect Mode	020:02:20 G.m.t. 007:16:52 MET CAR PR DR 110320	A problem was encountered by the Instrumentation and Communication Officer (INCO) when a time-executed command (TEC) was uplinked at 020:01:39 G.m.t. (07:16:11 MET). The TEC failed to toggle the Ku-band EVA protect mode bit in the Ku-band/S-band control word at its scheduled time. This problem appears to be the result of an incomplete implementation of Ku-band crew member protection software (CR 90850C) on the O1-25 version of the software. The Ku-band crew member protection feature added a Ku-band EVA protect mode capability to the flight software (FSW) Using this feature, the ground can define the protection area (box) for an EVA crewmember (or for the Mir) using Orbiter pitch and roll angles. If the Ku-band antenna points into this box while the mode is enabled, the FSW turns off the Ku-band traveling wave tube (TWT), preventing the Ku-band antenna from radiating within the protection box. This mode can be enabled or disabled from the ground using the Ku-band antenna control word. The ground has two ways of commanding the Ku-band EVA protect mode capability; the Ku-band/S-band antenna control uplink (uplink OP code 7), and the TEC (uplink OP code 46). These two uplinks go through separate paths in the FSW: Op code 7 implemented in the module SUL, and OP code 46 implemented in module PMQ. The ability to enable and disable the Ku-band EVA protect mode was added to the OP code 7 uplink (SUL) but was apparently not added to the OP code 46 uplink (PMQ). As a result, the capability to enable or disable the Ku-band EVA protect mode in the TEC software module PMQ resulted in a null operation. Although this was the third flight of the OI-25 version of the software, it was the first time that Ku-band EVA protect mode commanding was attempted as a part of a TEC. KSC: A software discrepancy report has been opened against this condition.
STS-81-V-06	Primary RCS Thruster F3F Fail Off	021:06:28 G.m.t. 008:21:01 MET PR FRC 4-19-0435 CAR 80RF08	During the reaction control subsystem (RCS) hot-fire test, primary RCS thruster F3F failed off on its first attempted firing. Review of the chamber pressure and injector temperature data from the firing, as well as vehicle acceleration data, indicates that the failure was most probably caused by iron nitrate contamination of the thruster oxidizer valve. The thruster remained deselected for the remainder of the mission. KSC: The thruster F3F chamber pressure (Pc) tube was inspected for blockage and none was found. Thruster F3F and the

TABLE II.- STS-81 ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-81-V-06 (Continued)	Primary RCS Thruster F3F Failed Off (Continued)	021:06:28 G.m.t. 008:21:01 MET PR FRC 4-19-0435 CAR 80RF08 (Continued)	other three thrusters on the manifold have been removed and replaced. This action required removing the forward RCS module and shipping it to the Hypergolics Maintenance Facility (HMF). The forward RCS module has been reinstalled on the vehicle.
STS-81-V-07	APU 3 Chamber Pressure Shifted Downward	022:14:37 G.m.t. Postlanding CAR 81RF06 IPR 84V-0008	Approximately 15 minutes after wheels stop, the APU 3 gas generator chamber pressure measurement shifted downward approximately 200 psi in two steps. Data review indicate that the shift was most probably caused by a bias shift in the chamber pressure transducer. This would be the fourth transducer that has exhibited this performance in the past 18 months. This transducer provides the best indication of proper APU performance and is mandatory for launch in the Launch Commit Criteria. KSC: Troubleshooting has verified that the chamber pressure transducer caused the shift. The APU has been removed and replaced.
STS-81-V-08	Unable to View ODS Center-Line Camera Video	019:14:12 G.m.t. 07:04:44 MET	After hatch closing, the crew disconnected the Mir camcorder from the ODS TV connector and configured for the ODS center-line camera. The crew reported their attempts to view video from the centerline camera were unsuccessful. The crew also confirmed installation of the ODS-to-Mir plug connected to the CIP J101 connector. Downlink of the centerline camera video (VSU input PL2) did not provide interleaved data which indicated that either the centerline camera (CTVC) was powered off, or video from the camera was not reaching the VSU. The same condition was evident with the backup centerline CTVC. The crew successfully activated the prime centerline CTVC-to-middeck TV port M058F. At 019:14:53 G.m.t. (07:05:25 MET), video from the centerline camera was recovered. The crew reported no problems with the truss camera indicating that at least part of the Mir-to-ODS plug was always functioning correctly. Questions were sent to the crew in an effort to better understand the actions taken in restoring the video. Data evaluation and crew responses to the questions has led the Engineering personnel to believe that the camera was not receiving power, perhaps due to a problem at the SSP (circuit breaker, switch, or wiring). KSC: Postflight troubleshooting is being performed.

TABLE III.- GOVERNMENT FURNISHED EQUIPMENT PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-81-F-01	Monitor-to-VIU/CM Cable Failed to Mate to TEAC	012:15:04 G.m.t. 00:05:36 MET	Just prior to crew sleep following flight day 1, the crew reported that the monitor-to-VIU/CM cable from CCTV monitor 1 to the TEAC recorder would not mate to the recorder. The cable connector was not keyed to accept the locking pins on the TEAC recorder connector. The two cables connected to CCTV monitors 1 and 2 for launch were part no. SED 39122074-303, serial nos. 1008 and 5009. The S/N 1008 cable had flown previously. This was the first flight for the S/N 5009 cable. The 1000 series cables were built by a previous contractor and the 5000 series were built by Boeing/Flight Equipment Processing Contractor (FEPC). The cables were built to the same drawing and specification. A comparison of the in-stock hardware revealed no differences between the two series and the build paper showed that the correct connectors were used on the cable on this flight. The cable used for CEIT should have been the same as the one used for the flight. A third cable (S/N 5010) was located in a camcorder bag. The crew called down after wake-up on flight day 2 and stated that the S/N 5009 cable had been replaced with a S/N 5010 cable from the camcorder camera bag. The two good cables supported the mission very satisfactorily, and all applicable mission objectives were accomplished. The cable was returned to JSC for evaluation.
STS-81-F-02	OCA Video Conferencing Audio Problem	013:12:42 G.m.t. 001:03:15 MET	During a private medical conference (PMC) at 013:12:42 G.m.t. (01:03:15 MET), two-way radio was not present via the Proshare video conference system. The private air-to-ground (A/G) link was used in place of the Proshare audio. The crew performed a troubleshooting procedure prior to the second PMC in which they verified that the configuration was correct, but the audio was still not functioning. The crew switched the very lightweight headset (VLHS) with portable speakers/ICOM recorder microphone and reported that the audio functioned in the new configuration. The crew performed further troubleshooting on the VLHS by switching the microphone and headphone inputs to verify that

TABLE III.- GOVERNMENT FURNISHED EQUIPMENT PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-81-F-02	OCA Video Conferencing Audio Problem	013:12:42 G.m.t. 001:03:15 MET	the cable jacks were not mislabeled. The audio did not function in this configuration. The portable speakers/ICOM recorder microphone were used in place of the VLHS for all future Proshare video conferences. The VLHS and its adapter cable were returned to JSC for troubleshooting.
STS-81-F-03	STS-4 PGSC Problems	018:15:46 G.m.t. 06:06:19 MET	The STS-4 PGSC was used for both DTO 700-12 (GPS/INS) and RME 1318 (TVIS). The crew reported that the STS-4 PGSC would not recognize the GPS/INS flash-card in the lower slot of that machine. Suspecting a problem with the STS-4 PGSC, the crew checked the TVIS PCMCIA card for data and did not find any. It is unclear as to the cause of these problems. However, as a result of these problems, the STS-4 PGSC is suspect. The PGSC was returned to JSC for evaluation.
STS-81-F-04	VIU S/N 1025 Failure	021:03:42 G.m.t. 08:18:15 MET	The crew connected a camcorder to panel 019 using video interface unit (VIU) S/N 1025 and attempted to route video of the flight deck from that camcorder to the CCTV monitor. The VIUs convert Orbiter 28 Vdc to 6 Vdc for the camcorder and perform video signal balancing for interface to the Orbiter CCTV system. The VIU supplied power to the camcorder, but no video was seen on the monitor. The VIU was swapped with a spare unit, and a good picture was obtained on the monitor. The VIU was returned to JSC for troubleshooting.
STS-81-F-05	Smudge on Camera A Lens	021:09:27 G.m.t. 09:00:00 MET	Camera A had a smudge on the center of its lens. The condition will be evaluated postflight.

DOCUMENT SOURCES

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

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

ACRONYMS AND ABBREVIATIONS

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

AOA	abort once around
APU	auxiliary power unit
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
BTS	Biotechnology System
CCTV	closed-circuit television
CEI	contract end item
CGBA	Commercial Generic Bioprocessing Apparatus
CMRS	crew medical restraint system
CPCG	Commercial Protein Crystal Growth experiment
CPM	cell performance monitor
CREAM	Cosmic Radiation Effects and Activation Monitor
CWC	contingency water container
DMHS	dome-mounted heat shield
DOSTEL	Dosimetry Telescope
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
ΔV	differential velocity
ECLSS	Environmental Control and Life Support System
EDLS	Enhanced Dynamics Load Sensor
EPDC	electrical power distribution and control
EOR/F	enhanced Orbiter refrigerator/freezer
ESC	Electronic Still Camera
e.s.t.	eastern standard time
ET	External Tank
ETTF	Extreme Temperature Translation Furnace
EVA	extravehicular activity
FCE	flight crew equipment
FCP	fuel cell powerplant
FCS	flight control system
FCV	flow control valve
FES	flash evaporator system
FSW	flight software
ft/sec	feet per second
g	gravity
GCIL	ground control interface logic
GFE	Government furnished equipment
GG	gas generator
GGVM	gas generator valve module
GH_2	gaseous hydrogen
G.m.t.	Greenwich mean time
GPS	Global Positioning System
H_2	hydrogen
HHL	Hand-held LIDAR

HPFTP	high pressure fuel turbopump
HPOTP	high pressure oxidizer turbopump
ICOM	intercommunications
IFM	in-flight maintenance
IMU	inertial measurement unit
INS	inertial navigation system
Isp	specific impulse
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt/hour
lb	pound
lbm	pound mass
LCC	Launch Commit Criteria
LED	light emitting diode
LH_2	liquid hydrogen
LiOH	lithium hydroxide
LMSMS&S	Lockheed Martin Space Mission Systems and Services
LO_2	liquid oxygen
MADS	modular auxiliary data system
MC	midcourse correction (maneuvers)
MCC	Mission Control Center
MECO	main engine cutoff
MET	mission elapsed time
MISDE	Mir Structural Dynamics Experiment
mmHg	millimeters Mercury
MMT	Mission Management Team
MPS	main propulsion system
MSX	Midcourse Space Experiment
NASA	National Aeronautics and Space Administration
NC1- 6	rendezvous maneuvers (four)
NCC	corrective combination maneuver
nmi.	nautical mile
NPSP	net positive suction pressure
NSTS	National Space Transportation System (i.e., Space Shuttle Program)
O_2	oxygen
OCA	Orbiter Communications Adapter
ODS	Orbiter docking system
OI	operational instrumentation
OMDP	Orbiter Maintenance Down Period
OME	orbital maneuvering engine
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OPM	Optical Properties Monitor
OSVS	Orbiter Space Vision Systems
PAL	protuberance air load
PC	personal computer
PCS	pressure control system
PCT	post contact thrust
PGSC	payload general support computer

PMBT	propellant mean bulk temperature
ppm	parts per million
PRSD	power reactant storage and distribution
psi	pound per square inch
psia	pound per square inch absolute
QD	quick disconnect
RCS	reaction control subsystem
RME	Risk Mitigation Experiment
RSRM	Reusable Solid Rocket Motor
S&A	safe and arm
SAMS	Space Acceleration Measurement System
SLF	Shuttle Landing Facility
S/N	serial number
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSCIF	Space Station Middeck Interface Facility
SSME	Space Shuttle main engine
STS	Space Transportation System
SVS	Space Vision System
TAEM	terminal area energy management
TCS	thermal control subsystem/trajectory control sensor
TEC	time executed command
TI	terminal phase initiation
TIG	time of ignition
TOC	total organic carbon
TPS	thermal protection system/subsystem
TVIS	Treadmill Vibration Isolation and Stabilization System
TWT	traveling wave tube
V	Volt
WCS	waste collection system
Vdc	volts direct current
V/hr	volts per hour
VIU	video interface unit
VLHS	very lightweight headset
VOA	Volatile Organic Analyzer
WCL	water coolant loop
WEK	Water Experiment Kit
WSB	water spray boiler

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