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STS-71
SPACE SHUTTLE
MISSION REPORT

August 1995

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

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MISSION REPORT

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INTRODUCTION

The STS-71 Space Shuttle Program Mission Report summarizes the Payload activities and provides detailed data on the Orbiter, External Tank (ET), Solid Rocket Booster (SRB), Reusable Solid Rocket Motor (RSRM), and the Space Shuttle main engine (SSME) systems performance. STS-71 is the 100th United States manned space flight, the sixty-ninth Space Shuttle flight, the forty-fourth flight since the return-to-flight, the fourteenth flight of the OV-104 Orbiter vehicle Atlantis, and the first joint United States (U.S.)-Russian docking mission since 1975. In addition to the OV-104 Orbiter vehicle, the flight vehicle consisted of an ET that was designated ET-70; three SSMEs that were designated 2028, 2034, and 2032 in positions 1, 2, and 3, respectively; and two SRBs that were designated BI-072. The RSRMs that were an integral part of the SRBs were designated 360L045A for the left SRB and 360W045B for the right SRB.

The STS-71 mission was planned as a 10-day plus 1-day-extension mission plus 2 additional days for contingency operations and weather avoidance. The primary objectives of this flight were to rendezvous and dock with the Mir Space Station and perform on-orbit joint U.S.-Russian life sciences investigations, logistical resupply of the Mir Space Station, return of the United States astronaut flying on the Mir, the replacement of the Mir-18 crew with the two-cosmonaut Mir-19 crew, and the return of the Mir-18 crew to Earth. The secondary objectives were to perform the requirements of the IMAX Camera and the Shuttle Amateur Radio Experiment-II (SAREX-II).

The STS-71 Space Shuttle Mission Report fulfills the Space Shuttle Program requirement as documented in NSTS 07700, Volume VIII, Appendix E. The requirement states that each major 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 STS-71 sequence of events is shown in Table I, the Orbiter Problem Tracking List is shown in Table II, the Government Furnished Equipment (GFE)/Flight Crew Equipment (FCE) Problem Tracking List is shown in Table III, and the Marshall Space Flight Center (MSFC) Problem Tracking List is shown in Table IV. In addition, the Shuttle Payload and Integration in-flight anomalies are referenced in applicable sections of the Report. Appendix A lists the sources of data, and Appendix B provides the definition of acronyms and abbreviations used in the document. All times from liftoff through landing are given in Greenwich mean time (G.m.t.) and mission elapsed time (MET).

The five-person STS-71 launch crew consisted of Robert L. "Hoot" Gibson, Capt., U. S. Navy, Commander; Charles J. Precourt, Lt. Col., U. S. Air Force, Pilot; Ellen S. Baker, M. D., Civilian, Mission Specialist 1; Gregory J. Harbaugh, Civilian, Mission Specialist 2; and Bonnie Dunbar, Ph.D., Civilian, Mission Specialist 3. STS-71 was the fifth space flight for the Commander, the fourth space flight for Mission Specialist 3, the third space flight for Mission Specialists 1 and 2, and the second space flight for the Pilot. In addition to the five-person U. S. crew, two Russian cosmonauts were taken to the Mir Space Station. These two cosmonauts, who relieved the present Mir-18 crew, were Anatoly Y. Solovyev, Mir-19 Commander, and Nikolai M. Budarin, Mir-19 Flight Engineer. The STS-71/Mir-19 flight was the fourth space flight for the Mir-19 Commander, and the first space flight for the Mir-19 Flight Engineer.

The Mir-18 crew of two Russian cosmonauts and one U. S. astronaut was returned to Earth from the Mir Space Station. The crew members were Vladimir N. Dezhurov, Lt. Col., Russian Air Force, Mir-18 Commander; Gennady M. Strekalov, Civilian, Mir-18 Flight Engineer; and Norman E. Thagard, M. D., Civilian, Mir-18 Cosmonaut Researcher. The Mir-18/STS-71 flight was the first space flight for the Mir-18 Commander, the fourth space flight for the Mir-18 Flight Engineer, and the fifth space flight for the Mir-18 Cosmonaut Researcher. On March 14, 1995, the Mir-18 Cosmonaut Researcher became the first U. S. astronaut to be launched into earth orbit on a Russian launch vehicle. The Mir-18 crew was also the first crew to be returned to Earth in a vehicle other than the one that took them to orbit.

MISSION SUMMARY

The STS-71 launch that was planned for June 23, 1995, was scrubbed at approximately 9:45 a.m. e.d.t. because ET propellant loading could not be performed due to lightning in the area.

The second attempt to launch STS-71 on June 24, 1995, was also scrubbed near the end of the T-9 minute hold because of unacceptable weather conditions that were not predicted to clear during the launch window. A three-day stand-down was instituted because of the forecast of continued unfavorable launch weather. During the stand-down, the power reactant storage and distribution (PRSD) subsystem cryogenics were replenished.

During the launch countdown on June 27,1995, a small leak of approximately 0.2 lb/hr was present from the PRSD subsystem oxygen tank 1. This leak continued throughout the mission with no impact to the planned activities. Postflight troubleshooting revealed a leak in the tank 1 fill quick disconnect (QD) poppet.

The vehicle was launched at 178:19:32:18.988 G.m.t. (3:32:19 p.m. e.d.t.) on June 27, 1995, from launch complex 39A. The orbital inclination was 51.6 degrees. The ascent phase was nominal, and no orbital maneuvering subsystem (OMS) 1 maneuver was required because of the satisfactory ascent trajectory. The OMS 2 maneuver was performed at 178:20:15:16.8 G.m.t. (00:00:42:57.8 MET). The maneuver was 47.7 seconds in duration and the differential velocity (ΔV) was 74 ft/sec. The orbit achieved was 160 by 85.3 nmi.

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

The postflight disassembly of the nozzle assemblies for the RSRMs revealed a nozzle internal joint gas path and primary O-ring erosion. An investigation into the cause of this problem was continuing as this report was being written. The findings of this investigation will be published in a separate report.

An analysis of the vehicle propulsive performance during ascent was made using vehicle acceleration and preflight propulsion prediction data. From these data, the average flight-derived engine specific impulse (Isp) that was determined for the time period between SRB separation and start of 3-g throttling was a satisfactory 452.1 seconds as compared to the MPS tag value of 452.67 seconds.

Review of ascent data indicated that the gaseous hydrogen (GH2) flow control valve (FCV) for SSME 3 exhibited slight sluggishness during the latter portion of ascent. The amount of sluggishness was minor and had no effect on overall GH2 system pressurization.

Ascent data also showed that the SSME 1 liquid hydrogen (LH2) recirculation valve closed slowly when commanded at T-10 seconds just prior to LH2 prevalve opening. This valve isolates hydrogen in the event of a premature engine shutdown; therefore, its slow closure posed no impact to the STS-71 ascent because no premature engine shutdown occurred.

The payload bay door opening sequence was completed satisfactorily at 178:21:07:15 G.m.t. (00:01:34:56 MET).

At 178:23:10:25.2 G.m.t. (00:03:38:06.2 MET), an OMS 3 dual-engine straight-feed firing was initiated to raise the orbit to 210 x 159 nmi. This firing was approximately 136.9 seconds in duration and imparted a 220.7 ft/sec ΔV to the vehicle. Subsystem performance was nominal for the firing.

The single-engine OMS-4 firing was approximately 12.4 seconds in duration. The firing was performed at 179:10:49:35.8 G.m.t. (00:15:17:16.8 MET) using the left OMS engine. A total of 10 ft/sec ΔV was imparted to the vehicle, and data indicate nominal subsystem performance.

The PRSD hydrogen manifold 1 valve failed to close when the flight day 1 pre-sleep cryogenics reconfiguration was performed. Following the failure, the oxygen manifold 1 valve was opened and both manifold 2 valves were closed for all sleep periods. Postflight inspection revealed a broken lug in the valve command ground path that prevented the valve from closing.

The initial preparation of the Androgynous Peripheral Docking System (APDS) was accomplished by system power-up and guide-ring extension. The guide ring was placed in the ready-for-docking position. APDS power-up occurred at approximately 179:15:44 G.m.t. (00:20:12 MET). The guide-ring extension occurred nominally within the planned dual-motor drive time of approximately 2.5 minutes. All status data from APDS were normal.

The crew found that no batteries were installed in the hand-held light distance and ranging (LIDAR) battery packs. An in-flight maintenance (IFM) procedure was developed that enabled the LIDAR to use Orbiter power via a break-out box. The LIDAR operated satisfactorily in this power configuration.

A dual-engine, 46-second OMS firing (NC4) was performed at 180:07:57:17.2 G.m.t. (01:12:24:58.2 MET) and a ΔV of 75 ft/sec was imparted to the vehicle.

An OMS left-engine-only terminal phase initiation (TI) maneuver was performed at 180:09:31:01.2 G.m.t. (01:13:58:42.2 MET). The 9.2-second maneuver imparted a ΔV of 7.2 ft/sec, and the resultant orbit was 218 by 208 nmi.

The Ku-band radar acquired the Mir at 132,000 ft, and lock was maintained until the Ku-band was switched to the communications mode. The ultra-high frequency (UHF) communications system, trajectory control sensor, hand-held LIDAR equipment, and centerline TV all performed satisfactorily during the rendezvous and docking activity.

Shuttle-approach plume loads on the Mir were benign, since no closing-rate braking was required. Only one significant reaction control subsystem (RCS) 0.080-second duration thruster firing occurred. It was an aft Z-axis thruster that was aligned toward the fully deployed Spektr module solar panel. Reconstructed structural margins were high.

The docking mechanism was powered up nominally prior to contact. Docking contact conditions were excellent. The closing rate was very close to the targeted 0.1 ft/sec. Interface contact occurred with very small misalignments. The lateral misalignment was less than one inch and the angular misalignment was less than 0.5-degree per axis. The closing velocity was approximately 0.107 ft/sec at contact. Post-contact thrusting (PCT) was initiated about 0.5 second before indicated capture. The capture-latch indication occurred at approximately 180:13:00:13.9 G.m.t. (01:17:27:18.9 MET). Since the PCT sequence was 2.4 seconds in duration, the second phase of the pulsing occurred after capture. The axial load response peaked at approximately 1000 kgf, two seconds after capture. The post-capture relative motion was benign. Reconstructed docking loads were benign with axial compression loads about 60 percent of the allowable at the Shuttle-Mir interface. Minimum load margins were 16 percent on Krystall-Base Module axial tension as predicted preflight, and 50 percent on Shuttle-Mir interface bending moment. Lateral shear loads were not significant.

The relative vehicle rotation peaked at approximately 2.0 degrees about 22 seconds after capture. All motion was damped out and the docking mechanism ring-align signal was received within 120 seconds of capture. Dampers deactivated nominally 35 seconds after capture and the ring drive command for extension occurred 60 seconds after capture. The ring drive was stopped nominally to allow for further damping. The ring-in command was given approximately one minute later. The ring drive and structural hooks performed nominally, mating the two vehicles, and docking was completed at 180:13:08:17.9 G.m.t. (01:18:35:22.9 MET). The system was powered down nominally.

External airlock-to-vestibule and Mir-to-vestibule atmospheric leak checks were performed with no leakage noted. At 180:13:59 G.m.t. (01:18:27 MET), vestibule and Mir pressures were equalized to 2.24-psia lower than the external airlock pressure (14.68 psia). The pressurization took two minutes. At 180:14:37 G.m.t. (01:19:05 MET), the upper hatch equalization valve was opened to equalize Shuttle and Mir pressures. The initial Orbiter cabin pressure was 14.68 psia and equalization was complete in 3.5 minutes with a resulting pressure of 13.20 psia.

At 181:05:08:59 G.m.t. (02:09:36:40 MET) general purpose computer (GPC) 4 (s/n 536), which had been functioning as the systems management (SM) machine, failed to sync with GPC 1 and was declared failed by GPC 1. Analysis confirmed that the fail-to-sync was the result of a hardware event, and it was most likely caused by a radiation upset. GPC 4 was reinitialized and the GPC operated satisfactorily for the remainder of the mission.

The forward RCS was using more propellant than predicted while in the inertial-hold attitude and docked with the Mir. As a result, a change to a gravity-gradient attitude was made that resulted in a large reduction in propellant consumption. The increased propellant usage in the inertial-hold attitude only occurred during negative pitch maneuvers. Analysis showed that this phenomenon was caused by the effects of R5D and L5D RCS thruster-plume impingement upon the elevons and body flap. The effect of this phenomenon is virtually undetectable in the Orbiter-only configuration; however, it is believed to be magnified in the Shuttle-Mir docked configuration because the center-of-gravity (c.g.) is external to the vehicle.

A fault message occurred on PRSD hydrogen (H_2) manifold 1 at 182:01:34:25 G.m.t. (03:06:02:06 MET) indicating that the isolation valve was closed when it should be open. The crew cycled the switch twice without effect. The valve was verified to be open using tank and manifold pressure data. The indication toggled several times during the flight.

At 182:08:50:30 G.m.t. (03:13:18:11 MET), a cathode ray tube (CRT) 2 built-in test equipment (BITE) message was annunciated against display electronics unit (DEU) 2. This error was attributed to a known "short store complete" scenario, which can occur on -0108 or -0109 DEUs (DEU 2 S/N 29 is a -0108). Crew procedures corrected the BITE condition.

The SM checkpoint at 182:09:10:36 G.m.t. (03:13:38:17 MET) failed with a "checkpoint fail" and an "off/busy" message annunicated against mass memory unit (MMU) 1. The SM checkpoint was reattempted successfully on MMU 1, and the MMU operated satisfactorily for the remainder of the flight. The signature observed is consistent with a known MMU power-supply problem caused by internal noise. A design modification exists to correct this phenomena.

The primary air-to-air very high frequency (VHF) radio was unable to transmit to the Mir. The crew switched to the backup VHF radio and two-way communications with the Mir were restored. Troubleshooting did not regain function of the primary VHF radio.

The Risk Mitigation Experiment (RME) 1301, Mated Structural Dynamics test, was performed. Analysis indicates nominal structural modeling.

The Mir assumed the attitude control function for the combined vehicles at 183:10:13 G.m.t. (04:14:41 MET). Mir control was monitored via the Shuttle digital autopilot (DAP) estimator. Mir appeared to require gyrodyne desaturation twice as often as shown in preflight estimates, but overall Mir control was satisfactory. The Orbiter resumed attitude control at 183:14:55 G.m.t. (04:19:23 MET). The Orbiter elevons were parked at -7.5° to aid in the investigation of the higher-than-predicted propellant usage during Orbiter-controlled inertial attitudes.

Eighteen Russian water tanks and three contingency water containers (CWCs) were filled for use by the Mir for waste system flushing and electrolysis. A total of 1,067 lb of water was provided to the Mir. Also during the docked period, the Shuttle environmental control system was used to raise the internal pressure of the Mir to 15.1 psia. In this process, a total of 48 lb of oxygen and 87 lb of nitrogen was provided to the Mir. This repressurization was requested by the Russians to improve the Mir consumable margins.

Development Test Objective (DTO) 1120, Mated Shuttle and Mir Free Drift Experiment, was successfully performed from 184:09:30 G.m.t. to 184:13:45 G.m.t. (05:12:58 MET to 05:18:13 MET). The attitude deviations remained below the 10-degree breakout limit. This test was performed at the 2-degree biased gravity orientation (GO) 1.2 attitude. Over the duration of the test, the yaw-axis attitude error was growing slowly in magnitude and approached the 10-degree limit. Following the test, the Shuttle resumed nominal control of the mated stack.

The Mir hatch was closed at 184:19:35 G.m.t.(06:00:03 MET) and the Orbiter hatch was closed at 184:19:48 G.m.t. (06:00:16 MET). At 184:19:59 G.m.t. (06:00:27 MET), the vestibule depressurization began. Low flow was observed when the primary depressurization valves were opened. After the low flow was noted, the secondary depressurization valves were also opened, but no change in flow rate occurred; however, completed depressurization of the vestibule was achieved prior to undocking. The slow vestibule depressurization appeared to be due to a thermal insulation blanket blocking the depressurization valve port.

The final preparations for undocking were performed, and the Orbiter undocking activities were successfully completed at 185:11:09:41.8 G.m.t. (06:15:37:22.8 MET). Data analysis indicated nominal APDS performance.

Both trajectory control sensor (TCS) units were activated at approximately 185:10:35 G.m.t. (06:15:03 MET), and the units operated satisfactorily throughout the undocking and initial separation. The Ku-band radar tracked the Mir throughout the undocking and separation activities to a range in excess of 50,000 feet.

DTO 1122, Androgynous Peripheral Assembly System (APAS) Thermal Data, was performed satisfactorily. No hot-case or cold-case attitude breakouts were required as all docking mechanism temperatures remained within the breakout criteria.

At 186:11:57 G.m.t. (07:16:25 MET), a vernier RCS firing test was performed to help resolve the increased propellant usage noted during docked operations. Analysis of the results indicates that the actual unmated Orbiter negative-pitch acceleration showed little variance from ground-calculated acceleration based on current predictions of Orbiter mass properties. This confirms that the effect of the modeling error is unique to the mated Shuttle/Mir configuration.

The crew reported that the Hasselblad 70mm camera (s/n 1026) shutter-release button was sticking. When the shutter release button was depressed, the camera cycled through the remainder of the film magazine. An IFM procedure was performed in which the shutter release button was moved from the primary receptacle to the secondary receptacle. The IFM was successful and the camera performed nominally for the remainder of the mission. The crew also stated that the lens had jammed, but they were able to restore proper operation of the lens. Another Hasselblad 70mm camera was available if the one in use had become inoperable.

Part I of the flight control system (FCS) checkout was performed at 187:10:27:32.280 G.m.t. (08:14:55:13.292 MET) using auxiliary power unit (APU) 1. APU 1 ran for 5 minutes, 28.710 seconds and 11 pounds of fuel were used. Data analysis shows nominal performance.

During the RCS hot-fire, RCS thruster R2U failed off due to low chamber pressure (2.5 psia). Injector temperatures showed pilot-valve-only flow through the oxidizer valve, and this is consistent with prior thruster failures caused by metal-nitrate contamination. The failure was on the first firing of R2U during this mission, and the thruster was left deselected for the rest of the flight.

During the landing-minus-1-day communications system checkout, short dropouts of network signal processor (NSP) and communications security (COMSEC) frame synchronizations were experienced. Troubleshooting isolated the problem to transponder 2. The system was configured to use transponder 1 for the remainder of the flight with no recurrence of the frame synchronization dropouts.

During entry preparations, the modular auxiliary data system (MADS) recorder did not begin recording when commanded at 188:13:31 G.m.t. (09:17:59 MET). The mode switch was found to have been placed in the neutral position and this prohibited uplink control of the MADS.

All entry stowage and deorbit preparations were completed in preparation for entry on the nominal end-of-mission landing day. The payload bay doors were successfully closed and latched at 188:11:06:03 G.m.t. (09:15:34:44 MET). The deorbit maneuver for a Kennedy Space Center (KSC) Shuttle Landing Facility (SLF) landing was performed at 188:13:45:19.3 G.m.t. (09:18:13:00.3 MET), and the maneuver was 213.3 seconds in duration with a ΔV of 373 ft/sec.

During entry, the gearbox pressure transducer became erratic when the APU 3 gearbox repressurization circuit was activated, and this resulted in approximately 80 percent of the GN_2 supply bottle being expelled into the gearbox. This excessive repressurization caused gearbox pressure to rise to over 30 psi, whereas a normal repressurization increases gearbox pressure to approximately 10 psi. The higher pressure did not affect the operation of APU 3. Postflight troubleshooting indicated that the gearbox GN_2 pressure transducer malfunctioned.

Entry was completed satisfactorily, and main landing gear touchdown occurred at KSC on SLF concrete runway 15 at 188:14:54:36 G.m.t. (09:19:22:17 MET) on July 7, 1995. The Orbiter drag chute was deployed at 188:14:54:38.8 G.m.t. and the nose gear touchdown occurred 6.2 seconds later. The drag chute was jettisoned at 188:14:55:09.2 G.m.t. with wheels stop occurring at 188:14:55:28 G.m.t. The rollout was normal in all respects. The flight duration was 09 days 19 hours 22 minutes and 17 seconds. The APUs were shut down 20 minutes 50 seconds after landing.

The successful completion of the STS-71 mission resulted in 100 percent of all objectives of the mission being accomplished. These objectives included the successful exchange of the Mir-18 and Mir-19 crews, retrieval of science data, the science resupply of the Mir for future missions, and the completion of the joint science activities.

SPACE STATION IMPLICATIONS, RECOMMENDATIONS AND LESSONS LEARNED

This first Shuttle-Mir flight provided new and valuable insights into Orbiter subsystem issues that will affect future Shuttle-Mir and International Space Station (ISS) missions. These new insights are discussed in the following paragraphs.

REACTION CONTROL SUBSYSTEM

Marginal heater power on the RCS vernier thrusters can result in injector temperatures below the 130 °F operational limit during extended non-active docked periods at low beta angles. The Mir cases were evaluated, and as a result, a flight rule was instituted to restrict vernier operation at temperatures below 130 °F based on extensive ground data monitoring. This flight rule requires re-evaluation for ISS docked missions based on the predicted thermal environment, ground monitoring capability, and workaround capabilities. Engineering is assessing the validity of the 130 °F operating limit and the 90 °F non-operating limit for vernier thrusters. Additionally, a DTO is being considered to determine how low the temperatures will actually reach in a docked attitude.

RCS vernier thruster usage was significantly higher than seen during typical missions in the areas of total pulses, duty cycle, firing duration, and accumulated thermal cycles. The following table reflects thruster firings until approximately 8 hours prior to entry.

VERNIER THRUSTER FIRINGS

Thruster	Firings	Firing time, sec	Thermal cycles
F5L	3530	4789	136
F5R	4435	4987	127
L5D	2839	8157	223
L5L	2683	3137	67
R5D	3078	8285	225
R5R	3342	2972	62

The number of firings falls well within the 500,000-cycle certified life; however, the firing time on the aft down-firing thrusters was marginal for the 125,000-second certified limit (approximately 15 missions equivalent). Additionally, a large number of long-duration firings (> 50 seconds) occurred on the aft down-firing thrusters for attitude maneuvering with some approaching the 125-second duration limit for steady-state firings. Also, the high duty cycles during the attitude-hold operations require evaluation to determine if the 1000-cycle/hour limit was exceeded. As a result, the RCS vernier thruster usage on STS-71 requires detailed evaluation to assess the long-term effects on the RCS hardware.

From a certified life standpoint, concerns exist primarily with the chamber/nozzle coating damage, which would require chamber replacement. Coating damage is driven primarily by thermal cycles. Although all vernier thruster usage parameters vary depending on the mission profile and mission duration, the average vernier mission thermal cycles for the previous 54 missions are as follows:

a. F5L and F5R thrusters - 42 thermal cycles per mission;
b. L5D and R5D thrusters - 105 thermal cycles per mission; and
c. L5L and R5R thrusters - 50 thermal cycles per mission.

With the STS-71 thermal cycles being on the order of 1.3 to 3 times higher than the average, chamber wear-out rate would be expected to increase if future Mir- and ISS-docked missions result in similar usage. This condition poses a spares risk to the program and must be evaluated by the engineering and logistics areas. If RCS vernier thruster usage can be optimized (reduced) by improved DAP models and/or primary RCS thruster usage, the vernier usage may be significantly reduced from the levels seen on STS-71, assuming future missions of similar duration.

A software patch is being developed for STS-74 to enable DAP logic that may alleviate the high propellant consumption. As assessment of spares is also underway by both Engineering and Logistics personnel.

Thermal issues continue to be a concern for future ISS-docked scenarios in which cold vernier thrusters and hot primary thrusters are expected. A plan for recertifying the thruster valves for the expected ISS thermal environment is being developed.

ACTIVE THERMAL CONTROL SUBSYSTEM

During the postlanding operations, KSC used the -508 cooling cart to maintain the evaporator outlet temperature between 35 °F and 40 °F to demonstrate this capability for future ISS missions carrying the mini-pressurized logistics module (MPLM). Further demonstrations are not required during Shuttle-Mir.

ATMOSPHERIC PRESSURE CONTROL SYSTEM

During the Mir/Orbiter repressurization, the high oxygen (O_2) flow caused the Freon cooling loop temperature to drop from 40 °F to 35 °F at the O_2 heat exchanger. This raises a concern for O_2 transfer to the ISS as Freon temperatures need to remain above 32 °F to prevent freezing the water loops. Analysis of the ISS repressurization effects on Freon temperature will be performed. Upcoming Shuttle-Mir repressurizations will not be as extensive as STS-71, so Freon temperatures approaching 32 °F should not be a concern for the remainder of these flights.

COMMUNICATIONS AND TRACKING SUBSYSTEMS

Communications link performance degradation was observed during the Shuttle/Mir docked configuration. Signal degradation and/or complete link dropouts have been attributed to signal deflection/defraction (multipath effects) and blockage from the Mir structure. The premission analysis through computer simulations using planned attitude information provided a valuable insight into this condition. The postmission correlation of the premission results and the real-time data was performed to calibrate the analysis model for future Mir flights. Similar analyses for Space Station assembly flight configurations are recommended to determine the communications profile and provide data for flight planning.

FLIGHT CONTROL SYSTEM

The STS-71 Shuttle/Mir flight demonstrated that the Orbiter can control and stabilize large space structures attached to the Orbiter. Although each of the Space Station assembly flights will be a different vehicle configuration, the results of this flight provide significant confidence that the process used to develop control system designs was very effective. The results also demonstrate that the notch-filter upgrade designed to stabilize these types of configurations worked well. Future flights will test/demonstrate other Shuttle upgrades, including the alternate primary RCS mode and the minimum-angle thruster-selection algorithm, further validating their performance for Space Station analysis and application. Additional Shuttle/Mir flight tests or software upgrades may be proposed to demonstrate and/or provide increased margins to modeling errors for later Shuttle-controlled assembly configurations.

The specific issue concerning the modeling error of the aft down-firing vernier thruster has resulted in a software solution that should eliminate a significant portion of the unrequired propellant consumption that was observed on the STS-71 mission. This software solution will be patched into the STS-74 I-loads. An analysis to determine the exact effects of plume self-impingement from all the down-firing thrusters has been initiated. Its conclusions will be verified based on STS-71 and STS-74 flight results. The model (force and moment) of these thrusters in the flight software will then be updated to accurately represent actual vehicle performance.

THERMAL EFFECTS

Significant thermal effects from the Mir on the Orbiter sill longerons and bondlines were observed during the inertial orientation (IO) 1.1 attitude. However, this condition is not expected to adversely affect the payload bay door closure "anytime return" requirements for the ISS missions.

A DTO is recommended to assess the concerns of potential violations of the vernier RCS non-operational limit of 90 °F for ISS missions by inhibiting forward vernier RCS thruster operations in a cold attitude

The TCS was shut down after 1.5 hours of operations due to the temperature rise rate being higher than predicted. This condition may be an issue for the warmer station attitudes.

An evaluation of the thermal impact of the APAS on the ISS APAS hardware will be conducted after the STS-71 thermal math model correlation has been completed.

FLIGHT CREW EQUIPMENT

Stowage and item tracking procedures will be reviewed after the destowage inventory has been completed. Consideration may be given new procedures to track items that have been removed from the original stowage location. Additionally, procedures to stow items in chronological order and with associated types of items will be investigated. A procedure of this type would expedite locating items and would prevent other items in the same stowage location from being misplaced.

MIR RENDEZVOUS, DOCKING, AND JOINT OPERATIONS

SUMMARY

The STS-71 mission was the first of seven planned Space Shuttle-Mir rendezvous, docking and crew-transfer missions that are planned to be completed between 1995 and 1997 during Phase 1 of the Space Station Program. During the first two days of the STS-71 mission, a number of small RCS and OMS firings were completed to bring the Orbiter within 8 nmi. of the Mir Space Station. The terminal phase initiation (TI) maneuver was performed at 180:09:31:01.2 G.m.t. (01:13:58:42.2 MET), and during the following orbit the Orbiter closed to within one-half mile of the Mir Space Station. The rendezvous radar and trajectory control sensor (TCS) were used extensively during the rendezvous process. In performing the rendezvous, the Atlantis aimed for a point directly below the Mir, along the Earth radius vector (R-Bar), which is an imaginary line drawn between the Mir center of gravity and the center of the Earth. This method of approach reduced the number of braking firings that were required as natural forces during this rendezvous trajectory braked the approach more than approaching the Mir from directly in front of it. The reduction in the number of RCS thruster firings in close proximity to the Mir reduced the amount of RCS plume impingement on the Mir.

DOCKED ACTIVITIES

The Orbiter docked with the Mir at 180:13:08:17.9 G.m.t. (01:18:35:22.9 MET), and the hatch was opened for initial greetings and the transfer of all seven Orbiter personnel to the Mir for joint photographs and the beginning of joint operations. Following these activities, the Mir-19 seat liners, the highest-priority item, were transferred to the Mir. With this transfer completed, the home vehicle for the Mir-18 crew was Atlantis and the home vehicle for the Mir-19 crew was the Mir. During the five days of docked operations, transfers to the Mir from the Atlantis included the following:

a. Russian extravehicular activity (EVA) tool;
b. U. S. EVA tool;
c. Russian soft bag containing pressure leak sealant;
d. Russian food;
e. TREK detector boxes (Boxes for return of witness plates that had been installed on the exterior of the Mir for an extended period. The plates were retrieved during an EVA and were returned to the sponsor in the boxes); and
f. Russian Mir-19 flight data file.

Transfer items from the Mir to the Shuttle included the following:

a. Command processor;
b. Mir surface and airborne samples;
c. Salyut-5B computer;

d. Elements of the TORU (avionics boxes that were carried on Spektr to allow a crew-commanded docking of Spektr to Mir, should the automated docking system have failed.)
e. Urine bags;
f. Metabolic cold storage containers;
g. Mir water samples; and
h. Foam padding from Spektr.

In addition, 200 percent more water was transferred to the Mir than requested prior to the flight by the Russians.

UNDOCKING ACTIVITIES

The final preparations for undocking were performed, and the Orbiter undocking activities were successfully completed at 185:11:09:41.8 G.m.t. (06:15:37:22.8 MET). The Atlantis was moved to a distance of 400 feet from the Mir at which time a fly-around of the Mir was initiated. The Orbiter circled the Mir 1 1/2 times, and during that period detailed engineering photographs and videos were taken of the Space Station.

During the Soyuz free-flight following the Shuttle undocking from the Mir, the Mir computer experienced a problem. The problem caused a loss of control/free drift. The Mir was nearing the end of a maneuver with rates of approximately 0.2 deg/sec on the vehicle. After an unsuccessful attempt to restore control, the ground made a decision to redock the Soyuz early, and this was performed successfully. The Russians reported that this was a software problem, in which a command over-wrote a segment of computer memory used by the control system. The gyrodines spun down, and the Mir was left adrift. Testing of the computer verified that this was not a hardware problem. On July 5, the software was restored to the correct state and the control system resumed nominal operations.

PAYLOADS

The joint Russian and U. S. scientific investigations, which began on Mir-18 and continued on the STS-71 mission, provided data in seven scientific and medical disciplines. These seven disciplines were metabolic research; cardiovascular and pulmonary research; neurosensory research; hygiene, sanitation, and radiation research; behavior and performance research; fundamental biology research; and microgravity research. A total of 28 experiments were conducted as part of the joint cooperative effort. Fifteen of these were continued on the STS-71 mission and 11 are being continued on the Mir-19 mission. Data collected during the Mir-18 mission as well as that collected during STS-71 were returned to Earth for analysis by the U. S. and Russian science communities.

Following the successful docking on flight day 3, joint science investigations were conducted on the Atlantis and the Mir until undocking on flight day 8. Additional countermeasures and data collections were conducted on flight days 9 and 10. Overall, the mission was extremely successful. Not only were the original preplanned science sessions completed, but additional science-related activities were performed. With the addition of the unscheduled science activities, successful data collection achieved 110-percent completion, even though a few individual sessions were not performed. Included with the successful science activities were numerous science hardware and science resupply transfers. These transfers included the retrieval of all of the science samples collected during Mir-18; two kits containing quail eggs, whose development has been stopped; and the science resupply for Mir-19 research. Transfers from the Atlantis to the Mir were 100-percent complete based on premission planning, and transfers from the Mir to the Atlantis were 92-percent complete. The less-than 100-percent transfer from the Mir resulted from unused science gear onboard the Mir being left there for future use.

SPACELAB

The Spacelab systems supported the STS-71 mission activities without any problems. The SL-M mission required a unique Spacelab configuration. To accommodate the Orbiter c. g. requirements, the Spacelab was located further aft in the payload bay than on previous missions. This relocation required a new tunnel extension that was installed in front of the Spacelab transfer tunnel.

The interior of the Spacelab module also was configured uniquely for this mission. Due to the mass limitations of the payload, one port and two starboard racks were removed. These rack spaces provided extra room for the crew to use for temporary and unique stowage of logistics transfer items. The Spacelab supported long-duration-stay countermeasure-exercise protocols and other life sciences experiments.

METABOLIC RESEARCH

Six metabolic experiments were conducted to examine a wide range of physiological responses as investigators strived to understand how the body's mechanisms work in space, and how gravity affects the body on Earth.

The STS-71 mission allowed continuation and expansion of the studies begun on the Mir to learn more about human metabolism and endocrinology, to determine how fluids redistribute themselves in the body, and to determine how microgravity affects bone density and red blood cell production. In addition, crew members aboard Atlantis participated in studies to determine if prolonged exposure to microgravity affects the body's ability to mount an antibody response, and whether immune cells are altered by exposure to microgravity.

CARDIOVASCULAR AND PULMONARY RESEARCH

Deconditioning of the cardiovascular and pulmonary system, with the occurrence of orthostatic intolerance (lightheadedness upon standing), has been observed in crewmembers returning from long-duration spaceflight. As a result, this condition is of primary interest to the medical researchers. The researchers measured blood volume changes during flight as well as pooling of blood in the legs and abdomen after entry.

Exercise as well as both the Russian and American lower body negative pressure (LBNP) units were evaluated as countermeasures to protect the returning crewmembers. The LBNP units mimicked increasing and decreasing arterial pressure by applying suction and pressure to the neck while heart rate responses to the changing pressure stimulus were measured.

The Mir-18 crewmembers returned to Earth in the reclining position and their changes in heart rate, blood pressure, voice, and posture were measured during the entry phase. After landing, the Mir-18 crew performed a "stand test" during which the extent of orthostatic intolerance was measured.

NEUROSENSORY RESEARCH

Neurosensor investigations that were begun during the Mir-18 mission focused on the mixed messages that the body receives when the brain integrates nerve impulses from the eyes, inner ear, muscles and joints. The brain cannot rely on gravity as a constant in determining body position and orientation. Data were collected for two of the studies in an effort to understand how humans adapt to spaceflight and readapt to the Earth environment. In addition, data were collected on the neuromuscular function and muscle deconditioning during extended spaceflights by measuring muscle tone, strength, and endurance using electromyography, as well as utilization of oxygen during treadmill and other forms of exercise.

HYGIENE, SANITATION, AND RADIATION RESEARCH

As microgravity is not the only environmental challenge facing spaceflight crewmembers, hygiene and sanitation data were collected concerning recycled air and water, possible microbial contamination, and radiation exposure to understand the condition and ensure good health in closed living systems.

Two investigations evaluated the radiation environment experienced during the extended stay in space, and two other investigations were performed to determine the presence of microbes or trace chemicals in the air and water consumed by the crewmembers. Also, microbial samples were collected from the Mir and Atlantis, as well as from the crewmembers themselves, for postflight analysis. Samples of air and water were also collected throughout the Mir-18 mission and during STS-71 for postflight analysis for the presence of atmospheric and water contaminants.

BEHAVIOR AND PERFORMANCE RESEARCH

Behavioral and performance data were collected throughout the three-month Mir-18 mission for use in a study of the long-term effects of microgravity on muscle coordination and mental acuity, and these data were returned to Earth aboard Atlantis. A Russian spacecraft control simulator was used before, during and after the flight. This simulator will allow researchers to measure crewmember's functional state and manual control performance.

FUNDAMENTAL BIOLOGY RESEARCH

Fundamental biology data were collected to determine through postflight testing how weightlessness affects embryo development of pre-fertilized quail eggs. These eggs were incubated onboard the Mir, and the incubation process was stopped at various stages of development by placing the embryos in a fixative solution.

Improved sensors were also carried to orbit by Atlantis for use in the Mir Station greenhouse by the Mir 19 crew. After addition of these sensors, the updated greenhouse was ready for plant experiments on future Mir missions.

MICROGRAVITY RESEARCH

Inanimate objects and materials, including crystals, are affected by the unique microgravity environment. As a result, the protein crystal growth experiment, discussed in the following paragraph, was placed onboard the Mir for an extended period of time (until November 1995).

PROTEIN CRYSTAL GROWTH EXPERIMENT

The Protein Crystal Growth Experiment, with several hundred protein samples, was carried on STS-71, and was placed in the Mir Space Station where it will remain until the STS-74 crew retrieves the samples in November of 1995. Researchers were able to observe the crystallization of a number of large proteins that may be used in basic biological research, pharmacology and drug development after return to Earth.

SPACE ACCELERATION MEASUREMENT EXPERIMENT

The Space Acceleration Measurement System (SAMS), which has flown on many missions during the Shuttle Program, was attached to the Mir Space Station, where data will be collected during the months and years to come in support of the Protein Crystal Growth Experiment.

IMAX CAMERA SYSTEM

A total of seven rolls of IMAX 70-mm film was exposed during the STS-71 mission. Two rolls were exposed on scenes exterior to the Shuttle and five rolls were used for interior photography. One of the two IMAX microphones failed during the flight, thus only a single voice channel was recorded during filming. However, this loss did not significantly affect IMAX operations.

IMAX activities went very well, although scene set-up took longer than expected. Scenes taken included middeck activities, Spacelab activities, the approach to the Mir, flyaround of the Mir after undocking, and interior Mir activities.

SHUTTLE AMATEUR RADIO EXPERIMENT-II

The Shuttle Amateur Radio Experiment-II (SAREX-II) was used to communicate with four schools in the United States and one school in Russia. STS-71 was the eighteenth mission on which the SAREX was flown.

SAREX contacts were made with the Benbrook, Texas, elementary school; the Forrest Avenue School in Hudson, Massachusetts; the Redlands High School in Redlands, California; the Suffolk Community College at Seldon, New Jersey; and the school in Yessentuki, Russia. The Russians were very pleased with the contact. Additionally, SAREX ground personnel supported troubleshooting of the Shuttle VHF audio problems discussed in the GFE/FCE section of this report.

RISK MITIGATION EXPERIMENTS

All eight test cases for Risk Mitigation Experiment (RME)1301, Mated Model and Mir Structural Dynamic Test, were successfully performed beginning at 183:12:32 G.m.t. (04:17:00 MET). Analysis of the data shows that the mated stack structural dynamic characteristics were within the loads and flight control margins predicted in the preflight analysis. The results indicate the models were within design tolerances; however, less free-play was apparent in the data than originally expected. The test results were reviewed with RSC-Energia loads and flight control specialists. Results of the test verified that the Shuttle Primary RCS ALT DAP could have been used for mated maneuvers and attitude hold on STS-71. Mir attitude control of the stack was as predicted.

A data take was scheduled and completed for the RME 1310, Shuttle/Mir Alignment Stability Experiment, without the Mir star tracker.

ORBITER DOCKING SYSTEM

The Orbiter docking system (ODS) operation successfully demonstrated the ability of the Androgynous Peripheral Docking System (APDS) to mate the Orbiter to a large space structure, the Mir, and to accommodate all mated load operations. Also, data obtained during the docking phase compared well with the preflight analyses that were performed, and this provides confidence for future docking-related activities for the ISS.

The Atlantis (OV-104) and the Mir Space Station were linked by an ODS (see following figure) that was jointly developed by the RSC Energia, Kaliningrad, Russia; the Orbiter prime contractor Rockwell International, Downey, CA.; and NASA. The ODS consisted of an external airlock, a supporting truss structure, a docking base, avionics required to operate the system, and a 632-lb Russian-built APDS, which is mounted externally on top of the airlock and docking base. The ODS measures nearly 15 feet wide, 6 1/2 feet long, 13 1/2 feet high, and weighs more than 3,500 lb. The ODS was installed near the forward end of the Orbiter payload bay and was connected by short tunnels to the existing airlock inside the Orbiter's pressurized cabin and the Spacelab module, which was mounted aft of the airlock in the payload bay.

The APDS is controlled from a Russian-built aft flight deck panel, through nine Russian-built avionics boxes, which are mounted in the bottom of the airlock. Joint Russian/U. S. cables connect the control panel, avionics boxes and the mechanism.

The APDS is a hybrid version of the docking system used by the Russians for the Apollo-Soyuz Test Project (ASTP) in 1975. It differed from that docking system in the following ways:

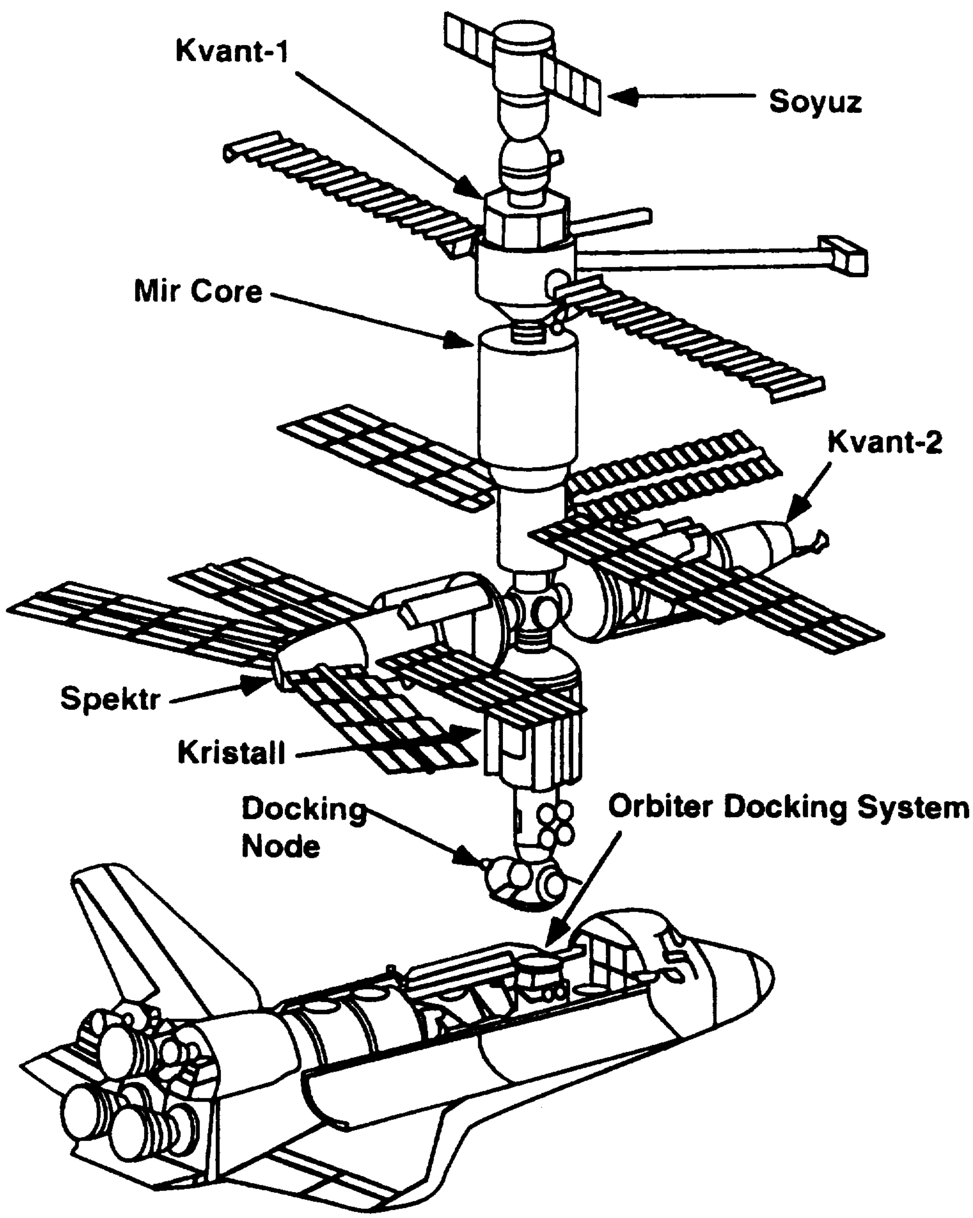
a. It is more compact with an overall external diameter of 60 inches compared to 80 inches for the ASTP, although the inner egress tunnel diameter remains approximately the same;

b. The APDS docking mechanism has 12 structural latches, compared to eight on the ASTP unit;

c. The APDS guide ring and extend/retract mechanism are packaged inside the egress tunnel rather than being outside of the mechanism as they were on ASTP; and

d. The three guide petals on the APDS point inboard rather than outboard.

Both Atlantis and the Mir were equipped with an APDS that had a three-petal androgynous capture ring mounted on six interconnected ball screw shock absorbers, which arrest the relative motion between the two vehicles and prevent a collision. The Orbiter crew's primary visual aid for aligning the docking mechanism during rendezvous was a television camera that was mounted inside the airlock of the ODS. The camera



Orbiter Docking System Mating to Mir Space Station

viewed a target at the center of the Mir mechanism through a window in the upper hatch.

Docking was initiated when the Orbiter and ODS were maneuvered to bring the active ODS on the Orbiter into contact with the passive docking system on the Mir. The maximum allowable axial rate of approach of the two vehicles was 0.2 ft/sec. The docking of these two massive vehicles was complicated by the Orbiter's large center-of-mass offset from the ODS longitudinal axis, which significantly reduces the effective mass of the vehicle at the docking interface, making capture more difficult.

Five seconds after capture, dampers were activated for 30 seconds and the relative motion between the two vehicles subsided. At this point, the vehicles were aligned and the retraction phase of the docking was initiated by the latched capture ring. Structural latching was complete at the end of the capture ring retraction process.

This first use of the APDS on the Orbiter occurred successfully on this mission. The initial preparations for docking were accomplished by system power-up and guide-ring extension, activities which took place on flight day 2 beginning at approximately 179:15:44 G.m.t. (00:20:12 MET). All operations were nominal with guide-ring extension performed within the dual motor planned time of approximately 2.5 minutes.

The actual docking to the Mir occurred on June 29, with the ODS being powered up at 180:12:25 G.m.t. (01:16:53 MET). Docking contact conditions were well within the allowables. The closing rate (docking axial velocity) was very near the targeted 0.1 ft/sec and angular misalignments were small. Post contract thrusting (PCT) began about one-half second before capture. Capture occurred at 180:13:00:13.9 G.m.t. (01:18:27:18.9 MET) Docking loads were reconstructed from flight data. The maximum axial load was about 1000 kg, compared to an allowable of 1900 kg. It should be noted that the loads were substantial because of the force induced by the PCT, even though contact conditions were benign. The electromagnetic dampers were activated about five seconds after capture and remained on for 30 seconds, as planned. The ring-extend command occurred about 60 seconds after capture. The crew initiated the automatic interrupt, as planned, to allow the APDS damping of the relative motion. The ring-in command followed about 75 seconds later. Ring extraction and structural hook drive were performed nominally with the docking completed at 180:13:08:17.9 G.m.t. (01:18:35:22.9 MET), and nominal system pressurization followed.

During the pre-undocking vestibule depressurization at 184:20:07 G.m.t. (06:00:35 MET), the rate at which the vestibule pressure was decreasing was lower than planned (Flight Problem STS-71-V-06). Initially, it was hypothesized that the vent inlet was blocked by mylar blankets that were covered with small pin holes. The pin holes were allowing a very slow venting of the vestibule pressure. A review of the manufacturing drawings revealed that no hole had been cut in the blankets over the vent to allow the valve to vent properly. Also, the test history showed that no depressurization test of the completed configuration with blankets had been performed prior to flight.

At the end of the docked phase of the mission, the latches were unhooked after the docking base was depressurized, and the preloaded separation springs separated the two vehicles at a low velocity. Undocking was completed at 185:11:09:41.8 G.m.t. (05:15:37:22.8 MET).

The following table shows the analytical predictions and processed inertial measurement unit (IMU) data for the Orbiter's undocking angular rates. The analytical predictions are a best-case estimate and are based upon the Orbiter's mass properties at the time of docking.

Structural axis	Analytical	Measured
ωx, deg/sec	-0.003	0.010
ωy, deg/sec	-0.101	-0.074
ωz, deg/sec	0.000	0.002

The Orbiter's measured roll rate (ωx) during the flight was notably higher than predicted. The predictions were based upon the 12 active structural hooks releasing simultaneously, while in reality the system has two separate motors driving alternate gangs of structural hooks. The undocking events were recorded during the flight in the following order:

1. Hooks no. 1 open position -185:11:09:40.811 G.m.t. (05:15:37:21.823 MET);
2. Undock complete - 185:11:09:41.892 G.m.t. (05:15:37:22.904 MET); and
3. Hooks no. 2 open position - 185:11:09:43.243 G.m.t. (05:15:37:24.355 MET).

In the actual hardware, the active hooks do not release at the same time.

The Orbiter's predicted pitch rate (ωy) was approximately 25 percent greater than the measured value. The predictions were based upon the maximum allowable capability of the separation devices as quoted in the APDS procurement specification. The Orbiter's yaw rate (ωz) was a small value in both cases. The reasons for predicting different ωx and ωy separation rates are currently being investigated.

VEHICLE PERFORMANCE

SOLID ROCKET BOOSTERS

All Solid Rocket Booster (SRB) systems performed as expected. The SRB prelaunch countdown was normal, and no SRB Launch Commit Criteria (LCC) or Operational Maintenance Requirements and Specification Document (OMRSD) violations were encountered. Data show that all SRB systems performed as designed and no in-flight anomalies were identified from the review of the data.

The low-pressure heated ground purge in the SRB aft skirt was used intermittently to maintain the case/nozzle joint temperatures within the required LCC ranges. At T-15 minutes, the high-pressure purge was activated to inert the SRB aft skirt.

Both SRBs were successfully separated from the External Tank (ET) at T+123.56 seconds, and the recovery reports indicate that all deceleration subsystems performed satisfactorily. Both SRBs were recovered and returned to KSC for inspection and refurbishment.

REUSABLE SOLID ROCKET MOTORS

The Reusable Solid Rocket Motors (RSRMs) performed the assigned functions satisfactorily, and no LCC or OMRSD violations were noted. All RSRM temperatures were maintained within acceptable limits throughout the countdown. The table on the following page provides data on the RSRM propulsion parameters.

Data indicate that the flight performance of both RSRMs was well within the allowable performance envelopes, and was typical of the performance observed on previous flights. The RSRM propellant mean bulk temperature (PMBT) was 79 °F.

The maximum trace shape variation of pressure versus time was calculated to be approximately 1.8 percent at 73.5 seconds (left motor) and approximately 1.2 percent at 80.0 seconds (right motor) versus the 3.2 percent allowable. Both values are well within the historical data base.

The field joint heaters were operated over 35 hours during the three countdowns. Power was applied to the heating element 16 percent (average) of the time during the LCC time-frame to maintain the field-joint temperatures within their normal operating range.

Igniter joint heaters operated for over 50 hours during the three countdowns. Power was applied to the igniter heating elements 26 percent of the time to maintain the igniter joint temperatures within their normal operating range.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 79 °F Predicted	Left motor, 79 °F Actual	Right motor, 79 °F Predicted	Right motor, 79 °F Actual
Impulse gates				
I-20, 10^6 lbf-sec	66.14	65.84	66.16	66.00
I-60, 10^6 lbf-sec	176.12	176.57	176.15	176.08
I-AT, 10^6 lbf-sec	297.19	298.08	297.00	297.25
Vacuum Isp, lbf-sec/lbm	268.6	269.4	268.6	268.8
Burn rate, in/sec @ 60 °F at 625 psia	0.3678	0.3680	0.3681	0.3680
Burn rate, in/sec @ 79 °F at 625 psia	0.3728	0.3730	0.3731	0.3730
Event times, seconds[a]				
Ignition interval	0.232	N/A	0.232	N/A
Web time[b]	109.0	108.5	108.9	108.8
50 psia cue time	118.7	118.8	118.6	118.3
Action time[b]	120.8	120.9	120.7	120.1
Separation command	123.6	123.7	123.6	123.7
PMBT, °F	79	79	79	79
Maximum ignition rise rate, psia/10 ms	90.4	N/A	90.4	N/A
Decay time, seconds (59.4 psia to 85 K)	2.8	3.1	2.8	2.5
Tailoff Imbalance Impulse differential, Klbf-sec	Predicted		Actual	
	N/A		406.2	

Impulse Imbalance = left motor minus right motor
[a] All times are referenced to ignition command time except where noted by a [b].
[b] Referenced to liftoff time (ignition interval).

The aft skirt purge operated for over 10 hours to maintain the nozzle-to-case joint above 75 °F. At T-15 minutes, the pressure was increased to inert the aft skirt compartment. The calculated flex bearing mean bulk temperature (FBMBT) was 81 °F.

All ground environmental instrumentation and operational instrumentation performed within established requirements. All available data were recorded and evaluated.

The postflight inspection indicated nominal performance. All J-joints (igniter and field) performed as designed. During the postflight disassembly of the left-hand and right-hand nozzle assemblies, the inspection revealed an abnormal condition in joint no. 3. Joint no. 3 joins the nose inlet assembly and the throat assembly with 72 bolts and a primary and secondary O-ring. The inspection after the disassembly of the joints revealed a gas path through the room temperature vulcanizing (RTV) back-fill, with soot up to the primary O-ring. Also, heat effect and erosion were observed on the left-hand primary O-ring (Flight Problem STS-71-M-1), Similar gas paths have been noted on 11 of 96 previous RSRM nozzle joints of this configuration (three static tests and eight flights). However, associated with this STS-71 gas path was a slight heat effect on the primary O-ring, whereas prior experience included only local heat effects to joint insulation phenolics. Heat effect existed in four small areas of the primary O-ring within a 1.78 inch circumferential distance. A maximum depth of 0.005 to 0.006 inch of removed O-ring material was detected on the 0.210 inch cross-sectional diameter O-ring. The primary O-ring maintained seal throughout the flight and the secondary O-ring was unaffected. In summary, the overall heat effects to the STS-71 left-hand joint varied only slightly from prior experience.

A detailed evaluation plan for the left-hand nozzle has been instituted. Photography and documentation of the joint is in progress. Samples have been taken of the affected areas, and these are being tested to determine the condition of the components. The assessment activities also include taking samples of/from the affected and unaffected areas for laboratory testing, evaluating all process data from the manufacturing of this nozzle and comparing it to history, evaluating the prelaunch/launch/recovery environments, performing sub-scale testing of the backfill operation to simulate the condition and assess potential causes, performing thermal analyses to simulate the STS-71 results and assess limit conditions, developing a fault-tree analysis, and other activities that are found necessary as a result of the investigation.

The STS-70 nozzles were evaluated upon receipt at the contractor facility, and their condition will be reported in the STS-70 Space Shuttle Program Mission Report.

EXTERNAL TANK

All objectives and requirements associated with the ET propellant loading and flight operations were met. All ET electrical equipment and instrumentation operated satisfactorily. No LCC or OMRSD violations were identified nor were any in-flight anomalies noted.

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

The nose cone purge heater and temperature control system operated successfully. Measured nose cone mass flow rate was within the Interface Control Document (ICD) requirement of 9 to 16 lbm/min, as it has been since a critical flow nozzle was installed to limit the flowrate.

The intertank purge heater and temperature control system operated successfully. Intertank temperatures were maintained within acceptable limits, all components within the intertank performed satisfactorily, and no hazardous gas violations were noted.

The ET pressurization system functioned properly throughout engine start and flight. The minimum LO_2 ullage pressure experienced during the ullage pressure slump was 13.8 psid.

Post-separation photographs of the ET were taken with an umbilical-mounted 35mm camera and two 16mm movie cameras. The following observations were made from the photography:

a. Eight areas of foam missing from intertank stringer tops, each approximately 12 to 24 inches long (possible contributor to above-average Orbiter lower surface tile damage on this flight);

b. One divot just aft of the -Y bipod attachment;

c. Two divots at or near the station 1377 liquid oxygen feedline support inboard attachment; and

d. Above average "popcorning" in the aft liquid hydrogen acreage foam insulation and on the thrust strut and liquid oxygen feed line flange foam insulation closeouts.

Similar observations have been noted on previous flights, and none of these conditions are considered anomalous.

ET separation occurred as planned, and the ET entry and breakup was within the footprint. The postflight predicted ET intact impact point was 2 nmi. downrange from the preflight prediction.

SPACE SHUTTLE MAIN ENGINES

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

Flight data indicate that SSME performance during start, mainstage, throttling, shutdown and propellant dump operations was normal. High pressure oxidizer turbopump (HPOTP) and high pressure fuel turbopump (HPFTP) temperatures were well within specification limits throughout engine operation. Space Shuttle main engine cutoff occurred at T + 510.48 seconds. No failures or significant SSME problems or anomalies were identified.

Analysis of the data showed a number of items that merit discussion::

1. The review of the SSME 3 chamber coolant valve actuator (CCVA) actuator checkout module (ACM) data showed very little margin to the channel A-channel B position differential limit. The data indicates that run-to-run variation could cause the actuator to fail the checkout limit (1.5 percent) during the next set of checkouts. The ACM limit ensures that no actuator will violate the rotary variable differential transformer (RVDT) miscompare limit of 3 percent.

2. The SSME 3 hot gas injection pressure measurement froze at engine start plus 310 seconds. This phenomenon has been observed on previous flights and is attributed to ice formation in the sense line.

3. The SSME 2 HPFTP coolant line pressure shifted at engine start plus 20 seconds and the amount of shift is within the previous experience base.

4. The SSME 2 main fuel valve (MFV) skin temperature sensor was erratic at engine start plus 440 seconds. Debonding of the sensor as well as an open circuit in the measurement have been seen on previous flights. The measurement is used for prelaunch leakage verification and is not used during mainstage.

5. The SSME 3 MFV skin temperature sensor spiked at engine start plus 390 seconds. The cause of this spike in the data is being evaluated for corrective action.

6. The SSME 3 HPFTP speed sensor spiked at engine cutoff plus 3.9 seconds. The cause of this spike in the data is being evaluated for corrective action.

7. The SSME 1 main combustion chamber (MCC) fuel injection pressure sensor experienced a negative 26 psia spike at engine start plus 108 seconds. The SSME 3 MCC chamber pressure (Pc) pressure sensor experienced a positive 15 psi spike at engine start plus 75.6 seconds. Likewise, the SSME 3 fuel system purge pressure sensor experienced a positive 3 psi spike at engine start plus 76.6 seconds. All of these pressure spikes have the characteristics of the noise (externally induced) spikes which have been experienced since the introduction of the block II controller.

8. The oxidizer preburner oxidizer valve (OPOV) liquid oxygen supply skin temperature sensor had a slow response during mainstage, indicating a debonding of the sensor, and this is within the experience data base. The measurement is used for prelaunch leakage verification and is not used during mainstage.

SHUTTLE RANGE SAFETY SYSTEM

Data analysis has shown nominal performance of the Shuttle Range Safety System (SRSS). The SRSS closed-loop testing was completed as scheduled during the launch countdown. All SRSS safe and arm (S&A) devices were armed and system inhibits turned off at the appropriate times. All SRSS measurements indicated that the system operated as designed throughout the 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 remained active until ET separation from the Orbiter.

ORBITER SUBSYSTEM PERFORMANCE

Main Propulsion System

The overall performance of the MPS was as expected with no OMRSD or LCC violations. During LO_2 and LH_2 loading, there were no stop-flows or reverts. During the countdown for the first launch attempt, some minor problems were noted, but none of the problems had any impact on the preparations for launch.

During the countdown for the second launch attempt, only one problem of significance was noted. The SSME 1 liquid hydrogen (LH_2) recirculation valve was slow in closing at T-10 seconds (Flight Problem STS-71-V-03) The valve specification allows 1.1 seconds from the loss of open switch to acquisition of close (sw/sw) and 2.0 seconds from loss of open power to acquisition of close switch (sig/sw). The STS-71 times were 3.190 seconds from sw/sw and 4.282 seconds from sig/sw. The valve is a criticality 1R2 for premature engine shutdown. The slow closure of the valve had no effect on the mission, and the valve was replaced during postflight turnaround activities.

Throughout the period of preflight operations, no significant hazardous gas concentrations were detected. The maximum hydrogen concentration level in the Orbiter aft compartment (which occurred shortly after the start of fast-fill) was approximately 120 ppm.

The liquid hydrogen (LH_2) loading operations were normal during all phases of the countdown. The analysis of loading system data shows the LH_2 load at the end of replenish was 231,841 lbm. Compared to the inventory (predicted) load of 231,832 lbm, this assessment yields a difference of +0.004 percent, which is well within the required MPS loading accuracy.

The liquid oxygen (LO_2) loading operations were normal during all phases of the launch countdown. Based on an analysis of the loading system data, the LO_2 load at the end of replenish was 1,388,264 lbm. Compared with the inventory (predicted) load of

1,387,844 lbm, this assessment yields a difference of +0.03 percent, which is well within the required loading accuracy.

The charging of the helium system to flight pressure levels was performed as scheduled, and all pressures and temperatures met the LCC limits. The Orbiter midbody helium concentration increased to 750 ppm during and after helium bottle pressurization. During the on-orbit phase of the mission, the SSME 2 helium system decayed at the rate of 0.4 lbm/day, and the requirement for this system is a maximum of 0.26 lbm/day. This leak did not impact the mission in any manner. Helium usage during entry was a nominal 57.8 lbm. Postflight troubleshooting revealed a loose fitting on the SSME 2 helium tank 8. This tank had been removed during the Orbiter maintenance down period (OMDP) to allow access for structural inspections. No further leakage was noted after tightening the fitting.

Ascent MPS performance was nominal. Data indicate that the LO_2 and LH_2 pressurization systems performed as planned, and that all net positive suction pressure (NPSP) requirements were met throughout the flight. The 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 13.7 psid.

The SSME 3 GH_2 FCV exhibited some sluggishness during the last half of ascent (Flight Problem STS-71-V-04). Three cycles violated the File IX requirement of 0.3 second maximum with values of 0.4 second. Ten cycles were 0.2 to 0.3 second maximum, which is slower than normal. This amount of sluggishness is considered minor and had no effect on overall GH_2 system pressurization. As a part of planned GH2 pressurization system modifications, OV-104 is scheduled to receive its reoriented manifold kit with newly refurbished FCVs during the next flow (STS-74). The currently installed valves will be sent back to the vendor where they will be disassembled, inspected, and cleaned per existing procedures to alleviate sluggishness.

Reaction Control Subsystem

The RCS performed nominally throughout the mission. A total of 4,129.6 lbm of RCS propellants were consumed during the mission. In addition, during left OMS and right OMS interconnect operations, a total of 21.43 percent (2775 lbm) of the OMS propellants were consumed by the RCS.

At 187:11:23:27 G.m.t. (08:15:51:08 MET) during the RCS hot-fire, primary RCS thruster R2U failed off because of low chamber pressure (Pc) (Flight Problem STS-71-V-07). The thruster was deselected after 320 msec when the Pc failed to exceed the deselect limit of 36 psia in three consecutive redundancy management (RM) cycles. The actual peak Pc was 2.4 psia. The injector temperature trend indicated that both the oxidizer and fuel flow occurred. Injector temperatures and inertial measurement unit (IMU) rates both confirmed the low performance. The failure signature is typical of previous fail-off indications related to nitrate-contaminated oxidizer valves. The most probable failure mode is nitrate contamination of the oxidizer valve pilot stage, and this restricted pilot flow and prevented valve upper cavity pressure bleed-off, which is required to hydraulically actuate the valve main stage. This thruster will be replaced prior to the next flight of this vehicle.

Orbital Maneuvering Subsystem

The OMS performed very satisfactorily throughout the mission. A total of 20,299 lbm of OMS propellants were used during the mission. Of this total, 2,775 lbm was used by the RCS during OMS interconnect operations. The remainder was used by the OMS during the six maneuvers shown in the following table. Total firing time for the left OMS engine was 465.5 seconds and for the right OMS engine was 443.9 seconds.

OMS FIRINGS

OMS firing	Engine	Ignition time, G.m.t./MET	Firing duration, seconds	ΔV, ft/sec
OMS-2	Both	178:20:15:16.8 G.m.t. 00:00:42:57.8 MET	47.7	75.3
OMS-3	Both	178:23:10:25.2 G.m.t. 00:03:38:06.2 MET	136.9	220.7
OMS-4	Left	179:10:49:35.8 G.m.t. 00:15:17:16.8 MET	12.4	10.1
OMS-5 (NC-4)	Both	180:07:57:17.2 G.m.t. 01:12:24:58.2 MET	46	75.0
OMS-6 (TI)	Left	180:09:31:01.2 G.m.t. 01:13:58:42.2 MET	9.2	7.2
Deorbit	Both	188:13:45:19.3 G.m.t. 09:18:13:00.3 MET	213.3	373

Early in the mission, the left forward fuel gaging probe was inoperative; however, beginning with the OMS-4 maneuver, the fuel probe operated properly for the remainder of the mission.

Power Reactant Storage and Distribution Subsystem

The PRSD subsystem performed nominally throughout the mission except as discussed in the following paragraphs. A total of 2,908 lbm of oxygen and 343 lbm of hydrogen was consumed during the mission. Of this total, 184 lbm was used by the crew and the Mir during docked operations. Reactants remaining at landing provided a mission extension capability of 65 hours at an average power level of 16.7 kW. Tanks 4 and 5 were depleted to residual quantities during the mission.

During the launch countdown on June 27,1995, a small leak of approximately 0.2 lb/hr was present from the PRSD subsystem oxygen tank 1. The leak rate decreased throughout the mission, but the leak had no impact to the planned mission activities. Postflight troubleshooting isolated the leak to the tank 1 fill quick-disconnect poppet. The poppet will be replaced.

The PRSD hydrogen manifold 1 valve failed to close when the flight day 1 pre-sleep cryogenics reconfiguration was performed at 179:00:06 G.m.t. (00:04:34 MET) (Flight Problem STS-71-V-02). This valve (s/n 20) passed the cryogenic screening at NASA Shuttle Logistics Depot (NSLD) during the Orbiter Maintenance Down Period (OMDP), and this is the second flight of the valve since OMDP. Following the failure, the oxygen manifold 1 valve was opened and both manifold 2 valves were closed for the sleep period. The manifold 1 valves were not used again due to the failure, and the manifold 2 valves were used for all subsequent pre-sleep cryogenic configurations. The manifold valve 1 failure-to-close was traced during postflight troubleshooting to a broken ground lug in the valve actuation circuitry. The ground lug will be replaced.

A fault message occurred on PRSD H_2 manifold 1 at 182:01:34:25 G.m.t. (03:06:02:06 MET) indicating that the isolation valve was closed when it should be open (Flight Problem STS-71-V-05). The crew cycled the switch twice without effect. The valve was verified to be open using tank and manifold pressure data. The indication toggled several times during the flight. Initial postflight troubleshooting has failed to recreate the problem.

A high temperature reading in oxygen tank 5 was noted at 188:15:36:32 G.m.t. (Flight Problem STS-71-V-10). Review of the full-rate data showed three occurrences of the oxygen tank 5 heater assembly 1 temperature suddenly increasing from 60 °F to approximately 200 °F, the highest recorded value being 250 °F. This temperature increase did not correspond to an increase in either of the other two temperature measurements in the tank, or a pressure increase, or heater-on discretes. The first occurrence, approximately three minutes prior to landing, set off a master alarm, which is set off when the temperature measurement reaches 349 °F. The sample rate for the heater temperature is one sample per second. The caution and warning samples at a rate of 80 samples per second, and a channel must be out of limits for 0.1 second for the caution and warning to turn on the master alarm. Consequently, the erratic data may have been out of limits long enough for the caution and warning to signal the event but was not out of limits when the data system sampled it. Initial postflight troubleshooting has failed to recreate the temperature measurement excursions.

Fuel Cell Subsystem

The fuel cell powerplant subsystem performed very satisfactorily throughout the mission. The fuel cells generated 3,942 kWh of electricity at an average power level of 16.7 kW and load of 549 amperes. In producing this power, the fuel cells used 343 lbm of hydrogen and 2724 lbm of oxygen, and the fuel cells produced 3,066 lbm of potable water.

Auxiliary Power Unit Subsystem

The APU subsystem performed in a nominal manner. The APUs were shut down after ascent in the manner prescribed by DTO 414 (B) - APU Shutdown Test. A pump load test was performed after landing with nominal results. The following table presents APU run-times and fuel consumption during the mission.

APU RUN TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (S/N 208)		APU 2 (S/N 406)		APU 3 (S/N 310)	
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	20:38	52	20:30	57	20:45	56
FCS checkout	5:29	11				
Entry[a]	64:56	121	94:57	177	65:00	135
Total[b]	91:03	184	115:27	234	85:45	191

[a] The APUs ran for about 20 minutes 48 seconds after landing.
[b] Mission totals do not include the APU 1, APU 2, and APU 3 confidence-run times or fuel consumption.

During entry, the APU 3 gearbox pressure transducer became erratic and caused approximately 80 percent of the GN_2 supply bottle to be dumped into the gearbox (Flight Problem STS-71-V-09). The bottle pressure dropped from approximately 180 psia until it became equalized with the gearbox GN_2 pressure at 35 psia. The lube oil outlet pressure rose to about 86 psi; however, this pressure did not impact APU operation. It was subsequently learned that this was the same sensor that was used on APU 204 on STS-50, which experienced the same event. A normal repressurization increases gearbox pressure to approximately 10 psi. Extensive testing following STS-50 did not define a problem with the transducer and it was reinstalled on APU 310. As a result of this incident, the sensor will be removed and removed and scrapped, and the oil changed.

The planned hydraulic load test was performed postlanding, and all APU parameters were nominal

Hydraulics/Water Spray Boiler Subsystem

The hydraulic/water spray boiler (WSB) subsystem performed nominally throughout the mission with the exception of an overcooling condition and an undercooling condition of systems 1 and 3, respectively. WSB 1 experienced and overcooling condition shortly after spray start. The APU lube oil return temperature dropped from a nominal temperature of 251 °F to 200 °F before returning to a steady-state cooling temperature of 252.7 °F. WSB 3 experienced an undercooling condition where the APU lube oil return temperature reached 289 °F prior to spray start. This was followed by an expected overcooling condition to 229 °F before returning to a steady-state cooling temperature of 256.7 °F. None of these conditions impacted mission operations.

DTO 414 was performed to investigate an anomalous 40-second hydraulics system 3 supply pressure hang-up observed when APU 3 was shut down early during ascent on STS-54. The shut-down sequence was APU 2, APU 1, and APU 3, with at least 5 seconds between each system. No back-driving of the power drive unit or anomalous pressure hang-ups were noted in the data after shutdown of the APUs after ascent.

STS-71 was the first of three flights of OV-104 in which the main case drain temperature sensors on hydraulic systems 1 and 2 were relocated because of a concern that the fluid inlet temperature minimum limit of 20 °F at circulation pump start might be violated. The system 1 temperature sensor was placed near the vehicle centerline on the 1307 bulkhead, and the system 2 sensor was placed just below the bulkhead sensor on the system 3 circulation pump inlet line. A bulkhead temperature of 1 °F was the coldest temperature recorded, while the corresponding temperature for circulation pump 3 was 38 °F. During most of the mission, circulation pump 3 inlet line temperature was considerably warmer than the bulkhead and well above the minimum requirement of 20 °F. Additionally, all three circulation pump body temperatures were above 50 °F. This flight data revealed that the fluid inlet temperatures for circulation pump 3 and probably circulation pumps 1 and 2 were always above the 20 °F requirement.

WSB performance during entry was nominal with WSB 3 being operated on the B controller. WSB 3 experienced three occurrences of overcooling and one minor undercool occurrence. The lube oil return temperature reached 273 °F prior to spray start. This was then followed by an overcooling condition in which the lube oil return temperature reached 236 °F. Approximately three minutes later, another overcooling condition was observed when the steady-state cooling temperature dropped from 252 °F to 236 °F. Twenty minutes later, the third and final overcooling condition occurred when the temperature went down to 207 °F. None of these occurrences impacted entry operations.

The hydraulic loads test was performed after landing using hydraulic systems 1 and 3. Both systems operated properly.

Electrical Power Distribution and Control Subsystem

The electrical power distribution and control (EPDC) subsystem performed satisfactorily during all mission phases with no anomalies or problems noted in the data.

Environmental Control and Life Support System

The active thermal control system (ATCS) performed satisfactorily throughout the mission. The ATCS successfully supported payload cooling requirements with the Freon coolant loop (FCL) 2 flow proportioning valve in the payload position. This was performed at 179:12:01 G.m.t. (00:16:29 MET) for an initial Spacelab activation prior to docking with the Mir. The flow proportioning module was returned to the interchanger position to support vehicle cooling needs during the Mir rendezvous and docking procedures. Payload cooling was reinitialized by placing the FCL2 flow proportioning valve in payload position at 180:17:29 G.m.t. (01:21:57 MET), where it remained for the duration of on-orbit operations. The loop was returned to the interchanger position at 188:08:06 G.m.t. (09:12:34 MET) for entry as a part of the final Spacelab Pallet deactivation procedures.

The radiator coldsoak provided cooling during entry through touchdown-plus-5-minutes when ammonia boiler system (ABS) A was activated using the primary/GPC controller. To minimize thermal stress on the long-duration Mir crew, ammonia cooling was activated early by selecting the high outlet temperature set-point (57 °F) on both FCL radiator flow controllers when the radiator controller outlet temperature exceeded 40 °F. This provided the necessary heat load for the ABS and avoided the increased cabin temperature transient which occurs during nominal postlanding operations between coldsoak depletion and ammonia activation. System A operated for 35 minutes until the ammonia was depleted. System B was activated postlanding at 188:15:34 G.m.t., using the secondary controller, and operated for 25 minutes before ground cooling was initiated.

The supply water and waste management systems performed normally throughout the mission. Supply water was managed through the use of the flash evaporator system (FES) and water transfer to the Mir. Three CWCs and 18 Russian EDV water tanks were filled with potable water, thus providing the Mir Space Station with 1,067 lbm of water. The supply water dump line temperature was maintained between 69 and 93 °F throughout the mission using the line heater.

Waste water was gathered at the predicted rate. Three waste water dumps were performed at an average rate of 1.96 percent/minute (3.25 lbm/min). The waste water dump line temperature was maintained between 55 and 73 °F throughout the mission. The vacuum vent line temperature was between 58 and 76 °F, and the vacuum vent nozzle was between 120 and 180 °F.

The waste collection system performed normally throughout the mission.

The atmospheric revitalization system (ARS) performed nominally throughout the mission. Air temperature control of the ODS was maintained within limits and above the dew-point temperature. The center-line camera hatch window was maintained free of condensation with the air flow duct. Since Spacelab coolant requirements were low, one Freon coolant loop was retained in the interchanger position, and this controlled the Orbiter dew-point to a lower level (50 vs. 55 °F) and provided satisfactory humidity control to the Mir. Orbiter and Spacelab carbon dioxide (CO_2) control maintained the Orbiter and Mir CO_2 levels within the agreed limits. Air flow to the Mir provided sufficient thermal conditioning when more than three crewmen were in the Mir.

The atmospheric revitalization pressure control system (ARPCS) performed satisfactorily throughout the flight. After docking with the Mir Space Station, the vestibule was pressurized using Mir consumables. Subsequently, the upper hatch equalization valves of the Orbiter airlock were opened, and the Mir and Orbiter volumes were equalized to a total pressure of 13.20 psia. Prior to opening these valves, the Orbiter and ODS pressure was 14.68 psia. Following opening of the Orbiter-to-Mir transfer hatches, the entire Mir/Orbiter volume was pressurized up to 14.62 psia using the Orbiter ARPCS. Prior to undocking, the entire Mir/Orbiter volume was further pressurized to 15.1 psia. Total consumables transferred to the Mir was 87.4 lb of nitrogen and 48.3 lb of oxygen. The nitrogen was used for Mir pressurization, and the oxygen was used for additional crew metabolic consumption during the docked operations and for raising the Mir partial pressure of oxygen before undocking.

Vestibule depressurization during the undocking required 1.5 hours as opposed to the planned 5 minutes. At 184:19:59 G.m.t. (06:00:27 MET), the vestibule depressurization began. Low flow was observed when the primary depressurization valves were opened (Flight Problem STS-71-V-06). After the low flow was noted, the secondary depressurization valves were also opened, but no change in flow rate occurred. The slow vestibule depressurization appeared to be due to a thermal insulation blanket blocking the depressurization valve port. In reviewing the drawings, no hole in the blanket was called out at the location of the valve port. The port is 1.5-inches in diameter with a debris screen across it. When the pressure in the vestibule reached about 1.9 psia, the valves were closed and the hatch leak check was successfully performed. The valves were then reopened at 184:22:38 G.m.t. (06:03:06 MET), remained open overnight, and the vestibule vented completely. Modifications are being made to remove the portion of the thermal blanket that covers the depressurization valve port for future ODS missions.

Airlock Support System

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

Smoke Detection and Fire Suppression System

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

Avionics and Software Systems

The ascent and entry guidance, navigation and control subsystem performance was nominal with the day of launch I loads updates (DOLILU) being used for ascent.

Flight control system performance was nominal. All on-orbit flight control mission objectives were accomplished including post-docking control, mated control, and residual rate control. Indications from the Russian counterparts are that the Mir control performance was also nominal.

The forward RCS was using more propellant than predicted while in the inertial-hold attitude and docked with the Mir. As a result, a change to a gravity-gradient attitude was made that resulted in a large reduction in propellant consumption. The increased propellant usage in the inertial-hold attitude only occurred during negative pitch maneuvers. Analysis showed that this phenomenon was caused by the effects of R5D and L5D RCS thruster-plume impingement upon the elevons and body flap. The effect of this phenomenon is virtually undetectable in the Orbiter-only configuration; however, it is believed to be magnified in the Shuttle-Mir docked configuration because the center-of-gravity (c.g.) is external to the vehicle. These results demonstrated that the Orbiter vernier RCS can successfully control the mated Shuttle/Mir configurations.

The Mir assumed the attitude control function for the combined vehicles at 183:10:13 G.m.t. (04:14:41 MET). Mir control was monitored via the Shuttle DAP estimator. Mir appeared to require gyrodyne desaturation twice as often as shown in preflight estimates, but overall Mir control was satisfactory. The Orbiter resumed attitude control at 183:14:55 G.m.t. (04:19:23 MET). The Orbiter elevons were parked at -7.5° to aid in the investigation of the higher-than-predicted propellant usage during Orbiter-controlled inertial attitudes.

The inertial measurement units (IMUs) performed satisfactorily with only one accelerometer compensation required to be uplinked. Drift of the units remained at one sigma (0.006 deg/hr) or better throughout the mission. No adjustment of gyro compensations was required. During the mission, accelerometer compensations were uplinked once. The uplink was performed about 13 hours after launch. As expected, the largest compensation was 98 μg for the IMU s/n 203 Z-axis, and this is typical for this particular unit.

Star tracker performance was also satisfactory with no problems noted.

The data processing system (DPS) hardware and software performed nominally; however, some operations problems were noted. These are discussed in the following three paragraphs.

At 181:05:08:59 G.m.t. (02:09:36:40 MET), GPC 4 (s/n 536), which had been functioning as the SM machine, failed to sync with GPC 1 and was declared failed by GPC 1. The crew brought up GPC 3 as the SM machine. A hardware/software dump analysis of the GPC 4 fail-to-sync was completed. Data showed that a dropped bit (change from '0111' to '0011') occurred in the hardware data flow when the data sector extension (DSE) register contents were stored in the SVC OLD PSW memory location. This erroneous value caused flight software to branch into the middle of a flight computer operating system (FCOS) routine without a correct pointer back to the calling routine. The analysis confirms that the fail-to-sync was most likely the result of a hardware event that was probably caused by a radiation upset. An initial program load (IPL) was performed on GPC 4 and placed in the common set in OPS 0 for one hour for driving CRT 2 and no anomalies were noted. GPC 4 was then brought into the G2 redundant set with no strings assigned and subsequently freeze-dried for the crew sleep period. During the following flight day, GPC 4 was reassigned as the SM machine. GPC 4 operated satisfactorily for the remainder of the mission.

At 182:08:50:30 G.m.t. (03:13:18:11 MET), a CRT 2 BITE message was annunciated against DEU 2. This error was attributed to a known "short store complete" scenario, which can occur on -0108 or -0109 DEUs (DEU 2 s/n 29 is a -0108). Crew procedures corrected the BITE condition.

The SM checkpoint at 182:09:10:36 G.m.t. (03:13:38:17 MET) failed with a "checkpoint fail" and an "off/busy" message annunicated against MMU 1. The SM checkpoint was reattempted successfully on MMU 1, and the MMU operated satisfactorily for the remainder of the flight. The signature observed is consistent with a known MMU power supply problem caused by internal noise.

The displays and controls operated nominally; however, a master alarm occurred during the final approach to landing with no associated fault message. The indications are that the alarm was caused by the PRSD O_2 tank 5 heater assembly temperature excursions.

Communications and Tracking Subsystems

The communications and tracking subsystems performed nominally. Satisfactory communications were maintained throughout the mission with only one anomaly noted.

Beginning at 187:15:33 G.m.t. (08:20:01 MET), the S-band system experienced dropouts and loss of frame synchronization intermittently over the next six hours while operating on the Spaceflight Tracking and Data Network (STDN) with a number of sites (Flight Problem STS-71-V-08). Tests were performed at 188:03:42 G.m.t.

(09:08:09 MET) with frame synchronization remaining satisfactory while operating on transponder 1. However, upon transition to transponder 2, the frame synchronization locked and unlocked continuously. This condition resulted in the Mission Control Center experiencing problems commanding the Orbiter. Communications were restored by stored program command (SPC) at the tracking and data relay satellite (TDRS) West acquisition when transponder 1 was reselected. This configuration was used satisfactorily for the remainder of the mission.

The S-band forward link dropouts were experienced during parts of TDRS-East passes on revolutions 31, 32, and 34 while transmitting on the lower right antenna. The interference with Mir frequencies and physical blockage have been ruled out because the problem did not occur on another antenna. Data evaluation did not show the cause of the poor communications. After revolution 34, the antenna provided satisfactory communications for the remainder of the mission.

Closed circuit television (CCTV) monitor 2 began flickering and went blank after being powered up following a one-hour down period. The unit was powered down and the filter was cleaned. Performance of the monitor was nominal for the remainder of the mission.

Operational Instrumentation/Modular Auxiliary Data System

The operational instrumentation and MADS performed nominally throughout the mission. However, the MADS recorder could not be ground-commanded on for entry. This condition resulted from the onboard panel switch being in the center neutral (non-functional) position, which prevented uplink command control.

Structures and Mechanical Subsystems

The structures and mechanical subsystems performed satisfactorily throughout the mission with no anomalies noted. The postflight inspection revealed that the tires and brakes were in good condition, and the landing and braking data are shown in the table on the following page.

The drag chute performance was nominal.

Orbiter windows 3 and 4 exhibited moderate hazing, and a light haze was present on the remaining windows. Tile damage on the window perimeter tiles was significantly less than usual, and the four damage sites in the perimeter tile above window 3 were not caused by debris impact.

Landing and Braking Parameters

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	2324	200.6	~ 2.0	N/A
Nose gear touchdown	5474	159.6	N/A	~5.2

Brake initiation speed	148.3 keas
Brake-on time	40.0 seconds
Rollout distance	8,353 feet
Rollout time	53.8 seconds
Runway	15 (Concrete) KSC SLF
Orbiter weight at landing	216,371 lb

Brake sensor location	Peak pressure, psia	Brake assembly	Energy, million ft-lb
Left-hand inboard 1	864	Left-hand outboard	16.77
Left-hand inboard 3	804	Left-hand inboard	19.62
Left-hand outboard 2	828	Right-hand inboard	24.18
Left-hand outboard 4	756	Right-hand outboard	23.09
Right-hand inboard 1	852		
Right-hand inboard 3	852		
Right-hand outboard 2	792		
Right-hand outboard 4	744		

Integrated Aerodynamics, Heating and Thermal Interfaces

The ascent and entry aerodynamics were nominal with no problems, anomalies or unexpected conditions identified in the data.

The integrated heating during ascent and entry was nominal, based on the data and plume appearance. The entry aerodynamic heating was also nominal; however, postflight analysis and heating calculations are continuing as this report is being written.

The performance of the thermal interfaces was nominal with all temperatures remaining within limits.

Thermal Control System

The thermal control system performance was nominal throughout the mission with all temperatures being maintained within allowable limits.

Thermal data were successfully collected for DTO 1122 - APAS Thermal Data, and these data will be used in the thermal math model correlation.

Aerothermodynamics

The acreage heating during entry was nominal. The structural temperatures were near the limits, and the structural temperature rises were within the experience data base. The structural temperature rise on the left and right wings was symmetrical and within the experience data base.

Local heating was nominal; however, analysis is continuing based on data from the postflight thermal protection system (TPS) inspection. The loss of MADS recorder data during entry will prevent any analysis based on that data. The Operational Instrumentation/Modified Auxiliary Data System section of this report discusses the loss of the MADS data.

Thermal Protection Subsystem and Windows

The TPS performed satisfactorily. Based on structural temperature response data (temperature rise), the entry heating was above average. Many of the measured structural temperature rises were above previous maximums for OV-104, but were within the experience base of the Orbiter fleet. Data to determine boundary layer transition time from laminar to turbulent flow is not available for this mission as the MADS recorder was not operational during entry.

The Orbiter TPS sustained a total of 164 hits, of which 25 had a major dimension of one-inch or larger. This total does not include the numerous hits on the base heat shield attributed to the flame arrestment sparkler system. A comparison of these numbers to previous missions indicates both the total number of hits and the number of hits one-inch or larger was above average.

Data show that the lower surface sustained a total of 149 hits of which 24 had a major dimension of one-inch or larger, and that is 10 more hits than average. Most of the tile debris damage sites were located to the right of the centerline, and none of the hits on the lower surface were unusually large or unique in nature. Most of the hits showed signs of thermal erosion, typical of entry heating. The upper surface had 10 hits, of which one had a major dimension of one-inch or larger. The right OMS pod had two hits and the left OMS pod had three hits.

The tile damage sites aft of the LH_2 and LO_2 ET/Orbiter umbilicals are believed to be caused by impacts from umbilical ice, and were typical in number and size. No tile damage from micrometeorites or on-orbit debris has been identified.

The ET/Orbiter separation devices functioned nominally. All separation ordnance retention shutters were closed properly. Umbilical closeout foam about 6 inches long and less than one inch wide, along with a one-inch long piece of the white RTV dam, had adhered to the umbilical plate near the LH_2 recirculation line disconnect. No debris was found on the runway below the umbilicals.

Two tiles on the nose landing gear door (NLGD) were identified as scrap due to edge-lip damage. All of the NLGD thermal barriers (T/Bs) were in good condition except for one breached T/B. One left-hand and two right-hand main landing gear door (MLGD) T/Bs were breached, with two being identified as probable scraps. No damage was noted on the MLGD tiles.

The ET door T/Bs and tile condition was nominal. Most of the ET door T/Bs had flown three flights and have performed well. A loose carrier panel on the leading edge of the right-hand inboard elevon, near the center hinge, was found; however, no thermal damage occurred as a result of this condition. Some thermal damage occurred at the left-hand inboard elevon center hinge area (charred polyimide seal, carrier panel discoloration, glazed/slumped tile, and charred filler bar). Slumped tiles were noted in this same area on the previous flight of this vehicle.

The engine dome-mounted heatshield blankets were in good condition, with only minor fraying observed on SSME 2 at the 12 o'clock position. Base heatshield tile peppering was less than usual. One tile near the lower right-hand corner of the drag chute opening was damaged due to the drag chute deployment. One of the "piano hinge tiles" located on the upper body flap stub near the SSME 3 5 o'clock position was broken. Similar damage has occurred to these tiles on previous flights of this vehicle.

No ice adhered to the payload bay door; however, a white residue was present around the waste water dump nozzle. Tile damage on the base heat shield was typical. All three dome mounted heat shield closeout blankets were in excellent condition.

FLIGHT CREW EQUIPMENT/GOVERNMENT FURNISHED EQUIPMENT

The performance of the flight crew equipment/Government furnished equipment was nominal. The recumbent seat system, flown for the first time, performed nominally. Seven anomalies were noted in this area and they are discussed in the following paragraphs.

The crew reported at approximately 187:03:57 G.m.t. (08:08:25 MET) that the Hasselblad 70mm camera (S/N 1026) shutter-release button was sticking (Flight Problem STS-71-F-05). When the shutter release button was depressed, the camera cycled through the remainder of the film magazine; however, the camera shutter did not open and the film was not exposed. An in-flight maintenance (IFM) procedure was performed in which the shutter release button was moved from the primary receptacle to the secondary receptacle. The IFM was successful and the camera performed nominally for the remainder of the mission. The crew also stated that the lens had jammed, but they were able to restore proper operation of the lens. Another Hasselblad 70mm camera was available if the one in use had become inoperable.

The very lightweight head set (VLHS) cable could not be found during the flight (Flight Problem STS-71-F-04). The lack of this cable resulted from the fact that the paperwork could not be completed in the time required to manifest the cable for stowage.

The environmental control and life support subsystem (ECLSS) booster fan dessicant bags were missing from locker MA9N (Flight Problem STS-71-F-03). The bags could not be located onboard the vehicle. Operations were conducted without the dessicant bags. No ODS overhead hatch window fogging was reported. A review of the preflight paperwork shows that the bags should have been onboard.

During power-up for the checkout of the rendezvous equipment, the LIDAR battery packs were providing zero voltage to the LIDAR. All battery packs were opened and it was discovered that no batteries had been installed (Flight Problem STS-71-V-01). Since the LIDAR was a necessary piece of equipment for the rendezvous operations, an IFM was developed to provide the Orbiter 28 Vdc to 10.5 VDC via the IFM breakout box. The IFM was successful and the LIDAR was used for the rendezvous operations. An investigation of the anomaly revealed that the personal illness of the individual who normally packs the batteries resulted in the battery installation being overlooked. Measures have been taken to ensure that this incident will not recur.

During three SAREX passes, the ground radio operators reported that the signal carrier was good but the audio level from the crew was very low (Flight Problem STS-71-F-06). During these passes, the crew was using the VHF communication system with the VHF transceiver's handset in the high-power mode. The crew reconfigured the VHF to the audio distribution system radio interface unit (ARIU) and a lightweight headset, and the radio operators reported good audio in the new configuration.

Also during SAREX operations, the crew attempted to used the VHF radio and ARIU in a dual headset mode so that two crewmembers could participate in the communication event. However, the crewmember connected to the ARIU could transmit and the second crewmember who was connected to the Commander's audio terminal unit (ATU) could not (Flight Problem STS-71-F-07). Troubleshooting revealed that the same problem existed in other transmit modes, and postflight testing and troubleshooting will be required to resolve this condition.

At 182:13:17 G.m.t. (03:17:45 MET), the crew reported that the primary air-to-air VHF radio would not transmit; however, the receive function still operated (Flight Problem STS-71-F-02). A power cycle of the radio was performed, but the radio transmit function remained inoperative. The crew reported and error message that indicated a failed power amplifier, which would result in the loss of the transmit capability. The backup VHF radio was used successfully for the remainder of activities. Postflight repair is planned.

CARGO INTEGRATION

Integration hardware performance was nominal throughout the mission, with one anomaly identified. At 185:15:50 G.m.t. (06:20:18 MET), the crew was unsuccessful in downlinking photographic images using the Ku-band communications adapter (KCA) through outlet 2 on the payload data interface panel (PDIP) in the Orbiter aft flight deck. Power had been lost to the outlet because of a open fuse, and satisfactory operation was regained through an IFM procedure.

DEVELOPMENT TEST OBJECTIVE/DETAILED SUPPLEMENTARY OBJECTIVES

A total of 11 development test objectives (DTOs) and seven detailed supplementary objectives (DSOs) was defined for the STS-71 mission. The preliminary results of the DTOs and DSOs are discussed in the following paragraphs.

DEVELOPMENT TEST OBJECTIVES

DTO 301D - Ascent Structural Capability Evaluation - This DTO was performed during the ascent phase of the mission and is a data-only DTO. The data were dumped postflight and given to the sponsor for evaluation, and the results will be published in separate documentation.

DTO 307D - Entry Structural Capability - This DTO was to be performed during the entry phase of the mission and is a data-only DTO. However, the MADS recorder could not be activated and no entry data were collected.

DTO 312 - External Tank Thermal Protection System Performance - The crew cabin photographs of the ET after separation were not taken on the STS-71 mission because the normal pitch maneuver that is required was not performed because of propellant limitations. The accomplishment of this DTO was based on the umbilical well photography.

Three rolls of umbilical well camera film were evaluated for this DTO. The evaluation of these films revealed no observations of anomalous performance.

DTO 414 - APU Shutdown Test - The APUs were shut down in the order specified. Data evaluation showed no evidence of power drive unit (PDU) back-driving. The sponsor will publish the results of this DTO in a separate document.

DTO 624 - Radiator Performance - This DTO of opportunity was not performed as the radiators were not deployed during this flight.

DTO 656 - PGSC Single Event Upset Monitoring Configuration - Data were collected for this DTO, and these data have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DTO 684 - Radiation Measurements in Shuttle Crew Compartment - The equipment for this DTO was deployed at 179:14:53 G.m.t. (00:20:11 MET) and data were collected for this DTO. The data were given to the sponsor for analysis, and the results of that analysis will be reported in separate documentation.

DTO 700-10 - Orbiter Space Vision System Flight Video Taping - Video taping using the Orbiter Space Vision System (OSVS) was very successful. The downlink showed views of the OSVS targets on the ODS from cameras A and D. The variety of Orbiter attitudes provided many different lighting and shadowing conditions. Additionally, views were recorded showing the activation of the forward bulkhead lights and the mag lights during night passes. The artificial lighting proved acceptable for tracking the ODS targets from both cameras. Alternating zoomed-in views from cameras A and D during day and night passes were used during postflight evaluations for simultaneous two-camera studies. The results of the analysis will be reported in separate documentation.

DTO 805 - Crosswind Landing Performance - This DTO of opportunity was not performed because conditions were not appropriate for data collection.

DTO 832 - Target of Opportunity Navigation Sensors - The crew completed target-of-opportunity navigation sensors (TONS) activities during the rendezvous/docking and the undocking/separation phases of the mission. Data have been given to the sponsor for analysis, and the results of the evaluation will be reported in separate documentation.

DTO 1118 - Photographic and Video Survey of Mir Space Station - The crew performed the photographic surveys of the Mir Space Station as well as selected Public Affairs activities using the onboard video systems, the Electronic Still Camera-II (ESC-II), and normal photographic equipment. Some of the video and ESC-II pictures were downlinked for evaluation during the flight. Additional evaluation was performed postflight when all the video and film were available. A PDIP power failure interrupted the downlink of ESC-II pictures until an IFM procedure was performed. The delayed downlink did not significantly affect DTO activities.

DTO 1120 - Mated Shuttle and Mir Free Drift Experiment - The test for this DTO was successfully performed at 184:09:45 G.m.t. (05:13:45 MET) in the 2-degree biased GO 1.2 attitude versus the non-biased GO 1.2 attitude that was planned during preflight activities to be used. The mated stack showed good stability during the test with very few thruster firings. A drift in the yaw axis was observed that had not been seen in the preflight predictions. This drift was most likely caused by the flight configuration of the Mir solar arrays, which were in a non-symmetric configuration. Data have been given to the sponsor for evaluation, and the results of the evaluation will be reported in separate documentation.

DTO 1122 - APAS Thermal Data - The APAS thermal data were collected to validate the thermal models. All docking mechanism temperatures remained within expected ranges.

DETAILED SUPPLEMENTARY OBJECTIVES

DSO 487 - Immunological Assessment of Crewmembers - Data were collected for this DSO, and these data have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DSO 608 - Effects of Spaceflight on Aerobic and Anaerobic Metabolism During Exercise - Data were collected for this DSO, and these data have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DSO 624 - Pre and Postflight Measurement of Cardiorespiratory Responses to Submaximal Exercise - Data were collected for this DSO, and these data have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DSO 901 - Documentary Television - Data were collected for this DSO, and these data have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DSO 902 - Documentary Motion Picture Photography - Data were collected for this DSO, and these data have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DSO 903 - Documentary Still Photography - Data were collected for this DSO, and these data have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

PHOTOGRAPHY AND TELEVISION ANALYSIS

LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS

A total of 24 videos of launch and 52 films of launch were reviewed and analyzed. One camera did not operate during the launch operations. No potential anomalies were noted in any of the videos or films.

DTO 312 photography was not taken from the flight deck; however, three rolls of film were exposed from the umbilical wells. This DTO is discussed in a previous section of this report.

ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS

DTO 1118 - Photographic and Video Survey of Mir Space Station - Photographic and video documentation of the Mir Space Station were collected. A ground-controlled survey of the Mir's exterior surfaces was accomplished during the first two sleep periods of the docked phase. Detailed views of the Orbiter-facing side of the Kvant-2 and Spektr modules were acquired. Film and video of the Mir exterior surfaces will require analysis through the end of August 1995. The results of the analysis will be reported in separate documentation.

LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSIS

Twelve videos of the Orbiter's approach and landing were reviewed and no anomalies were noted in the review.

TABLE I.- STS-71 MISSION EVENTS

Event	Description	Actual time, G.m.t.
APU Activation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	178:19:27:32.192 178:19:27:33.538 178:19:27:34.790
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	178:19:31:51.278 178:19:31:51.278 178:19:31.51.438 178:19:31:51.438
Main Propulsion System Start[a]	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	178:19:32:12.429 178:19:32:12.566 178:19:32:12.682
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	178:19:32:18.988
Throttle up to 104 Percent Thrust[a]	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	178:19:32:23.829 178:19:32:23.843 178:19:32:23.847
Throttle down to 68 Percent Thrust[a]	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	178:19:32:47.948 178:19:32:47.963 178:19:32:47.967
Throttle up to 104 Percent[a]	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	178:19:33:13.707 178:19:33:13.724 178:19:33:13.728
Maximum Dynamic Pressure (q)	Derived ascent dynamic pressure	178:19:33:22.712
Both SRM's Chamber Pressure at 50 psi[a]	LH SRM chamber pressure mid-range select RH SRM chamber pressure mid-range select	178:19:34:17.668 178:19:34:18.028
End SRM [a] Action[a]	LH SRM chamber pressure mid-range select RH SRM chamber pressure mid-range select	178:19:34:19.338 178:19:34:20.098
SRB Physical Separation[a]	LH rate APU turbine speed - LOS RH rate APU turbine speed - LOS	178:19:34:22.548 178:19:34:22.548
SRB Separation Command	SRB separation command flag	178:19:34:23
3g Acceleration	Total load factor	178:19:39:47
Throttle Down for 3g Acceleration[a]	ME-3 command accepted ME-1 command accepted ME-2 command accepted	178:19:39:47.293 178:19:39:47.295 178:19:39:47.335
Throttle Down to 68 Percent Thrust[a]	ME-3 command accepted ME-1 command accepted ME-2 command accepted	178:19:40:43.293 178:19:40:43.295 178:19:40:43.636
SSME Shutdown[a]	ME-3 command accepted ME-1 command accepted ME-2 command accepted	178:19:40:49.493 178:19:40:49.495 178:19:40:49.536
MECO	MECO command flag MECO confirm flag	178:19:40:50 178:19:40:50
ET Separation	ET separation command flag	178:19:41:09.33

[a]MSFC supplied data

TABLE I.- STS-71 MISSION EVENTS
(Continued)

Event	Description	Actual time, G.m.t.
APU Deactivation	APU-2 GG chamber pressure APU 1 GG chamber pressure APU 3 GG chamber pressure	178:19:48:04.044 178:19:48:10.200 178:18:48:19.699
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	178:20:15:16.8 178:20:15:16.8
OMS-2 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	178:20:16:04.4 178:20:16:04.5
Payload Bay Doors (PLBDs) Open	PLBD right open 1 PLBD left open 1	178:21:05:57 178:21:07:15
OMS-3 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	178:23:10:25.2 178:23:10:25.2
OMS-3 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	178:23:12:42.1 178:23:12:42.1
OMS-4 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	179:10:49:35.8 N/A
OMS-4 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	179:10:49:48.2 N/A
OMS-5 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	180:07:57:17.2 180:07:57:17.2
OMS-5 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	180:07:58:03.2 180:07:58:03.2
OMS-6 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	180:09:31:01.2 N/A
OMS-6 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	180:09:31:10.4 N/A
Mir/Shuttle Capture	Capture	180:13:00:13.9
Docking Completed	Docking ring final position	180:13:08:17.9
Undocking Completed	Undocking completed	185:11:09:41.8
Flight Control System Checkout APU Start APU Stop	 APU-1 GG chamber pressure APU-1 GG chamber pressure	 187:10:27:32.280 187:10:33:00.990
Payload Bay Doors Close	PLBD left close 1 PLBD right close 1	188:11:04:26 188:11:06:03
APU Activation for Entry	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	188:13:40:25.404 188:14:10:23.720 188:14:10:25.588
Deorbit Burn Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	188:13:45:19.3 188:13:45:19.3
Deorbit Burn Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	188:13:48:52.6 188:13:48:52.7
Entry Interface (400K feet)	Current orbital altitude above	188:14:23:09
Blackout end	Data locked (high sample rate)	No blackout
Terminal Area Energy Mgmt.	Major mode change (305)	188:14:48:13

TABLE I.- STS-71 MISSION EVENTS (Continued)

Event	Description	Actual time, G.m.t.
Main Landing Gear Contact	LH main landing gear tire pressure 1 RH main landing gear tire pressure 2	188:14:54:35 188:14:54:35
Main Landing Gear Weight on Wheels	RH main landing gear weight on wheels LH main landing gear weight on wheels	188:14:54:36 188:14:54:38
Drag Chute Deployment	Drag chute deploy 1 CP Volts	188:14:54:38.8
Nose Landing Gear Contact	NLG LH tire pressure 1	188:14:54:44
Nose Landing Gear Weight On Wheels	NLG weight on wheels 1	188:14:54:45
Drag Chute Jettison	Drag chute jettison 1 CP Volts	188:14:55:09.2
Wheel Stop	Velocity with respect to runway	188:14:55:28
APU Deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	188:15:15:20.110 188:15:15:22.686 188:15:15:25.518

TABLE II.- ORBITER PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-71-V-01	Deleted		
STS-71-V-02	PRSD H_2 Manifold 1 Valve Did Not Close	179:00:06 G.m.t. CAR 71RF01 IPR 74V-0006	The hydrogen manifold 1 valve failed to close when presleep cryogenic configuration was performed. The valve (s/n 20) had passed cryogenic screening at NSLD. Further closure attempts were not made during the flight. KSC: Postflight troubleshooting performed and broken ground lug found. A replacement was made and the failed hardware was sent to the contractor for failure analysis.
STS-71-V-03	Slow Closure of MPS SSME 1 LH_2 Recirculation Valve	178:19:32 G.m.t. CAR 71RF02 IPR 74V-0005	The MPS SSME 1 recirculation valve (PV14) was slow to close when commanded at T-10 seconds. Closing times were 3.190 seconds from loss of open switch to acquisition of close switch (requirement is 1.1 seconds), and 4.282 seconds from loss of open power to acquisition of the close switch (requirement is 2.0 seconds). KSC: Valve was removed and replaced.
STS-71-V-04	SSME 3 GH_2 Flow Control Valve Sluggish Level III Closure	178:19:35 G.m.t. CAR 71RF03	The SSME 3 GH_2 flow control valve exhibited sluggishness during last half of ascent. The OMRSD File IX requirement on 3 cycles was violated plus the valve had 10 more cycles that were slower-than-normal. KSC: The valve will be removed and replaced as a part of the planned FCV modification.
STS-71-V-05	PRSD H_2 Manifold 1 Valve False-Closed Indication	182:01:34 G.m.t. CAR 71RF04 IPR 74V-0007	The hydrogen manifold 1 valve indicated closed at the listed time, setting off the FDA alarm. The crew attempted to command the valve to open, but were unsuccessful. Pressure data indicate that the valve was not closed. At 182:11:09 G.m.t., the valve indication returned to open. The indicator toggled a number of times during the remainder of the mission. KSC: Postflight troubleshooting failed to recreate the problem.
STS-71-V-06	Low Vestibule Depressurization Rate	184:21:25 G.m.t.	The depressurization rate was lower than expected. Thermal blanketing was found to be covering the depressurization valve inlet. KSC: The engineering instructions to remove thermal blanketing from the valve inlet prior to the next docking flight with the Mir have been released..
STS-71-V-07	RCS Thruster R2U Failed Off. Level III Closure	187:11:23 G.m.t. CAR 71RF05	RCS thruster R2U (s/n 224) failed off during the RCS hot-fire. The thruster failed off because of low chamber pressure. Partial flow of oxidizer and fuel were observed. Probable iron nitrate contamination. KSC: Remove and replace thruster.

TABLE II.- ORBITER PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-71-V-08	S-Band Transponder 2 Frame-Synchronization Dropouts	187:15:33 G.m.t. CAR 71RF06 PR COM-4-15-0181	Starting with the MILA landing - one day checkout, S-Band transponder 2 showed numerous frame synchronization dropouts. S-Band transponder 1 functioned nominally when cross-strapped to NSP 2., KSC: Removed and replaced transponder and sent to vendor for failure analysis.
STS-71-V-09	APU 3 Excessive Repressurization	188:14:32 G.m.t. CAR 71RF07 IPR-74V-0008	The gearbox repressurization circuit was activated and approximately 80 percent of the GN_2 supply bottle contents was dumped into the APU gearbox. Gearbox pressure reached 30 psi and the normal pressure is 10 psi. Pressure transducer measurement was erratic during the repressurization. Same transducer showed similar behavior on STS-50. KSC: Removed and replaced transducer, and send erratic unit to contractor for failure analysis.
STS-71-V-10	PRSD O_2 Tank 5 Heater Assembly 1 Temperature Measurement Excursions.	188:14:53:14 G.m.t. IPR 74V-0009	At least three excursions of this measurement were noted starting at the time shown with the highest reading reaching 240 °F. Heaters were off. Heater assembly 2 temperature measurement stayed steady state during the excursions. Most likely cause of prelanding master alarm. Postflight troubleshooting failed to recreate the problem.

TABLE III.- GOVERNMENT FURNISHED EQUIPMENT PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-71-F-01	LIDAR Batteries Missing	179:21:14 G.m.t. 01:01:42 MET	Neither LIDAR would operate because batteries had not been installed in the battery packs. The crew performed and IFM to power the LIDAR with Orbiter power via a breakout box.
STS-71-F-02	VHF System 1 Transmit Failure	182:13:17 G.m.t. 03:17:45 MET	The crew reported that the air-to-air VHF radio would not transmit but would receive, and the unit displayed the "ERR-TR PR" message when keyed. Power cycle did not restore function. System 2 was used nominally for the remainder of the mission.
STS-71-F-03	Missing Dessicant Bags	180:11:15 G.m.t. 01:15:43 MET	The crew reported that the ECLSS booster fan dessicant bags were missing from locker MA9N and could not be located. Operations were conducted without the bags, and no ODS overhead hatch window fogging was reported.
STS-71-F-04	Missing VLHS Cable	183:02:08 G.m.t. 004:06:36 MET	The crew could not find the VLHS cable. As a result, live video could not be downlinked from the Mir using the Orbiter camcorder.
STS-71-F-05	Hasselblad Camera Sticky Shutter Release	187:03:57 G.m.t. 08:08:25 MET	The crew depressed the Hasselblad 70mm camera (s/n 1026) shutter release push-button and the camera cycled through the remainder of the entire film magazine. The crew removed the shutter release-button from its primary receptacle hole and inserted it into its secondary receptacle. Normal camera operation was restored.
STS-71-F-06	Handset H-189/GR Transmit Problem	185:22:03 G.m.t. 07:02:31 MET	At 185:22:03 G.m.t., It was reported that during the previous three SAREX passes, the ground was receiving low volume from the crewmember. At 185:22:19 G.m.t., (07:02:47 MET), the crew reported that the headset must have been the problem. They reported that during the three degraded SAREX passes, the H-189/GR handset had been used. The crew then checked their audio configuration and reconfigured to use the nominal configuration (ARIU/ATU, headset) and subsequently performed a satisfactory communications check.
STS-71-F-07	SAREX Low Volume Using Dual Headset Mode	85:15:00 G.m.t. 06:19:28 MET)	Low transmit volume experienced in dual headset mode on both ICOM B and A/A.

DOCUMENT SOURCES

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

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

ACRONYMS AND ABBREVIATIONS

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

ABS	ammonia boiler system
APAS	Androgynous Peripheral Assembly System
APDS	Androgynous Peripheral Docking System
APU	auxiliary power unit
ARIU	audio distribution system radio interface unit
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
ASTP	Apollo-Soyuz Test Project
ATCS	active thermal control system
ATU	audio terminal unit
BITE	built-in test equipment
CCTV	closed circuit television
CCVA	chamber coolant valve actuator
c.g.	center of gravity
COMSEC	communications security
CO_2	carbon dioxide
CRT	cathode ray tube
CWC	contingency water carrier
DAP	digital autopilot
DEU	display electronics unit
DOLILU	day of launch I loads
DPS	data processing system
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
ΔV	differential velocity
EDV	Russian water bottle
EPDC	electrical power distribution and control subsystem
ESC-II	electronic still camera-II
ET	External Tank
EVA	extravehicular activity
FCE	flight crew equipment
FCL	Freon coolant loop
FCOS	flight control operating system
FCS	flight control system
FCV	flow control valve
FES	flash evaporator system
ft/sec	feet per second
GFE	Government furnished equipment
GH_2	gaseous hydrogen
G.m.t.	Greenwich mean time
GN_2	gaseous nitrogen
GO	gravity orientation
GPC	general purpose computer

HAINS	high accuracy inertial navigation system
HPFTP	high pressure fuel turbopump
HPOTP	high pressure oxidizer turbopump
IFM	in-flight maintenance
IMAX	Canadian camera system
IMU	inertial measurement unit
IO	inertial orientation
Isp	specific impulse
ISS	International Space Station
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt hour
LCC	Launch Commit Criteria
LESC	Lockheed Engineering and Science Company
LH_2	liquid hydrogen
LIDAR	light distance and ranging
LO_2	liquid oxygen
MADS	modular auxiliary data system
MCC	main combustion chamber
MECO	main engine cutoff
MET	mission elapsed time
Mir	Russian Space Station
MLGD	main landing gear door
MMU	mass memory storage unit
MPLM	mini-pressurized logistics module
MPS	main propulsion system
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NLGD	nose landing gear door
nmi.	nautical mile
NPS	net positive suction pressure
NSLD	NASA Shuttle Logistics Depot
NSTS	National Space Transportation System (i.e., Space Shuttle Program)
O_2	oxygen
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OPOV	oxidizer preburner oxidizer valve
OSVS	Orbiter Space Vision System
PAL	protuberance air load
Pc	chamber pressure
PCT	postcontact thrusting
PDIP	payload data interface panel
PDU	power drive unit
PMBT	propellant mean bulk temperature
ppm	parts per million
PRSD	power reactant storage and distribution
RCS	reaction control subsystem
RM	redundancy management
RME	radiation monitoring equipment

RSRM	Reusable Solid Rocket Motor
RTV	room temperature vulcanizing
RVDT	rotary variable differential transformer
S&A	safe and arm
SAMS	Shuttle Acceleration Monitoring System
SAREX-II	Shuttle Amateur Radio Experiment-II
SLF	Shuttle Landing Facility
SM	system management
s/n	serial number
SPC	stored program command
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSME	Space Shuttle main engine
STDN	Spaceflight Tracking and Data Network
TB	thermal barriers
TCS	thermal control system
TDRS	Tracking and Data Relay Satellite
TI	terminal phase initiation
TONS	Target Opportunity Navigation Sensors
TORU	Russian tele-operated docking system
TPS	thermal protection subsystem
TV	television
UHF	ultrahigh frequency
Vdc	Volts, direct current
VHF	very high frequency
VLHS	very lightweight head set
WSB	water spray boiler

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