

# **STS-84 SPACE SHUTTLE MISSION REPORT**

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August 1997



**National Aeronautics and  
Space Administration**

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

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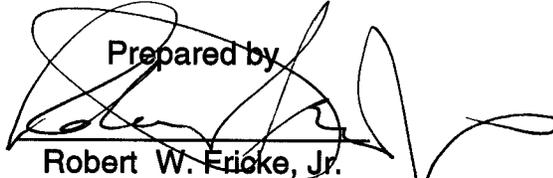
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STS-84

SPACE SHUTTLE

MISSION REPORT

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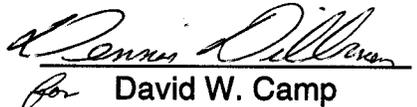
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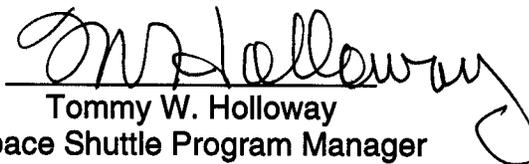
  
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## INTRODUCTION

The STS-84 Space Shuttle Program Mission Report presents a discussion of the Orbiter subsystem operation and the in-flight anomalies that were identified during this sixth Mir rendezvous mission. The report also summarizes the activities of the STS-84 mission and presents a summary of the External Tank (ET), Solid Rocket Booster (SRB), Reusable Solid Rocket Motor (RSRM), and Space Shuttle main engine (SSME) performance during this eighty-fourth mission of the Space Shuttle Program. STS-84 was the fifty-ninth flight since the return to flight, and the nineteenth flight of the OV-104 (Atlantis) Orbiter vehicle.

The flight vehicle consisted of the OV-104 Orbiter; an ET that was designated ET-85; three Phase II SSMEs that were designated as serial numbers (S/N) 2032, 2031, and 2029 in positions 1, 2, and 3, respectively; and two SRBs that were designated BI-087. The two RSRMs were designated RSRM 060 with one installed in each SRB. The individual RSRMs were designated 360L060A for the left SRB, and 360L060B for the right SRB.

The STS-84 Space Shuttle Program Mission Report fulfills the Space Shuttle Program requirements as documented in NSTS 07700, Volume VII, Appendix E. The requirement is that each organizational element supporting the Program will report the results of their hardware and software evaluation and mission performance plus identify all related in-flight anomalies.

The primary objective of the STS-84 flight was to rendezvous and dock with the Mir Space Station, and perform the exchange of a Mir astronaut. A double Spacehab module and the crew compartment carried science experiments including Protein Crystal Growth - Single Locker Thermal Enclosure System (PCG-STES); Liquid Motion Experiment (LME) hardware; Risk Mitigation Experiments (RME's) including the Cosmic Radiation Effect and Activation Monitor (CREAM), Electrolysis Performance Improvement Concept Study Experiment (EPICS), and the Radiation Monitoring Experiment -III (RME-III); and Russian logistics in support of the Phase 1 Program requirements. Secondary objectives of this flight were to perform the requirements of the Shuttle Ionospheric Modification with Pulsed Local Exhaust (SIMPLEX), and the requirement of the Midcourse Space Experiment (MSX).

The STS-84 mission was a planned 9-day plus 1 day plus 2-contingency-day mission during which logistics for the Mir station would be transferred and experiments would be performed. The plus 1 day provided an opportunity for docking on flight day 4 should the phasing angle or other problems prevented the docking on flight day 3. The two contingency days were available for bad weather avoidance for landing, or other Orbiter contingency operations. The STS-84 sequence of events is shown in Table I, and the Space Shuttle Vehicle Engineering Office (SSVEO) In-Flight Anomaly List is shown in Table II. Appendix A lists the sources of data, both informal and formal, that were used in

the preparation of this report. Appendix B provides the definitions of all acronyms and abbreviations used in this report. All times are given in Greenwich mean time (G.m.t.) and mission elapsed time (MET).

The eight-person crew of the STS-84 mission consisted of Charles J. Precourt, Col., United States Air Force, Commander; Eileen Marie Collins, Lt. Col., United States Air Force, Pilot; Jean-Francois Clervoy, Civilian, Payload Commander and Mission Specialist 1; Carlos I. Noriega, Major, USMC, Mission Specialist 2; Edward Tsang Lu, Ph. D., Civilian, Mission Specialist 3; Elena V. Kondakova, Russian Space Agency Cosmonaut, Civilian, Mission Specialist 4; C. Michael Foale, Ph. D., Civilian, Mission Specialist 5 (ascent through docking with the Mir Space Station); and Jerry M. Linenger, M. D., Captain, MC, United States Navy, Mission Specialist 6 (docking through landing). STS-84 was the fourth space flight for Mission Specialist 5 (ascent), the third space flight for the Commander, and Mission Specialist 6 (landing), the second space flight for the Pilot, Mission Specialist 1, and the first space flight for Mission Specialist 2, Mission Specialist 3. STS-84 was also the first flight for Mission Specialist 4 on the Space Shuttle; however, she performed her first space mission as the flight engineer on the seventeenth mission to the Mir Space Station, where she spent 169 days in space.

## MISSION SUMMARY

The STS-84 mission was launched at 135:08:07:48.003 G.m.t. (4:08 a.m. e.d.t. on May 15, 1997) after a flawless countdown with no unplanned holds. The ascent phase was nominal in all respects with no significant problems identified.

A determination of vehicle performance was made using vehicle acceleration and preflight propulsion prediction data. From these data, the average flight-derived engine specific impulse ( $I_{sp}$ ) determined for the time period between SRB separation and start of 3-g throttling was 452.34 seconds as compared with the main propulsion system (MPS) tag value of 452.54 seconds.

The orbital maneuvering subsystem (OMS) 1 maneuver was not required as the direct ascent trajectory was satisfactorily flown. The payload bay doors were opened at 135:09:45:56 G.m.t. (00:01:38:08 MET) in dual motor times. No problems were noted during the door-opening sequence.

The following table summarizes the OMS and reaction control subsystem (RCS) maneuvers that were performed to effect the Mir rendezvous.

<b>Maneuver</b>	<b>Time, G.m.t./MET</b>	<b><math>\Delta V</math>, ft/sec</b>	<b>Duration, sec</b>
OMS 2	135:08:51:52.4 00:00:44:04.4	75.0	47.6
NC1/ OMS 3	135:11:47 00:03:39	108.1	67.6
NC2/ OMS 4	135:23:47:17 00:15:39:29	8.5	10.8
NC3/ OMS 5	136:10:56 01:02:48	93.5	57.9
NC4/ OMS 6	136:22:20 01:14:13	88.7	54.1
NCC/ RCS	136:22:55 01:14:48	1.2	5.0
Ti/ OMS 7	136:23:53 01:15:45	7.3	9.1
MC1/ RCS	137:00:15 01:16:08	0.2	1.0
MC2/ RCS	137:00:47 01:16:40	1.9	8.0
MC3/ RCS	137:00:57 01:16:50	0.3	1.0
MC4/ RCS	137:01:07 01:17:00	1.0	1.0

The Orbiter Docking System (ODS) docking ring was extended at 136:07:13:59 G.m.t. (00:23:06:11 MET), and the data review showed that the extension was nominal.

ODS capture occurred at 137:02:33 G.m.t. (01:18:25 MET). The post contact thrusting (PCT) maneuver was initiated at 137:02:33:23 G.m.t. (01:18:25:35 MET) using RCS thrusters F3D, F4D, L3D, and R3D. The structural hooks were closed and docking was completed at 137:02:41 G.m.t. (01:18:33 MET).

Two problems were noted with camera C. The first appeared to be a circular blurred area in the center of the lens (Flight Problem STS-84-V-01). The second was a focusing problem noted by the ground controller operating the camera. It was reported that the camera focus seemed slow to respond and the focus ring did not seem to stop at the hard-stop position. It was determined that there is material on the inside surface of the lens. The camera was sent to the vendor for evaluation and repair. The reported focus problem will be evaluated at the vendor.

Two problems were also noted with camera A. Early in the mission, it was noted on several occasions that many white spots appeared in the image in lower-light-level conditions. This condition had no mission impact, and the camera image was excellent in higher-light-level scenes (its intended use). This condition is probably permanent and due to charged couple device (CCD) pixel failures. There is no functional impact to the camera's intended use. However, when camera A was selected for downlink at 142:12:30 G.m.t. (07:04:22 MET), a circular blurred area was observed in the center of the image (Flight Problem STS-84-V-03). The condition is similar to the camera C problem discussed previously. It was determined that there is material on the inside surface of the lens, and the camera was sent to the vendor for evaluation and repair.

Eleven contingency water containers (CWCs) were filled with water and transferred to the Mir. The total amount of water transferred was approximately 1038 lb.

The hatch on the Mir side of the ODS vestibule was closed at 141:12:40 G.m.t. (06:04:32 MET), followed by the closure of the hatch on the Orbiter side four minutes later. Hatch mechanism operations were nominal. Depressurization of the vestibule was completed at 141:13:00 G.m.t. (06:04:52 MET) and the vestibule leak check was successfully completed at 141:13:43 G.m.t. (06:05:35 MET).

The ODS was powered up for undocking at 142:00:36:42 G.m.t. (06:16:28:54 MET), and undocking was completed at 142:01:03:56 G.m.t. (06:16:56:08 MET). The ODS was powered down at 142:01:17:26 G.m.t. (06:17:09:38 MET). The ODS performed nominally during undocking operations.

During separation from the Mir, which is a period of high forward RCS utilization, the RCS oxidizer ullage pressure dropped into the 233- to 234-psia range on several occasions (Flight Problem STS-84-V-02). The ullage pressure should be maintained in the 239- to 259-psia range. The RCS oxidizer tank was configured to the B-leg regulator at the time of the occurrence. Low regulation pressure with this regulator is a known condition, having been seen during previous flights and on the ground. A waiver was taken during the STS-84 flow for this condition. Under similar high-flow-rate conditions during the previous flight of OV-104 (STS-81), the lowest regulated pressure was 238 psia, 5 psia higher than that seen during this mission. This regulator was tested during the postflight turnaround activities to determine if corrective action was required prior to STS-86. The testing determined that the regulator performance was the same as it had been prior to the STS-84 mission, and the regulator will be flown as-is. The waiver written prior to the STS-84 mission that was effective until the Orbiter Maintenance Down Period (OMDP), following the STS-86 mission, will remain applicable for the STS-86 mission.

The flight control system (FCS) checkout was performed using APU 1. The APU and hydraulics subsystems performed nominally during the checkout. APU 1 was started at 143:05:19 G.m.t. (07:21:11 MET) and ran for 7 minutes 24 seconds. The fuel consumption during this run was 14 lb. No water spray boiler operation occurred due to the short APU run time. FCS performance was nominal.

The RCS hot-fire was initiated at 143:06:30 G.m.t. (07:22:22 MET) and was completed six minutes later with satisfactory results. Due to the limited amount of propellant available, each thruster was fired only once for a nominal 320-msec (240-msec minimum) period. Prior to RCS hot-fire, 23 of 38 primary thrusters had been fired. During the hot-fire, all 38 primary thrusters were fired. The chamber pressures and injector temperature signatures on all thrusters was as expected.

During the installation of the mission specialist 4 lightweight seat (seat 6 position) for landing, the crew noted that there was interference between the A hatch handhold and the seat (Flight Problem STS-84-V-04). The handhold was unbolted and removed to provide clearance for the seat. The seat was then successfully installed for landing. During ascent, the seat position was two degrees forward, and the seat was rotated 10 degrees aft for entry. This is the first flight with a lightweight seat and an internal airlock. In the future, the internal airlock A hatch handhold will be removed when the lightweight seat is flown in seat position 6.

In preparation for landing, the payload bay doors were closed and latched at 144:08:08 G.m.t. (09:00:00 MET). Nominal dual motor times were observed. Unacceptable weather conditions existed at the Kennedy Space Center (KSC) Shuttle Landing Facility (SLF) for a landing on the first opportunity and it was waved off. Weather for the second opportunity at KSC was acceptable. The

dual-engine deorbit maneuver for the landing at the SLF runway 33 was performed on orbit 144 at 144:12:23:33 G.m.t. (09:04:15:45 MET). The maneuver was 189.2 seconds in duration with a  $\Delta V$  of 331.2 ft/sec.

Entry was completed satisfactorily, and main landing gear touchdown occurred on SLF concrete runway 33 at 144:13:27:44 G.m.t. (09:05:19:56 MET) on May 24, 1997. The Orbiter drag chute was deployed at 144:13:27:46.9 G.m.t. and the nose gear touchdown occurred 5 seconds later. The drag chute was jettisoned at 144:13:28:17.3 G.m.t. with wheels stop occurring at 144:13:28:36 G.m.t. The rollout was normal in all respects. The flight duration was 9 days 05 hours 19 minutes and 56 seconds. The APUs were shut down 16 minutes 8 seconds after landing.

## **PAYLOADS**

The primary objectives of crew exchange, transfer of logistics including critical hardware to upgrade Mir subsystems, and science and risk mitigation experiment (RME) transfers were completed. Almost 100 percent of the science and RME objectives were completed.

### **SPACEHAB AND SPACEHAB SCIENCE**

The Spacehab subsystems operated nominally throughout the flight. The Spacehab supported mission requests to power off/on the cabin fan to aid in the generation of water. Turning the fan off minimized thermal loads and flash evaporator system (FES) usage during the day cycle. Turning the fan on at night maximized the electrical loads to increase water production.

Both the Life Science Laboratory Equipment refrigerator/freezer (LSLE) and the enhanced Orbiter refrigerator/freezer (EORF) performed flawlessly throughout the flight and supported science transferred from the Mir as well as Shuttle science operations.

### **Biorack**

The Biorack was housed in the Spacehab and was the main science payload onboard the STS-84 mission. This large multi-purpose unit provided temperature-controlled environments, centrifuges for simulating gravity and a protected workspace for specimen handling. This entire Biorack facility was integrated into a single rack. On this the sixth flight of the Biorack facility, the unit carried a total of 11 experiments sponsored by France, Germany, and United States.

The Biorack facility operated nominally during the mission, and all Biorack operations were completed. The assessment of the Principal Investigators of the potential science gained showed that the 11 science objectives, which included various samples from human cellular science and animal and plant science, were 100 percent successful. The inflatable thermal control unit (ITCU) hardware demonstration was only 50-percent successful. The ITCU was not able to reach its set point of -17 °C while in the freezer mode.

The Biorack payload general support computer (PGSC) locked up six times during the flight. Five of the six lockups occurred during the docked phase of the mission. Discussions with the Orbiter PGSC users determined that the flight crew was told during the preflight activities that at least one lockup per day may be expected on the PGSC's that were onboard. The frequency of Biorack lockups (five during docked phase) will be investigated. However, since the PGSC stored only housekeeping data, Biorack science data were not impacted.

## **Self-Standing Drawer/Morphological Transition and Model Substances**

The self-standing drawer/morphological transition and model substances (SSD/MOMO) experiment investigated the fundamental process of solidification, one of the most basic processes in the industrial production of materials. The SSD/MOMO experiment successfully completed 11 of the 15 planned steps. Throughout the mission, the SSD/MOMO facility operated 30-percent slower than expected. Facility operating data were downlinked and analyzed. The data showed that the cooling phase was requiring 30-percent longer to complete its operations. Postflight analysis was performed to determine the cause of this anomaly.

## **Commercial Vapor Diffusion Apparatus**

The second-generation commercial vapor diffusion apparatus (CVDA) grew high-quality crystals of various proteins using the vapor diffusion method. The production of high-quality crystals is critically important in the design of drugs. This experiment has flown on 22 previous Space Shuttle missions.

The four vapor diffusion apparatus (VDA) trays, each containing 20 experiment chambers, were installed in a commercial refrigerator/incubator module (CRIM) that controlled temperatures very closely throughout the mission. The CVDA hardware operated nominally throughout the mission with no in-flight anomalies noted. Status checks were performed daily to verify that the thermal control was being maintained within 0.1 °C as the CRIM was designed to maintain.

## **Liquid Motion Experiment**

The liquid motion experiment (LME) payload was activated on flight day 7. During the set-up of the experiment hardware, the crew noted that the ¼ turn fasteners would not turn to support the door. Gray tape was used to support the door, and the payload was activated. However, the LME was terminated because the door was identified as an inhibit for the LME containment of the rotating parts per the safety hazard report. Further evaluation showed that the gray tape was sufficient to secure the door and the safety issue was resolved. The payload was reactivated, but it was automatically shut down because the payload accelerometer exceeded its limit of  $3 \times 10^{-3}$  g. The accelerometer alarm was disabled and the payload continued operations. The first two runs were totally completed, and 2/3 of the third run was completed. During run 3, the LME performed another automatic shut down. The LME was restarted; however, some data were lost with the shut down. Video from inside the LME was downlinked, and excellent views of the experiment were provided. The data are being evaluated by the Principal Investigators (PI's), and the results of this experiment will be published in a separate report.

## **MIDDECK SCIENCE**

### **Protein Crystal Growth-Single Locker Thermal Enclosure System**

The second generation vapor diffusion apparatus (VDA-2) experiment was supported by the Protein Crystal Growth-Single Locker Thermal Control System (PCG-STES) personnel. The CRIM was the carrier for the payload. All hardware for this experiment operated nominally during the entire flight. Experiment status checks were performed daily, and these verified that the 0.1 °C thermal control was not violated. The VDA has provided ultra pure samples of several protein systems for use in providing scientific data for the development of new therapeutic treatments.

### **Fundamental Biology Beetle Kit**

The Fundamental Biology Beetle Kit, which was a powered payload, was transferred from the Orbiter middeck to the Mir. Installation of the hardware was verified through the use of photographs of the Mir location and installation taken with the electronic still camera (ESC).

### **Gaseous Nitrogen Freezer/Dewar Experiment**

The GN<sub>2</sub> freezer/dewar experiment unit was transferred to the Mir, and the unit onboard the Mir was transferred to the Orbiter.

### **Cosmic Radiation Effects and Activation Monitor**

The Cosmic Radiation Effects and Activation Monitor (CREAM) components were deployed and the active monitor was activated in the airlock nominally. The active monitor was moved after approximately 48 hours from the airlock to the starboard sleep station and back to the airlock 48 hours later. The CREAM lost power on flight day 2 when the dc power was inadvertently turned off. The error was corrected about 16 minutes later when the power was turned back on and the status light confirmed that the power was on. The CREAM operated nominally for the remainder of the mission.

## **RISK MITIGATION EXPERIMENTS**

### **Mir Electric Field Characterization**

The Mir Electric Field Characterization (MEFC) (RME 1302) did not operate as planned during the flight. The plan was to perform operations on the Mir; however, at 140:04:08 G.m.t. (04:20:01 MET), the crew reported that the MEFC spectrum analyzer was not operating properly. The analyzer was moved to the Mir base block and was powered on nominally, but when observed at the time noted previously, the unit was locked up. The unit was deactivated and a recovery plan was developed and performed while still on the Mir. The analyzer was powered on, the unit activated through the boot process and then shut down during the calibration cycle. Mir operations were then terminated. The unit was

checked out after undocking. A revised procedure was performed twice, and in both cases, the analyzer shut down automatically. The decision was made to stow the MEFC, and conduct a post-flight evaluation to determine the cause of the shut downs.

### **Shuttle/Mir Experiment Kit Transport**

The Shuttle/Mir Experiment Kit Transport (RME 1303) was transferred to the Mir for use during their operations.

### **Real-Time Radiation Monitor Device**

The Real-Time Radiation Monitor Device (RME 1312) dosimeters, Biospecimen Box, Spore Culture and Silkworm Egg samples all operated nominally. The Spore Culture chamber remained wet throughout the mission as designed. A video downlink of an inspection allowed the PI to compare real-time development with ground samples. The Biospecimen Box sample was operated for 19 hours rather than 9.5 hours to allow the deoxyribonucleic acid (DNA) repair function a longer exposure to the microgravity environment. The Spacehab temperature was maintained between 70 and 73 °F, which was cool enough not to kill the spores, but resulted in the silkworm eggs developing slower than predicted. To allow the silkworm eggs additional time for maturing, the early development and dormant silkworm eggs were stored in the Spacehab FDF locker and remain there until the early destowage after landing. The PI's were very pleased with the development of the spores and eggs and are expecting excellent data.

### **ESA Proximity Operations Sensor**

The European Space Agency (ESA) Proximity Operations Sensor (EPOS) (RME 1314) was powered on at 136:23:14 G.m.t. (01:15:07 MET). The laser EPS functioned normally during the docking phase. The Global Positioning System (GPS) receiver on the experiment maintained lock with the GPS satellites through docking, and that was better than expected because of the prelaunch concerns about multi-path effects close to the Mir. Temperatures of the equipment were higher than the prelaunch thermal analysis prediction for the docked-phase.

The rendezvous sensor and GPS receivers on the Mir and Orbiter operated successfully during the undocking and separation maneuver. The GPS receiver did not achieve a position fix until a distance of 630 meters, but the receiver continued good data collection for the remainder of the separation phase. The cause of this problem was investigated during the postflight testing. The optical rendezvous sensor operated successfully out to a distance of 750 meters; however, the return signal from the ESA reflectors was weak because the sensor locked on to only one reflector after a separation of 300 meters was achieved. This condition was caused by one reflector having a higher reflectivity.

### **Mir Structural Dynamics Experiment Joint Operations**

The Mir Structural Dynamics Experiment Joint Operations (MiSDE) (RME 1317) was not supported by the Mir because of concerns about available propellant and the fact that this test required routing cables between Mir modules so that thruster firing commands could be issued. However, the Orbiter portion of the experiment was performed satisfactorily with nominal results.

On flight day 6, the crew performed a series of vernier RCS pulses to excite the mated stack for structural identification. The tests were designed to provide unipolar and bipolar sequences of thruster firings at the modal periods to excite the stack dynamics. The procedures used I-loads different from the actual vehicle configuration that resulted in the notch filters being disabled during the drift periods following the tests. As a result, data were obtained both on the structural response, as well as the autopilot rate estimate without notches. All of the firings were correctly commanded and the crew performance was excellent.

One of the sets of MiSDE firings was designed to excite the principal pitch bending modes of most significance to the Orbiter flight control system. This set consisted of four bipolar pitch firings of approximately 3 seconds each. The results of these firings indicate that the latest Shuttle/Mir structural models provide an excellent match to the flight data, and also comparing well with the latest model. The results indicate that the up-linked notch filters, which were designed to be robust to 30-percent frequency and 6dB amplitude uncertainties are conservative.

As was the case on STS-81, some non-linear effects were noted in the bipolar firing case. The frequencies corresponding to the first four half-periods of the response were 0.1136 Hertz, 0.1136 Hertz, 0.1471 Hertz, and 0.1786 Hertz, respectively. The average frequency of the rest of the response is about 0.18 Hertz. The effect is likely related to the effects of the known free-play in the ODS-to-Orbiter interface and the effects of friction.

### **Treadmill Vibration Isolation System Configuration B - Treadmill Hardmounted Only**

The Treadmill Vibration Isolation System (TVIS) (Configuration B) (RME 1318) set-up, exercise and stowage activities were completed nominally. Postflight discussions with the crew revealed which crewmembers used the treadmill during the mission. Some preliminary acoustic values from the first run on the treadmill were collected. The maximum value recorded at ear-level was 87 dB, and the maximum value recorded at the tread level was between 78.7 and 83 dB.

### **Electrolysis Performance Improvement Concept Study**

The red automatic-shutdown light on the Electrolysis Performance Improvement Concept Study (EPICS) (RME 1321) was observed on integrated electrolysis cells one and two. Both of these cells had shut down and remained shut down

for the remainder of the mission, while the third cell remained functional for the rest of the mission. The decision was to continue with the second and third data run on cell three, and no attempts were made to troubleshoot the hardware anomaly. The normally used final deactivation procedure of the third cell was completed satisfactorily after three successful runs.

## **VEHICLE PERFORMANCE**

### **SOLID ROCKET BOOSTERS**

Data analysis shows that all Solid Rocket Booster (SRB) systems performed nominally during the prelaunch countdown and during ascent. The SRB countdown was normal and no SRB Launch Commit Criteria (LCC) or Operational Maintenance Requirements and Specifications Document (OMRSD) violations occurred.

Both SRBs were successfully separated from the External Tank (ET) at approximately 123.964 seconds after liftoff. The data acquisition system acceleration data and the onboard video cameras showed that the no. 2 main parachute on the right SRB remained under-inflated into the third (full-open) stage. The parachute fully inflated approximately 12 seconds prior to water impact, and the nominal water impact velocity of 75 ft/sec was attained. The postflight inspection revealed four broken ribbons (minor damage) in gore 79 of this parachute. The premise is that these ribbons became entangled with the reefing-line cutter, thereby keeping the canopy skirt closed until the ribbons ripped away from the cutter. No other abnormal damage to any of the hardware or parachutes was noted.

The SRBs were towed to port and transferred to the KSC where disassembly and refurbishment activities were initiated.

### **REUSABLE SOLID ROCKET MOTORS**

All Reusable Solid Rocket Motor (RSRM) subsystems performed satisfactorily. No RSRM LCC or OMRSD violations occurred nor were any in-flight anomalies noted from the review of the ascent data.

Power-up and operation of all igniter and field-joint heaters was accomplished routinely. All RSRM temperatures were maintained within acceptable limits throughout the countdown. The high-pressure heated ground purge of the SRB aft skirts was used to maintain the case/nozzle joint temperatures within the required LCC ranges. The calculated flex bearing mean bulk temperature was a nominal 83 °F.

Data indicate that the flight performance of the RSRMs was well within the allowable contractor end-item specification limits, and was typical of the performance observed on previous flights. The RSRM propellant mean bulk temperature (PMBT) was 73 °F at liftoff. The propulsion system performance is shown in the table on the following page. The maximum trace shape variation of pressure versus time was calculated to be 0.44 percent at 78 seconds for the left motor and 1.10 percent at 79.5 seconds for the right motor. These values are well within the 3.2 percent allowable limits.

The postflight disassembly and inspection revealed a gas path through the left-hand nozzle-to-case joint polysulfide. Normal heat effects were also observed in the gas path. The wiper O-ring, which is not a seal, eroded to a maximum depth of 0.037 inch, which is well within the 3  $\sigma$  specification of 0.056 inch. The maximum depth measured on previously flown RSRM's was 0.029 inch.

### RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 73 °F		Right motor, 73 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10 <sup>6</sup> lbf-sec	65.82	65.78	66.01	65.89
I-60, 10 <sup>6</sup> lbf-sec	175.38	175.84	175.78	176.28
I-AT, 10 <sup>6</sup> lbf-sec	296.83	297.02	296.77	297.59
Vacuum Isp, lbf-sec/lbm	268.5	268.7	268.5	269.3
Burn rate, in/sec @ 60 °F at 625 psia	0.3686	0.3690	0.3693	0.3694
Event times, seconds <sup>a</sup>				
Ignition interval	0.232	N/A	0.232	N/A
Web time <sup>b</sup>	109.4	109.1	109.1	108.9
50 psia cue time	119.1	118.8	118.8	118.2
Action time <sup>b</sup>	121.2	120.7	120.9	120.4
Separation command	124.0	124.0	123.7	124.0
PMBT, °F	73	73	73	73
Maximum ignition rise rate, psia/10 ms	90.4	N/A	90.4	N/A
Decay time, seconds (59.4 psia to 85 K)	2.8	2.6	2.8	3.1
Tailoff Imbalance Impulse differential, Klbf-sec	Predicted		Actual	
	N/A		404.3	

Impulse Imbalance = Integral of the absolute value of the left motor thrust minus right motor thrust from web time to action time.

<sup>a</sup>All times are referenced to ignition command time except where noted by a <sup>b</sup>

<sup>b</sup>Referenced to liftoff time (ignition interval).

### EXTERNAL TANK

All objectives and requirements of the ET propellant loading and flight operations were met in an excellent manner. All electrical and instrumentation equipment operated satisfactorily. There was no ice predicted or observed for the ET acreage. Also there was no unacceptable ice/frost formations reported by the Red Team. The ET purge and heater operations were satisfactory. No ET LCC or OMRSD violations occurred, nor were any in-flight anomalies noted. All flight objectives were satisfied.

Normal quantities of ice or frost were present on the liquid oxygen (LO<sub>2</sub>) and liquid hydrogen (LH<sub>2</sub>) feed-lines, the pressurization line brackets, and along the LH<sub>2</sub> protuberance air load (PAL) ramps. All of these observations were acceptable per NSTS 08303. Measured nose-cone mass flow-rate was within the Interface Control Document (ICD) requirement of 9-16 lb/min.

Intertank temperatures were maintained within acceptable limits, all components within the intertank performed satisfactorily and there were no hazardous gas violations. The indicated flow-rate in the intertank was below the ICD lower limit while other related measurements indicated normal operation. A problem with the signal conditioner and transducer is the most probable cause of the erroneous data.

The ET pressurization system functioned properly throughout engine start and the flight. The minimum LO<sub>2</sub> ullage pressure experienced during the ullage pressure slump was 13.8 psid.

ET separation was confirmed as occurring at 135:08:16:41 G.m.t. (00:00:08:53 MET). ET entry and breakup occurred within the predicted footprint, and the impact point was 63 nmi. uprange of the preflight predicted impact point.

### **SPACE SHUTTLE MAIN ENGINES**

All Space Shuttle main engine (SSME) performance parameters were normal during the prelaunch countdown and were typical of the data observed on previous flights. Engine ready was achieved at the proper time; all LCC were met; and engine start and thrust buildup was normal. No OMRSD violations were noted during the prelaunch operations.

Flight data indicate that the SSME performance during mainstage, throttling, shut down, and propellant dumping operations were normal, and no in-flight anomalies were noted. The high-pressure oxidizer turbopump (HPOTP) and high-pressure fuel turbopump (HPFTP) temperatures were normal and within specification throughout engine operation. Space Shuttle main engine cutoff (MECO) occurred at 512.8 seconds after liftoff. No significant failures or problems were noted during the countdown and flight.

### **SHUTTLE RANGE SAFETY SYSTEM**

The Shuttle Range Safety System (SRSS) performance was nominal throughout the first stage of ascent. The SRSS system on the ET has been deleted.

The prelaunch SRSS closed-loop testing was completed as scheduled with nominal results. 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. As planned, the SRB S&A devices were safed, and SRB system power was turned off prior to SRB separation.

## **ORBITER SUBSYSTEM PERFORMANCE**

### **Main Propulsion System**

The overall performance of the main propulsion system (MPS) was nominal. The LO<sub>2</sub> and LH<sub>2</sub> loading was performed with no stop-flows or reverts. No LCC or OMRSD violations were noted during the countdown.

The LH<sub>2</sub> loading operations were nominal and based on an analysis of the loading system data, the LH<sub>2</sub> load at the end of replenish was 231,361 lbm. Compared to the inventory (predicted) load of 231,332 lbm, this assessment yields a difference of +0.01 percent, which is within the required MPS loading accuracy of  $\pm 0.37$  percent.

The LO<sub>2</sub> loading operations were nominal throughout the countdown and based on an analysis of loading system data, the LO<sub>2</sub> load at the end of replenish was 1,388,542 lbm. Compared to the inventory (predicted) load of 1,388,277 lbm, this assessment yields a difference of +0.02 percent, which is within the required MPS loading accuracy of  $\pm 0.43$  percent.

Throughout the period of preflight operations, no significant hazardous gas concentrations were detected. The maximum hydrogen concentration level in the Orbiter aft compartment was approximately 170 ppm, which compares favorably with previous flight data for this vehicle.

Ascent MPS performance was nominal. No in-flight anomalies or significant problems were identified in the analysis of the flight data.

The LH<sub>2</sub> and LO<sub>2</sub> pressurization and feed systems performed nominally and satisfied all tank ullage pressure and SSME inlet net positive suction pressure (NPSP) requirements. The gaseous oxygen (GO<sub>2</sub>) fixed-orifice pressurization system performed as predicted. Reconstructed data from engine and MPS parameters closely matched the actual ET ullage-pressure measurements. Also, all three flow control valves (FCVs) performed nominally. STS-84 was the second flight of the reshimmed GH<sub>2</sub> flow control valve and the GO<sub>2</sub> four-way-swap fixed orifice for this vehicle, and both performed as expected.

The LO<sub>2</sub> and LH<sub>2</sub> propellant dump operations were initiated at main engine cutoff (MECO) + 122 seconds as planned. Postflight analysis indicated that the performance was nominal. Likewise, the MPS hydrogen and oxygen feed system vacuum inerting operations were performed as planned with excellent results.

Helium system performance for the SSME and pneumatic helium systems were nominal. Entry helium usage was 60 lbm, which is within the requirements.

### Reaction Control Subsystem

The reaction control subsystem (RCS) performed satisfactorily throughout the mission. One in-flight anomaly was noted during the data review and analysis.

A total of 7214 lbm of propellants (4423 - oxidizer, 2791 - fuel) were used during the rendezvous and docking mission with the Mir. The orbital maneuvering subsystem (OMS) provided 2579 lbm of propellants during interconnect operations. The primary RCS thrusters had 5,805 firings and a total firing time of approximately 1,296.5 seconds. The vernier RCS thrusters had 22,386 firings and a total firing time of 35,735.6 seconds. The following table shows the major maneuvers performed by the primary RCS during the flight.

### PRIMARY RCS MANEUVERS

Maneuver	Time, G.m.t./MET	$\Delta V$ , ft/sec	Duration, sec
NCC/ RCS	136:22:55:12 01:14:47:24	1.2	5.0
MC1/ RCS	137:00:14:58 01:16:07:10	0.2	1.0
MC2/ RCS	137:00:47:09 01:16:39:21	1.9	8.0
MC3/ RCS	137:00:57:09 01:16:49:21	0.3	1.0
MC4/ RCS	137:01:07:09 01:16:59:21	1.0	1.0
Undocking	142:01:04:13 06:16:56:25		
Separation	142:01:34:11 06:17:26:23		

During separation from the Mir, which is a period of high forward-RCS utilization, the forward RCS oxidizer ullage pressure dropped to the 233- to 234-psia range on several occasions (Flight Problem STS-84-V-02). The ullage pressure should be maintained in the 239- to 259-psia range. The RCS oxidizer tank was configured to the B-leg regulator at the time of the occurrence. Low regulation pressure with this regulator is a known condition, having been seen during previous flights and on the ground. A waiver was taken during the STS-84 flow for this condition. Under similar high-flow-rate conditions during the previous flight of OV-104 (STS-81), the lowest regulated pressure was 238 psia, 5 psia higher than that seen during this mission. This pressure is lower than the fuel

pressure and this results in unbalanced utilization of propellants. On STS-84, the remaining fuel was 1.0 percent (12 lbm) and the remaining oxidizer was 4.8 percent (55 lbm), a condition that is undesirable on propellant-critical missions such as STS-84. This regulator was tested during the postflight turnaround activities with the same results as determined prior to STS-84. Therefore, the regulator will be flown as-is on STS-86, and the waiver written prior to STS-84 that was effective until OMDP will be applicable for STS-86. The regulator will probably be replaced during OMDP, which follows STS-86.

### Orbital Maneuvering Subsystem

The OMS performed satisfactorily throughout the STS-84 mission. Seven firings were performed and pertinent parameters of these firings are shown in the following table.

No deviations from the OMRSD or LCC requirements occurred during prelaunch operations. No in-flight anomalies were identified from the data review and analysis. The seven OMS maneuvers plus interconnect operations during which 2579 lbm were consumed, resulted in 19,216.3 lbm of OMS propellants being used during the mission.

Maneuver	Configuration	Time, G.m.t./MET	$\Delta V$ , ft/sec	Duration, sec
OMS 2	Two-engine	135:08:51:52.4 00:00:44:04.4	75	47.6
NC1/ OMS 3	Two-engine	135:11:47:41 00:03:39:52	108.1	68.0
NC2/ OMS 4	Right-engine	135:23:47:18.2 00:15:39:29.2	8.5	11.0
NC3/ OMS 5	Two-engine	136:10:56:34.2 01:02:48:46.2	93	58.4
NC4/ OMS 6	Two-engine	136:22:19:59 01:14:12:11	88	54.4
TI/ OMS 7	Left-engine	136:23:52:45 01:15:44:57	7	9.6
Deorbit	Two-engine	144:12:23:33 09:04:15:45	331.2	189.4

The left OMS fuel tank totalizer indicated a constant quantity of 44.4 percent after the 14-second lockout during the OMS 2 maneuver. The left OMS fuel totalizer returned to normal operation following the lockout at the beginning of the NC3/OMS 5 maneuver, only to have the forward probe signal drop out again during the NC4/OMS 6 maneuver. Similar behavior occurred during STS-71, STS-74, STS-76, STS-79, and STS-81. During each of these missions, the forward probe output to the left OMS fuel totalizer was lost during the OMS 2 maneuver. With the exception of STS-74, the forward probe output returned

during the OMS 5 maneuver with normal operation thereafter. On STS-74, the forward probe output was not regained during the mission. This loss and return of the signal suggests that there is a possible intermittent short in the system associated with the totalizer/forward probe. The OMS fuel tank total quantity system is primarily used for propellant loading. There was no mission impact from this condition, and no postflight action was planned.

### **Power Reactant Storage and Distribution Subsystem**

The power reactant storage and distribution (PRSD) subsystem performance during the STS-84 mission was nominal with no in-flight anomalies or significant problems identified. The PRSD subsystem supplied the fuel cells with 2443 lbm of oxygen and 308 lbm of hydrogen for the production of electrical energy. In addition, the environmental control and life support system (ECLSS) was supplied with 152 lbm of oxygen, which included approximately 81 lbm that was supplied to the Mir. A mission extension of nearly four days was possible at the average power level with the reactants remaining at landing. At extension day power levels, a mission extension of 114 hours could have been supported.

The oxygen (O<sub>2</sub>) manifold 2 pressure transducer continued to be biased approximately 24- to 28-psia high relative to the O<sub>2</sub> manifold 1 pressure transducer. This bias has been seen on previous flights and there was no mission impact.

### **Fuel Cell Powerplant Subsystem**

Performance of the fuel cell powerplant subsystem was nominal throughout the mission, and no in-flight anomalies or significant problems were noted. The average electrical power level and load was 16.0 kW and 524 amperes. The fuel cells produced 2750 lbm of potable water and 3548 kWh of electrical energy from 2443 lbm of oxygen and 308 lbm of hydrogen.

The fuel cell 3 hydrogen (H<sub>2</sub>) flowmeter operated erratically for several hours following the end of the fuel cell startup purge prior to launch. The indicated flow became less erratic during the remainder of the prelaunch period and then again became erratic following ascent with indicated flow-rates in the range of 0.4 to 2.4 lb/hr (the actual flow is about 0.5 to 0.6 lb/hr). During purges, the flow rate changed, indicating proper hydrogen purge valve operation. The erratic performance of the flowmeter lessened during the first two days on-orbit with near nominal performance being observed from 2-days MET until the end of the mission. The fault detection and annunciation (FDA) alarm for this flow measurement was inhibited throughout the mission, and there was no mission impact. This flowmeter exhibited erratic performance during its previous flight, STS-77, when S/N 124 was flown in the fuel cell 2 position on OV-105.

Early in the mission, the fuel cell 3 alternate water line temperature rose into the 120 °F range, indicating that there was a slight leakage of warm fuel cell water

through the alternate water-line check valve. The leak rate lessened during the mission to the point where cycling of the alternate water-line heater was observed (70 to 90 °F heater set-point range). Slight leakage of alternate water-line check valves have been seen in the past and there was no mission impact due to this condition. This check valve also showed slight leakage on the previous flight of OV-104 (STS-81).

At 138:12:00 G.m.t. (03:03:52 MET), the fuel cell 1 coolant pressure fluctuations increased in amplitude (1.2-1.6 psia versus 0.8 psia). Fluctuations of approximately 1.6 psia were noted throughout the previous flight (STS-81) of this fuel cell. It is believed that the indicated change in coolant-pressure behavior is an instrumentation phenomenon and does not represent an actual change in coolant-pressure behavior. The fuel cell 1 coolant pressure was monitored throughout the mission and there was no flight impact. No postflight action is planned.

Mission data also indicated a slight degradation in the fuel cell 1 O<sub>2</sub> flowmeter reading. Fuel cell performance and calculated O<sub>2</sub> flow-rate indicated that this was an instrumentation problem. There was no flight impact and no postflight action is planned.

### Auxiliary Power Unit Subsystem

The auxiliary power unit (APU) subsystem performed nominally throughout the STS-84 mission. No significant APU problems were recorded. The run times and fuel consumption for the APU's are summarized in the following table.

#### APU RUN TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (S/N 407)		APU 2 (S/N 402)		APU 3 (S/N 308)	
	(a) (b)	(a)	(a)	(a)	(a)	(a)
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	20:37	48	20:39	50	20:44	51
FCS checkout	07:21	16				
Entry <sup>a</sup>	60:39	103	85:07	149	60:43	119
Total	88:37	167	105:46	199	81:27	170

<sup>a</sup> APUs were shut down 16 minutes 6 seconds after landing.

<sup>b</sup> APU 1 was used for the FCS checkout.

During entry, two APU 1 gearbox repressurizations occurred. The second repressurization was triggered by a WSB over-cooling condition that caused a pressure drop in the gearbox. This APU (S/N 407) has a history of gearbox repressurizations with one or more repressurizations occurring in seven of the last nine flights. This condition is not a problem, since the leakage seen was

within limits. However, the repressurizations resulted in five master alarms during entry. As a result, KSC will pressurize the gearbox to the high end of the allowable range prior to STS-86.

The APU 2 exhaust gas temperature (EGT) measurement became erratic for approximately 20 minutes during entry. This condition did not impact the entry and landing operations. The EGT sensor will be flown as-is and replaced during the OMDP following STS-86.

### **Hydraulics/Water Spray Boiler Subsystem**

The overall performance of the hydraulics/water spray boiler subsystem was nominal during the mission; however, a slight under-cooling condition occurred during ascent on WSB system 3, and an over-cooling condition occurred during entry on WSB systems 1 and 3. These conditions are discussed in the following paragraphs. Also, a known problem with a pressure transducer repeated. This is discussed in the last paragraph of this section.

Water spray boiler (WSB) 3 exhibited a slight under-cooling condition during ascent resulting in the auxiliary power unit (APU) 3 lubrication oil return temperature reaching 285 °F prior to spray cooling being achieved. The OMRSD File IX upper limit for the initiation of spray cooling is no more than 275 °F. The under-cooling of the APU 3 lubrication oil was followed by an over-cooling to 237 °F prior to the WSB achieving a steady-state lubrication oil return temperature of 256 °F. Note that over-cooling following a period of under-cooling is typical behavior. This event occurred on the WSB A controller but is not believed to be a controller problem. This behavior is believed to be caused by ice forming on the WSB spray bars and it has been observed on prior flights of all vehicles.

During entry, WSBs 1 and 3 each exhibited one period of over-cooling of the APU lubrication oil. The APU 1 lubrication oil return temperature dropped from a steady-state temperature of 251 °F to 189 °F before returning to the steady-state temperature. Similarly, WSB 3 over-cooled the APU 3 lubrication oil from a steady-state temperature of 253 °F down to approximately 203 °F before returning to the steady-state temperature. These conditions, which have been seen on other WSBs in the past are being evaluated, did not impact the flight operations nor will any ground checkout be required.

The WSB 3 gaseous nitrogen (GN<sub>2</sub>) system regulator outlet-pressure transducer exhibited one period of data dropout after wheels stop. Previous flights of OV-104 have exhibited similar behavior on this transducer. No spare transducers are currently available; however, a new design is being developed to replace the existing transducer. The transducer will be flown as-is on STS-86.

## **Electrical Power Distribution and Control Subsystem**

The electrical power distribution and control (EPDC) subsystem performed nominally throughout the mission. No in-flight anomalies or significant problems were noted.

## **Orbiter Docking System**

The Orbiter Docking System (ODS) performed nominally throughout the three phases of docking operations:

- a. Docking ring extension in preparation for docking;
- b. Docking with the Mir Space Station; and
- c. Undocking from the Mir Space Station.

The ODS was powered for docking ring extension at approximately 136:07:09:43 G.m.t. (00:23:01:55 MET) for docking ring extension. The actuation of the docking ring drive occurred at 136:07:11:24 G.m.t. (00:23:03:25 MET) with the docking ring in the final position. The docking ring extended to the initial position at 136:07:13:59 G.m.t. (00:23:06:11 MET), and the ODS was powered down 45 seconds later.

The ODS was powered up for docking at 137:01:59:48 G.m.t. (01:17:52:00 MET). Capture occurred nominally at 137:02:33:19 G.m.t. (01:18:25:31 MET). The electromagnetic brakes activated five seconds later and remained active for the nominal 30 seconds. Twenty-seven seconds after the electromagnetic brakes were deactivated, the automated sequence began driving the docking ring toward the "forward" position. The crew depressed the Androgynous Peripheral Docking System (APDS) "power-on" switch, and halted the automated sequence to allow the relative motion between the two vehicles to become dampened. After the completion of damping, the crew initiated the "ring-in" command, driving the docking ring toward the final position. The structural hooks were subsequently activated as planned, and the capture latches were opened nominally. The docking ring then proceeded to the final position, and the automated docking sequence was completed at 137:02:41:56 G.m.t. (01:18:34:08 MET) followed by powering down of the ODS.

The ODS was powered up for undocking from the Mir at 142:00:36:42 G.m.t. (06:16:28:54 MET). The structural hooks were activated in the open direction and traveled from approximately 92 percent to 5 percent nominally. The undocking-complete signal was received at 142:01:03:56 G.m.t. (06:16:56:08 MET), and the ODS was powered down at 142:01:17:26 G.m.t. (06:17:09:38 MET).

The expected deviation, the heater no. 2/DCU power bus indication toggling off, recurred when the ODS was powered during the docking. This toggling-off

problem had been previously observed during STS-76 and STS-81 missions. The signal was present when the ODS was initially powered up and toggled off approximately three seconds later. It then toggled back on at 137:02:20 G.m.t. (01:18:13 MET), 20 minutes and 52 seconds later, and remained on until the ODS was powered down. The toggling-off problem did not recur during the undocking operations. This condition will be flown as-is unless another problem occurs which would require the removal and replacement of any item in the heater no. 2 DCU power indication string.

### **Pressure Control System**

The pressure control system performed normally throughout the flight. After docking, the vestibule was pressurized using Mir consumables, and the checkout of the Orbiter/Mir docking system interface was verified by leak-checking the vestibule. Subsequently, the Orbiter airlock upper hatch equalization valves were opened and the Mir and Orbiter volumes were equalized to a total pressure of 14.07 psia. Prior to opening these valves, the Orbiter cabin and ODS pressure was 14.70 psia. The Orbiter-to-Mir transfer hatches were opened and the entire Orbiter/Mir volume was pressurized from 14.07 psia to 14.70 psia using the Orbiter pressure control system. The total consumables transferred to the Mir during the docked phase was 20.9 lb of nitrogen and 81.5 lb of oxygen. The nitrogen was used for Mir pressurization, and the oxygen was used for the three additional crew metabolic consumption during docked operations when the oxygen generating Elektron equipment was turned off as well as for raising the Mir pressure and partial pressure oxygen (PPO<sub>2</sub>) before undocking. The total pressure before undocking was 15.18 psia and PPO<sub>2</sub> was 3.92 psia.

### **Atmospheric Revitalization System**

The atmospheric revitalization subsystem (ARS) performed satisfactorily throughout the mission with no in-flight anomalies or significant problems identified. All monitored parameters were nominal.

### **Active Thermal Control System**

The active thermal control subsystem (ATCS) operation was satisfactory throughout the mission. No in-flight anomalies or problems were noted during the mission. The radiator cold-soak provided cooling during entry through touchdown plus six minutes when the ammonia boiler system (ABS) was activated using the secondary/on A controller. ABS system A operated for 35 minutes at which time it was deactivated in preparation for ground cooling connection.

### **Supply and Waste Water System**

The supply water and waste water system performed satisfactorily with no in-flight anomalies or significant problems noted.

The prelaunch supply water sample passed the launch minus three day requirement for the level of bacteria with a microbial count of 13 colony forming units (CFU's) per milliliter, which was well below the limit of 100 CFU's/ml. All other prelaunch requirements were also within specification.

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

Supply water was managed through the use of the FES water dump system, and water transfer to the Mir Space Station. One supply water dump was performed during the mission, and it was simultaneous with a waste water dump. The average dump rate was 1.76 percent/min (2.9 lb/min).

A total of 11 contingency water containers (CWC's) were filled with a total of 1038 lb of water, which was transferred to the Mir Space Station. The eleventh CWC was only half-filled. Five of the CWC's had only silver biocide added while six had silver biocide and minerals. The CWC's were filled at an average rate of 2.35 lb/min.

Waste water was gathered at approximately the predicted rate. Four waste water dumps were performed at an average dump rate of 2.00 percent/minute (3.30 lb/min).

### **Waste Collection System**

The waste collection system performed satisfactorily throughout the flight. No problems or in-flight anomalies were noted during the flight.

### **Airlock Support System**

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

### **Smoke Detection and Fire Suppression System**

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

### **Flight Data System**

The flight data system performed satisfactorily throughout the mission with no in-flight anomalies or significant problems noted.

Following Mir undocking and separation operations, general purpose computers (GPCs) 2 and 3 were taken out of the redundant set and GPC 2 was made a G2 freeze dry (FD) machine. During the procedure to verify a good G2 load, when GPC 2 was being moded from halt to standby, the mode talkback did not go to run as expected. The crew also reported that cathode ray tube (CRT) 1 had logged an "illegal entry" message. Upon instructions from the ground, the crew cycled the switch back to halt and then again to standby, and the mode talkback then indicated run. Based on air-to-ground discussions with the crew, it was initially suspected that the unexpected mode indication was caused by an incomplete mode switch actuation from halt to standby, a condition known as switch tease. It was assumed that the illegal entry was from an inadvertent keystroke. However, since a GPC problem could not be definitively ruled out, a hardware-initiated stand-alone memory (HISAM) dump was performed and a GPC initial program load (IPL) was performed. An analysis of the dump during the mission indicated there was not a hardware problem and since the IPL had been accomplished, the software integrity was not in question. Performance of the GPC was nominal during the remainder of the mission.

Additional analysis of data from the downlist and from the GPC 2 dump revealed that GPC 2 was moded from run to standby before the G2 FD load from the mass memory unit (MMU) was complete. Three different sources of information support this "early" standby action. First, the GPC 2 standby discrete was visible in the downlist from GPC 1 three seconds before the MMU ready-discrete came on at the conclusion of the FD load operation. Second, at the time of the fail-to-synchronize caused by the software detecting the standby discrete, the software was still monitoring for the completion of the MMU FD load operation. And third, the software was processing actions related to standby processing at the same time it was processing events related to the MMU FD operation. Since the early standby action resulted in standby processing beginning when a reconfiguration was in progress, the software generated the illegal entry and the software cleanup processing was not completed. The incomplete software cleanup processing resulted in the mode talkback remaining barberpole and not moding to run during the first halt-to-standby switch actuation. In conclusion, both the unexpected illegal entry and the barberpole talkback on the first halt to standby switch actuation can be explained by the detection of the mode switch in standby while the MMU FD load was still in progress.

### **Flight Software**

The flight software performed nominally throughout the mission. No in-flight anomalies or problems were noted during the mission.

### **Flight Control System**

The flight control system (FCS) performance was nominal throughout the mission. No in-flight anomalies significant problems were identified.

The flight control system (FCS) performance was nominal throughout the mission. No in-flight anomalies significant problems were identified.

All aspects of the rendezvous flight phase was nominal. Docking was accomplished in accordance with the Flight Data File. Likewise, the undocking and separation activities were also nominal.

On-orbit FCS performance during docked operations with the Mir was nominal. No dynamic interaction stability concerns were observed. During one period of attitude hold, the inertial measurement unit (IMU) switching noise caused increased fuel consumption. Upon deselection of one IMU, fuel consumption returned to near the predicted rates. The Orbiter controlled the mated stack with the vernier RCS for the entire mated phase, except for two periods of Mir control.

The entry inertial guidance, navigation and control (IGN&C) performance was nominal. Descent navigation was also nominal. There were no anomalies nor deselections by redundancy management (RM). The external sensor data were incorporated in the onboard navigation states at their expected regions of operations.

IMU performance was nominal during all phases of the flight with no in-flight anomalies or significant problems noted. Only one adjustment to the onboard IMU accelerometer compensations was performed for each IMU during the flight. The three IMU's flown on this flight have been declared acceptable as-is for the next flight of this vehicle.

### **Displays and Controls Subsystem**

The displays and controls subsystem performed satisfactorily throughout the flight. No in-flight anomalies or significant problems were noted during the flight.

### **Communications and Tracking Subsystems**

During several consecutive Tracking and Data Relay Satellite-West (TDRS-W) passes when the Orbiter was docked to Mir, the lower starboard S-band antenna experienced data dropouts. The Goddard Space Flight Center reported that the Orbiter signal levels during downlink remained within limits. Data dropouts were not observed during the majority of the time that the antenna was used during the docked phase, and no dropouts were observed during the undocked mission phase. The most probable explanation is radio frequency interference (RFI).

During the rendezvous with Mir, the crew reported a problem with the primary audio/radio interface unit (ARIU). The crew description of the problem indicated that the Mir audio received from the VHF radio was not being outputted by the ARIU which sends the signal to the Orbiter audio distribution system (ADS) air-to-ground (A/G) 2 audio loop. Also, the crew transmissions on the VHF were not being heard on Air-to-Ground 2. After verifying all of the connections and switch

positions, the crew replaced both the VHF radio and the ARIU with the backup unit. Without any other changes to the setup, the replacement unit provided normal audio to the ADS A/G 2 loop. The ARIU will undergo troubleshooting by the Flight Equipment Processing Facility personnel.

Two problems were noted with camera C. The first appeared to be a circular blurred area in the center of the lens (Flight Problem STS-84-V-01). The second was a focusing problem noted by the ground controller operating the camera. It was reported that the camera focus seemed slow to respond and the focus ring did not seem to stop at the hard-stop position. It has been determined that there is material on the inside surface of the lens. The camera was sent to the vendor for evaluation and repair. The reported focus problem will be evaluated at the vendor.

Two problems were also noted with camera A. Early in the mission, it was noted on several occasions that many white spots appeared in the image in lower-light-level conditions. This condition had no mission impact, and the camera image was excellent in higher-light-level scenes (its intended use). This condition is permanent and due to charged couple device (CCD) pixel failures. There is no functional impact to the camera's intended use. However, when camera A was selected for downlink at 142:12:30 G.m.t. (07:04:22 MET), a circular blurred area was observed in the center of the image (Flight Problem STS-84-V-03). The condition is similar to the camera C problem discussed previously. It was determined that there is material on the inside surface of the lens, and the camera was sent to the vendor for evaluation and repair.

### **Operational Instrumentation/Modular Auxiliary Data System**

The aft payload main bus C current measurement indicated 0.0 ampere during the entire period that the bus was powered. The bus should have been reading up to 5 amperes during the operation of the European proximity operations sensor (EPOS). Postflight troubleshooting determined that the current sensor had failed. The sensor was removed and replaced.

### **Structural and Mechanical Subsystems**

The payload bay doors were opened at 135:09:45:57 G.m.t. (00:01:38:09 MET). No problems were noted during the door-opening sequence.

During the installation of the mission specialist 4 lightweight seat (seat 6 position) for landing, the crew noted that there was interference between the A hatch handhold and the seat (Flight Problem STS-84-V-04). The handhold was unbolted and removed to provide clearance for the seat. The seat was then successfully installed for landing. During ascent, the seat position was 2 degrees forward, and the seat was rotated 10 degrees aft for entry. This is the first flight with a lightweight seat and an internal airlock. In the future, the internal

airlock A hatch handhold will be removed when the lightweight seat is flown in seat position 6. This modification has been completed for STS-86.

In preparation for landing, the payload bay doors were closed and latched at 144:08:08 G.m.t. (09:00:00 MET). Nominal dual motor times were observed.

The pertinent landing and braking data are shown in the following table.

### LANDING AND BRAKING PARAMETERS

Parameter	Distance from threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	3152	191.0	0.2	N/A
Nose gear touchdown	5731	155.8	N/A	-5.87
Brake initiation speed			131.5 knots	
Brake-on time			38.0 seconds	
Rollout distance			8,200.8 feet	
Rollout time			52.1 seconds	
Runway			33 (Concrete) KSC	
Orbiter weight at landing			216,167.2 lb	
Brake sensor location	Peak pressure, psia	Brake assembly		Gross energy, million ft-lb
Left-hand inboard 1	1056	Left-hand inboard		28.20
Left-hand inboard 3	1008			
Left-hand outboard 2	972	Left-hand outboard		24.90
Left-hand outboard 4	924			
Right-hand inboard 1	804	Right-hand inboard		20.80
Right-hand inboard 3	900			
Right-hand outboard 2	876	Right-hand outboard		21.94
Right-hand outboard 4	924			

The tires were in average condition for a landing on the KSC concrete runway. Some ply under-cutting occurred on the main landing gear (MLG) tires with the worst under-cutting observed on the right outboard tire. Very small pieces of rubber were found on the runway scattered along the rollout ground track.

The ET/Orbiter separation devices (EO-1, EO-2, and EO-3) functioned normally. No ordnance fragments were found on the runway beneath the umbilical devices. Virtually no umbilical closeout foam or white room temperature vulcanizing (RTV) dam material adhered to the umbilical plate near the LH<sub>2</sub> recirculation line disconnect. The EO-2 and EO-3 retainer springs were dislodged, a condition observed on previous flights.

## **Integrated Aerodynamic and Vehicle Heating and Thermal Interfaces**

The prelaunch thermal interface purges were normal with no problems noted. The ascent aerodynamic and plume heating was normal, as was the entry aerodynamic heating on the SSME nozzles.

### **Thermal Control Subsystem**

The performance of the thermal control subsystem (TCS) was nominal throughout the mission. All subsystem temperatures were maintained within limits. No heater failures or in-flight anomalies were noted. The beta angle ranged from -2 degrees to +41 degrees at entry interface.

### **Aerothermodynamics**

The boundary layer transition was symmetrical and the onset time was nominal. The acreage heating was higher than normal because of the high inclination entry. Local heating was also normal.

### **Thermal Protection Subsystem and Windows**

The thermal protection system (TPS) and windows performed nominally with no in-flight anomalies identified. Entry heating was nominal based on lower-surface structural temperature response data. Boundary layer transition from laminar to turbulent flow was symmetric and occurred at 1215 seconds after entry interface. This time was nominal based on the average time of 1210 seconds.

The Orbiter TPS sustained a total of 103 tile damage sites of which 13 had a major dimension of 1-inch or larger. This total does not include the numerous damage sites on the base heat shield that are attributed to the SSME vibration/acoustics, exhaust plume recirculation, and the flame arrestment sparkler system. The following table reflects the damage sites by areas of the Orbiter.

**TPS DAMAGE SITES**

<b>Orbiter Surfaces</b>	<b>Hits &gt; 1 Inch</b>	<b>Total Hits</b>
Lower Surface	10	67
Upper Surface	2	23
Right Side	0	5
Left Side	0	3
Right OMS Pod	0	2
Left OMS Pod	1	3
Total	13	103

The largest damage site on the lower surface was located on the Orbiter centerline between the two main landing gear doors. The site measured 1.5 inches long by 0.5 inch wide by 0.375 inch maximum depth. Tile damage sites around the LH<sub>2</sub> and LO<sub>2</sub> ET/Orbiter umbilicals was typical. The damage was most likely caused by impacts from umbilical ice or shredded pieces of umbilical purge barrier material flapping in the airstream, both of which were observed in the launch films.

No tile damage from micrometeorites or on-orbit debris was identified during the inspection.

The SSME dome-mounted heat shield (DMHS) closeout blankets were in excellent condition with no fraying or tearing. A corner was missing from a tile located on the base heat shield nears SSME 2 and the body flap hinge.

Tiles on the vertical stabilizer "stinger" were intact and undamaged. A trailing edge tile near the split in the rudder/speedbrake exhibited cracks and missing surface coating material, though there was no measurable depth. Also, there was significant damage to the leading edges of the OMS pods and the vertical stabilizer. A yellow/gold stain about 1 square foot in size was located over the plume shield, adjacent tiles and advanced flexible reusable surface insulation (AFRSI) blanket just above thruster F3D in the forward RCS module.

Hazing and streaking of the forward-facing Orbiter windows was typical. Damage sites on the window perimeter tiles appeared to be less than usual in quantity and size with the exception of one damage site greater than 1-inch in size in the black perimeter tiles on window 3. The damage appeared to be the result of impacts from excessive RTV adhesive used in attaching paper to the forward RCS thrusters.

## **GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT**

The overall performance of the Government furnished equipment/flight crew equipment was very satisfactory. The following paragraphs discuss the most significant items that occurred during the mission.

During the rendezvous with Mir, the crew reported a problem with the primary audio/radio interface unit (ARIU). The crew description of the problem indicated that the Mir audio received from the VHF radio was not being outputted by the ARIU which sends the signal to the Orbiter audio distribution system (ADS) air-to-ground (A/G) 2 audio loop. After verifying all of the connections and switch positions, the crew replaced the ARIU with the backup unit. Without any other changes to the setup, the replacement unit provided normal audio to the ADS A/G 2 loop. The ARIU and associated cabling will undergo troubleshooting at the Flight Equipment Processing Facility at JSC.

Two problems were noted with camera C. The first appeared to be a circular blurred area in the center of the lens (Flight Problem STS-84-V-01). The second was a focusing problem noted by the ground controller operating the camera. It was reported that the camera focus seemed slow to respond and the focus ring did not seem to stop at the hard-stop position. It has been determined that there is material on the inside surface of the lens. The camera was sent to the vendor for evaluation and repair. The reported focus problem will be evaluated at the vendor.

Two problems were also noted with camera A. Early in the mission, it was noted on several occasions that many white spots appeared in the image in lower-light-level conditions. This condition had no mission impact, and the camera image was excellent in higher-light-level scenes (its intended use). This condition is permanent and due to charged couple device (CCD) pixel failures. There is no functional impact to the camera's intended use. However, when camera A was selected for downlink at 142:12:30 G.m.t. (07:04:22 MET), a circular blurred area was observed in the center of the image (Flight Problem STS-84-V-03). The condition is similar to the camera C problem discussed previously. It was determined that there is material on the inside surface of the lens, and the camera was sent to the vendor for evaluation and repair.

During the installation of the mission specialist 4 lightweight seat (seat 6 position) for landing, the crew noted that there was interference between the A hatch handhold and the seat (Flight Problem STS-84-V-04). The handhold was unbolted and removed to provide clearance for the seat. The seat was then successfully installed for landing. During ascent, the seat position was two degrees forward, and the seat was rotated 10 degrees aft for entry. This is the first flight with a lightweight seat and an internal airlock. In the future, the internal airlock A hatch handhold will be removed when the lightweight seat is flown in seat position 6. This modification is complete for STS-86.

At the flight crew equipment (FCE) crew debriefing, the crew reported that it was extremely difficult to align the lugs and insert the last of the 4 pip pins used to attach the lightweight seat (LWS) to the recumbent seat kit (RSK) rail. The installation was performed twice and each time it required a crewman standing on the LWS and pushing off of the ceiling to attain the necessary alignment. Two different diameter pip pins (2 of each) are used in the design. On each of the two installations, a different diameter pin was left as the last pin installed, with no difference in the difficulty noted.

During the postflight investigation, it was found that two of the LWS seat-backs (including the STS-84 unit) would not align properly to the rail, even though the seats and rails were verified as built-to-print. These two seat-backs will be used only as Pilot seat-backs, thus eliminating their need to mate with the RSK's.

## **CARGO INTEGRATION**

The integration hardware performance was nominal throughout the mission, with no in-flight anomalies or significant issues noted.

## DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

### DEVELOPMENT TEST OBJECTIVES

**DTO 255 - Wraparound Digital Autopilot Flight Test Verification (Part 5)** - All of the programmed test inputs (PTI's) were performed as planned. The data have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

**DTO 312 - External Tank Thermal Protection System Performance (Methods 1 and 4)** - A total of eight photographs of the External Tank (ET) were exposed using the 35 mm camera with a 400 mm lens and a 2X extender, and no anomalies were identified in the photography. Six views were of the ET -Z /-Y axis. The other two views were of the aft dome and the +Z axis of the ET. The first photograph was taken 18 minutes after liftoff, and the last photograph was taken approximately 3 minutes later. The ET was approximately 2.5 kilometers from the Orbiter when the first photograph of the ET was taken, and the ET was tumbling at a rate of approximately 0.4 deg/sec.

STS-84 was the first flight of the new liquid hydrogen (LH<sub>2</sub>) tank sidewall thermal protection system (TPS) (NCFI 24-184). The new material appeared to be in good condition. The new intertank access door and the new LH<sub>2</sub> tank aft dome TPS (NCFI 24-57) (flown for the first time on STS-82) appeared also to be in good condition.

Three rolls of photographs of the ET and SRB were taken with the three cameras in the umbilical wells - two 16 mm cameras and one 35 mm camera. Good coverage of the left-hand SRB was on the 16 mm films. The first portion of the ET separation views were not exposed because the vehicle was in darkness.

Numerous light-colored pieces of debris (insulation and frozen hydrogen) and dark debris (possibly charred insulation) were seen throughout the 16-mm film sequence. Two larger irregular-shaped pieces of debris (charred insulation) were seen near the base of the left-hand SRB cable tray prior to SRB separation. Also, three TPS divots, approximately six inches in size, were seen on the intertank-to-LH<sub>2</sub> tank flange closeout between the legs of the bipod (+Z axis).

In addition to the still photography, approximately 10 minutes of excellent quality hand-held camcorder (video) views of the ET were also acquired. All aspects of the ET were imaged, and no anomalies were noted in the camcorder views.

**DTO 416 - Water Spray Boiler Quick Restart Capability** - This DTO was performed during the post-ascent time frame, and was the last time that the DTO

will be performed. Data from this DTO will be used to help determine the capability of the WSB to support a revolution 2 deorbit and abort-once-arounds.

**DTO 663 - Acoustical Noise Dosimeter Data (Treadmill Data)** - This DTO was performed during treadmill operations. The maximum value recorded at ear level was 87 dBm, and the maximum value at the tread level was between 78.7 and 83 dBm. The final results of this DTO will be published in separate documentation.

**DTO 700-10 - Orbiter Space Vision System Flight Video Taping** - A total of 13 video data-takes were downlinked, primarily of the camera A and D view of the target dots on the ODS and Docking Module. The characterization of response rate of the payload bay cameras will be used to develop camera lens control commands for the operational vision system. The down-linked video was also used to continue the evaluation of the space vision system (SVS) procedures and techniques that are being investigated in support of station assembly tasks. Video was also recorded during the approach to and separation from Mir. After docking, a smudge developed on the camera C lens, and this rendered the camera unusable for postflight analysis. As a result, the separation video recording procedures were modified to use camera B as a replacement for camera C.

**DTO 700-12 - Global Positioning System/Inertial Navigation System** - The Global Positioning System/Inertial Navigation System (GPS/INS) successfully provided approximately 30 hours of ascent and on-orbit data for the Honeywell H-764-G system, which exhibited excellent performance during that time period. In the on-orbit phase, however, the system began experiencing 1553 data communication problems between the GPS/INS payload and general support computer (PGSC) and the H-764-G during the third data-take. An in-flight maintenance (IFM) procedure in which the crew switched out the GPS/INS PGSC 1553 card with a spare card did not resolve the problem. One of several attempts was successful in initializing the GPS/INS using a contingency cold-start procedure, but the H-764-G blended navigation solution was unable to recover because of an incorrect vertical velocity initialization parameter. This problem was corrected and a new PGSC cold-start software executable was uplinked, but all subsequent attempts were unsuccessful because of an intermittent 1553 communications board problem. DTO 700-12 provided the first insight into the H-764-G attitude reinitialization and cold-start procedures which will be required to be operational for the Space Integrated GPS/INS (SIGI) Program when the H-764-G GPS/INS unit will replace the tactical air navigation and inertial measurement unit systems.

**DTO 700-14 - Single String Global Positioning System** - The miniature Airborne GPS receiver (MAGR) operated in an excellent manner. On three occasions, The MAGR-S became lost, and it was necessary for the crew to perform the manual reinitialization procedure. All reinitializations were successful. It is not known when the GPS DTO PGSC did not automatically

perform the reinitialization procedure, as it should have. Readouts from the crew confirmed that the input was correct. Postflight analysis of recorded data should prove insightful.

**DTO 805 - Crosswind Landing Performance** - This DTO of opportunity was not performed because crosswinds were not sufficient to meet the minimum requirements of the DTO.

**DTO 1118 - Photographic and Video Survey of the Mir (Configuration A and B)** - The Mir photography (IDTO 1118) was performed nominally with the exception of the problem found with the payload bay camera C. Camera C was usable but had a smudge in the center of the field-of-view, and the focus ring had slipped such that the focus at infinity did not hold. The problem was not deemed critical to DTO objectives and all work was completed as planned. Video of the Mir solar array showed movement during the Orbiter vernier RCS thruster firings in support of the MiSDE experiment.

#### **DETAILED SUPPLEMENTARY OBJECTIVES**

**DSO 331 - The Interaction of the Space Shuttle Launch and Entry Suit and Sustained Weightlessness on Egress Locomotion** - Temperature sensors were donned by two crewmembers during de-orbit preparations. After landing, one of the two crewmembers had a 5-minute treadmill test while onboard the crew return vehicle. The data from this onboard activities as well as the treadmill test were given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

**DSO 487 - Immunological Assessment of Crewmembers** - This DSO was performed during the postflight medical tests. The results of the assessment were given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

**DSO 802 - Educational Activities** - This DSO was performed during the flight and the videos of these activities were given to the sponsor for evaluation as well as distribution for use by schools. The results of the evaluation will be reported in separate documentation.

## **PHOTOGRAPHY AND TELEVISION ANALYSIS**

### **LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS**

A total of twelve 16 mm films, nine 35 mm films and 24 launch videos of the launch and associated activities were screened, and no anomalies were noted during the detailed review.

### **ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS**

No on-orbit photography evaluation was required in support of the mission.

### **LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSIS**

A total of 12 landing videos were screened, and no anomalies were noted. All events that occur during the landing activities appeared to be nominal.

**TABLE I.- STS-84 SEQUENCE OF EVENTS**

<b>Event</b>	<b>Description</b>	<b>Actual time, G.m.t.</b>
APU Activation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	135:08:02:57.943 135:08:02:59.668 135:08:03:01.233
SRB HPU Activation <sup>a</sup>	LH HPU System A start command LH HPU System B start command RH HPU System A start command RH HPU System B start command	135:08:07:20.133 135:08:07:20.293 135:08:07:20.453 135:08:07:20.613
Main Propulsion System Start <sup>a</sup>	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	135:08:07:41.458 135:08:07:41.577 135:08:07:41.700
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	135:08:07:48.003
Throttle up to 104 Percent Thrust <sup>a</sup>	ME-3 Command accepted ME-2 Command accepted ME-1 Command accepted	135:08:07:51.914 135:08:07:51.939 135:08:07:51.940
Throttle down to 67Percent Thrust <sup>a</sup>	ME-3 Command accepted ME-2 Command accepted ME-1 Command accepted	135:08:08:18.475 135:08:08:18.499 135:08:08:18.501
Maximum Dynamic Pressure (g)	Derived ascent dynamic pressure	135:08:08:39
Throttle up to 104 Percent <sup>a</sup>	ME-3 Command accepted ME-2 Command accepted ME-1 Command accepted	135:08:08:48:876 135:08:08:48.900 135:08:08:48.901
Both RSRM's Chamber Pressure at 50 psi <sup>a</sup>	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	135:08:09:46.003 135:08:09:46.843
End RSRM <sup>a</sup> Action <sup>a</sup> Time	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	135:08:09:48.653 135:08:09:48.973
SRB Physical Separation <sup>a</sup>	LH rate APU turbine speed - LOS RH rate APU turbine speed - LOS	135:08 09:51.963 135:08:09:51.963
SRB Separation Command	SRB separation command flag	135:08:09:52
Throttle Down for 3g Acceleration <sup>a</sup>	ME-1 command accepted ME-3 command accepted ME-2 command accepted	135:08:15:18.629 135:08:15:18.644 135:08:15:18.666
3g Acceleration	Total load factor	135:08:15:18.5
Throttle Down to 67 Percent Thrust <sup>a</sup>	ME-1 command accepted ME-3 command accepted ME-2 command accepted	135:08:16:14.631 135:08:16:14.645 135:08:16:14.667
SSME Shutdown <sup>a</sup>	ME-1 command accepted ME-3 command accepted ME-2 command accepted	135:08:16:20.871 135:08:16:20.886 135:08:16:20.907
MECO	MECO command flag MECO confirm flag	135:08:16:21 135:08:16:22
ET Separation	ET separation command flag	135:08:16:41

<sup>a</sup>MSFC supplied data

**TABLE I.- STS-84 SEQUENCE OF EVENTS  
(Continued)**

Event	Description	Actual time, G.m.t.
APU Deactivation	APU-1 GG chamber pressure APU 2 GG chamber pressure APU 3 GG chamber pressure	135:08:02:57.943 135:08:02:59.668 135:08:03:01.233
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	135:08:51:52.4 135:08:51:52.4
OMS-2 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	135:08:52:40.0 135:08:52:40.0
Payload Bay Doors (PLBDs) Open	PLBD right open 1 PLBD left open 1	135:09:44:39 135:09:45:57
OMS-3 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	135:11:47:41.0 135:11:47:41.0
OMS-3 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	135:11:48:49.0 135:11:48:49.0
OMS-4 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	N/A 135:23:47:18.2
OMS-4 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	N/A 135:23:47:49.2
OMS-5 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	136:10:56:34.2 136:10:56:34.2
OMS-5 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	136:10:57:32.4 136:10:57:32.6
OMS-6 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	136:22:20:00.0 136:22:20:00.0
OMS-6 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	136:22:20:54.4 136:22:20:54.4
OMS-7 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	136:23:52:46.2 N/A
OMS-7 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	136:23:52:55.8 N/A
Ring Capture	Capture	136:02:33:19
Docking	Docking ring final position	136:02:41:47
Initiation of Undocking	Actuation of hooks no. 1 drive	142:01:01:40
Undocking - Complete	Undock complete	142:01:03:57
Flight Control System Checkout Circulation Pump Start Circulation Pump Stop	APU 1 GG chamber pressure APU 1 GG chamber pressure	143:05:19:56.033 143:05:27.16.976
Payload Bay Doors Close	PLBD left close 1 PLBD right close 1	144:08:06:52 144:08:08:26
APU Activation for Entry	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	144:12:18:43.167 144:12:43:06.716 144:12:43:10.977

**TABLE I.- STS-84 SEQUENCE OF EVENTS  
(Concluded)**

<b>Event</b>	<b>Description</b>	<b>Actual time, G.m.t.</b>
Deorbit Burn Ignition	Left engine bi-prop valve position	144:12:23:33.3
	Right engine bi-prop valve position	144:12:23:33.4
Deorbit Burn Cutoff	Left engine bi-prop valve position	144:12:26:42.7
	Right engine bi-prop valve position	144:12:26:42.8
Entry Interface (400K feet)	Current orbital altitude above	144:12:56:12
Blackout end	Data locked (high sample rate)	No blackout
Terminal Area Energy Mgmt.	Major mode change (305)	144:13:21:23
Main Landing Gear Contact	RH main landing gear tire pressure 2	144:13:27:43
	LH main landing gear tire pressure 2	144:13:27:44
Main Landing Gear Weight on Wheels	LH main landing gear weight on wheels	144:13:27:44
	RH main landing gear weight on wheels	144:13:27:44
Drag Chute Deployment	Drag chute deploy 1 CP volts	144:13:27:47.0
Nose Landing Gear Contact	NLG LH tire pressure 1	144:13:27:52
Nose Landing Gear Weight On Wheels	NLG weight on wheels 1	144:13:27:52
Drag Chute Jettison	Drag chute jettison 1 CP Volts	144:13:28:17.3
Wheel Stop	Velocity with respect to runway	144:13:28:36
APU Deactivation	APU-1 GG chamber pressure	144:13:43:45.416
	APU-2 GG chamber pressure	144:13:43:50.228
	APU-3 GG chamber pressure	144:13:43:54.021

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

No.	Title	Reference	Comments
STS-84-V-01	Camera C Blurred Image (GFE)	137:16:39 G.m.t. 02:08:31 MET PR COM-4-20-0233	<p>There was a circular-shaped blurred area at the center of the camera C (CTVC S/N 202) image. The blur was not evident early in the mission. The blurred area became larger and smaller as the camera was zoomed, indicating that the problem was on the lens. The Television Laboratory analysis of the video confirmed that material on the lens was the cause of the problem. The material could be outgassing within the lens assembly or foreign material on the external surface of the lens. The mission impact was degraded camera C video images.</p> <p>KSC: Camera was removed from the vehicle and sent to the Flight Crew Equipment (FCE) facility at KSC for analysis. It was determined that material was on the inside surface of the lens. The camera was sent to the vendor for evaluation and repair.</p>
STS-84-V-02	Low Forward RCS Oxidizer Tank Ullage Pressure on the B-leg Regulator (ORB)	142:01:04 G.m.t. 06:16:56 MET CAR 84RF03 PR FRC4-A0036	<p>During separation from the Mir, a period of high forward RCS utilization (approximately 80 scfm), the forward RCS oxidizer ullage pressure dropped into the 233 to 234 psia range on several occasions. The ullage pressure should be maintained in the 239 to 259 psia range (test flow rate of 140 to 150 scfm). The forward RCS oxidizer tank was configured to the B-leg regulator at the time of the occurrence. Low regulation pressure with this regulator is a known condition, having been seen during previous flights and on the ground. A waiver was taken during the STS-84 flow for this condition. Under similar high-flow rate conditions during the previous flight of OV-104 (STS-81), the lowest regulated pressure was 238 psia, 5 psia higher than that seen during this mission.</p> <p>KSC: This regulator was tested postflight to determine if corrective action was required prior to STS-86. Note that the intent going into the STS-84 mission was to remove and replace the regulator at the Orbiter Maintenance Down Period (OMDP), which follows STS-86. Testing during the STS-86 flow determined that the regulator performance was the same as it had been prior to STS-84. Therefore, the waiver written prior to STS-84 that was effective until OMDP will be applicable for STS-86. No other action is required.</p>
STS-84-V-03	Camera A Blurred Image (GFE)	142:12:30 G.m.t. 07:04:22 <ET PR COM-4-20-0234	<p>There was a circular-shaped blurred area at the center of the camera A (CTVC S/N 216) image. The blur was not evident early in the mission. The blurred area became larger and smaller as the camera was zoomed, indicating that the problem was on the lens. This anomaly is similar to the camera C blurred image identified as STS-84-V-01.</p> <p>KSC: Removed camera and sent it to FCE facility at KSC for troubleshooting and analysis. It was determined that material was on the inside surface of the lens. The camera was sent to the vendor to evaluation and repair.</p>

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

No.	Title	Reference	Comments
STS-84-V-04	MS4 Seat Interference With The A-Hatch Handhold (ORB)	144:07:22 G.m.t. 08:23:14 MET CAR 84RF07	<p>During deorbit preparations, the crew noted that there was an interference between the A-hatch handhold and the mission specialist 4 lightweight seat (seat 6 position). During ascent, the seat back was inclined 2 degrees forward and there is no interference. However, the seat back is rotated 10 degrees aft for entry and the interference exists. The handhold was unbolted and removed to provide clearance for the seat. This was the first flight of a lightweight seat on a vehicle with an internal airlock. This interference was a known problem, but at the time it was understood that a lightweight seat would not fly on a vehicle with an internal airlock.</p> <p>The decision has been made to fly STS-86 (next flight of OV-104) without the handhold. An MCR was approved to remove the handhold when a lightweight seat is installed in position 6. The crew can open the hatch by using the structural ribs.</p>

## **DOCUMENT SOURCES**

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

1. Flight Requirements Document
2. Public Affairs Press Kit
3. Customer Support Room (CSR) Daily Science Reports, and Final  
CSR Report
4. MER Daily Reports
5. MER Mission Summary Report
6. MER Problem Tracking List
7. MER Event Times
8. Subsystem Manager Reports/Inputs
9. MOD Systems Anomaly List
10. MSFC Flash Report
11. MSFC Event Times
12. MSFC Interim Report
13. Crew Debriefing comments
14. Shuttle Operational Data Book
15. STS-84 Summary of Significant Events
16. Contractor Reports of Subsystem Operation

## ACRONYMS AND ABBREVIATIONS

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

ABS	ammonia boiler system
ADS	audio distribution system
ADTA	air data transducer assembly
AFRSI	advanced flexible reusable surface insulation
A/G	air-to-ground
APDS	Androgynous Peripheral Docking System
APU	auxiliary power unit
ARS	atmospheric revitalization system
ATCS	active thermal control system
CFU	Colony Forming Unit
CREAM	Cosmic Radiation Effect and Activation Monitor
CRIM	commercial refrigerator/incubator module
CTVC	color television camera
CVDA	commercial vapor diffusion apparatus
CWC	contingency water container
dB	decibel
DMHS	dome-mounted heat shield
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
$\Delta V$	differential velocity
ECLSS	Environmental Control and Life Support System
e.d.t.	eastern daylight time
EGT	exhaust gas temperature
EO	ET/Orbiter
EOR/F	enhanced Orbiter refrigerator/freezer
EPDC	electrical power distribution and control
EPICS	Electrolysis Performance Improvement Concept Study Experiment
EPOS	European Proximity Operations Sensor
ESA	European Space Agency
ESC	electronic still camera
ET	External Tank
EVA	extravehicular activity
FCE	flight crew equipment
FCS	flight control system
FCV	flow control valve
FDA	fault detection and annunciation
FES	flash evaporator system
ft/sec	feet per second
g	gravity
GFE	Government furnished equipment
GH <sub>2</sub>	gaseous hydrogen
G.m.t.	Greenwich mean time
GN <sub>2</sub>	gaseous nitrogen
GO <sub>2</sub>	gaseous oxygen

GPC	general purpose computer
GPS	Global Positioning System
GSFC	Goddard Space Flight Center
H <sub>2</sub>	hydrogen
HPFTP	high pressure fuel turbopump
HPOTP	high pressure oxidizer turbopump
ICD	interface control document
IFM	in-flight maintenance
IGN&C	Inertial guidance, navigation and control
IMU	inertial measurement unit
INS	inertial navigation system
I <sub>sp</sub>	specific impulse
ITCU	inflatable thermal control unit
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt/hour
lb	pound
lb/hr	pound/hour
lbm	pound mass
lb/min	pound per minute
LCC	Launch Commit Criteria
LH <sub>2</sub>	liquid hydrogen
LME	liquid motion experiment
LMSMS&S	Lockheed Martin Space Mission Systems and Services
LO <sub>2</sub>	liquid oxygen
LSLE	Life Science Laboratory Equipment refrigerator/freezer
MAGR	Miniature airborne GPS receiver
MC	midcourse correction (maneuvers)
MECO	main engine cutoff
MEFC	Mir Electric Field Characterization
MET	mission elapsed time
MISDE	Mir Structural Dynamics Experiment
MLG	main landing gear
MPS	main propulsion system
MSBLS	microwave scanning beam landing system
MSX	Midcourse Space Experiment
NASA	National Aeronautics and Space Administration
NC1-4	rendezvous maneuvers (four)
NCC	corrective combination maneuver
nmi.	nautical mile
NPSP	net positive suction pressure
NSTS	National Space Transportation System (i.e., Space Shuttle Program)
O <sub>2</sub>	oxygen
ODS	Orbiter docking system
OMDP	Orbiter Maintenance Down Period
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
PAL	protuberance air load
PCG-STES	Protein Crystal Growth-Single Locker Thermal Enclosure System

PCT	post contact thrust
PGSC	payload general support computer
PI	Principal Investigator
PMBT	propellant mean bulk temperature
ppm	parts per million
PPO <sub>2</sub>	partial pressure oxygen
PRSD	power reactant storage and distribution
psia	pound per square inch absolute
psid	pound per square inch differential
PTI	programmed test input
RCS	reaction control subsystem
RFI	radio frequency interference
RM	Redundancy Management
RME	Risk Mitigation Experiment
RME-III	Radiation Monitoring Experiment-III
RSRM	Reusable Solid Rocket Motor
RTV	room temperature vulcanizing (material)
S&A	safe and arm
SIGI	Space Integrated GPS/INS
SIMPLEX	Shuttle Ionospheric Modification with Pulsed Local Exhaust
SLF	Shuttle Landing Facility
S/N	serial number
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSD-MOMO	Self-Standing Drawer-Morphological Transition and Model Substances Experiment
SSME	Space Shuttle main engine
STS	Space Transportation System
SVS	space vision system
TACAN	tactical air control and navigation
TCS	thermal control subsystem/trajectory control sensor
TDRS-W	Tracking and Data Relay Satellite-West
TI	terminal phase initiation
TIG	time of ignition
TPS	thermal protection system/subsystem
TVIS	treadmill vibration isolation system
VDA	Vapor Diffusion Apparatus
VHF	very high frequency
WSB	water spray boiler