

STS-83 SPACE SHUTTLE MISSION REPORT

June 1997



**National Aeronautics and
Space Administration**

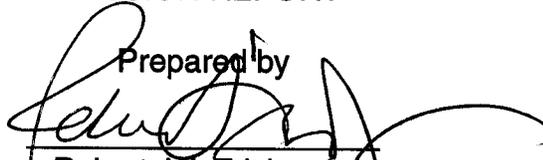
**Lyndon B. Johnson Space Center
Houston, Texas**

STS-83

SPACE SHUTTLE

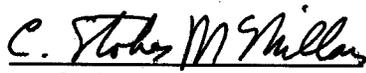
MISSION REPORT

Prepared by



Robert W. Fricke, Jr.
LMSMS&S/Operations Engineering Office

Approved by



C. Stokes McMillan
STS-83 Lead Mission Evaluation Room Manager



David W. Camp
Manager, Operations Engineering Office



Ronald D. Dittmore
Manager, Space Shuttle Vehicle Engineering Office



Tommy W. Holloway
Space Shuttle Program Manager

Prepared by
Lockheed Martin Space Mission Systems and Services
for
Operations Engineering Office

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS 77058

June 1997

NOTE

The STS-83 Space Shuttle Mission Report was prepared from inputs received from the Space Shuttle Operations Engineering Office as well as other organizations. The following personnel may be contacted should questions arise concerning the technical content of this document.

C. Stokes McMillan, JSC
281-483-5913

Orbiter and subsystems

M. George Harsh, MSFC
205-544-4827

MSFC Elements (SRB,
RSRM, SSME, ET,
SRSS, and MPS)

Greg Buoni, JSC
281-483-0639

Payloads/Experiments
DTOs and DSOs

Ralph V. Anderson, JSC
281-483-1271

FCE and GFE

STS-83 Table of Contents

<u>Title</u>	<u>Page</u>
<u>INTRODUCTION</u>	1
<u>MISSION SUMMARY</u>	3
<u>PAYLOADS</u>	7
<u>SPACELAB SYSTEMS OPERATION</u>	7
<u>Spacelab Command and Data Management System</u> .	7
<u>Mission Peculiar Equipment</u>	7
<u>COMBUSTION SCIENCE RESULTS</u>	8
<u>MATERIALS SCIENCE</u>	8
<u>Physics of Hard Spheres Experiment</u>	8
<u>Large Isothermal Furnace</u>	8
<u>Electromagnetic Containerless Processing Facility</u> .	9
<u>BIOTECHNOLOGY</u>	9
<u>MIDDECK GLOVEBOX</u>	9
<u>ACCELEROMETERS</u>	10
<u>Microgravity Measurement Assembly</u>	10
<u>Space Acceleration Measurement System</u>	10
<u>Quasi-Steady Acceleration Measurement</u>	10
<u>Orbital Acceleration Research Experiment</u>	10
<u>Midcourse Space Experiment</u>	10
<u>CRYOGENIC FLEXIBLE DIODE EXPERIMENT</u>	11
<u>SHUTTLE AMATEUR RADIO EXPERIMENT</u>	11
<u>RISK MITIGATION EXPERIMENT</u>	12
<u>Wireless Data Acquisition System</u>	12
<u>VEHICLE PERFORMANCE</u>	13
<u>SOLID ROCKET BOOSTERS</u>	13
<u>REUSABLE SOLID ROCKET MOTORS</u>	13
<u>EXTERNAL TANK</u>	14
<u>SPACE SHUTTLE MAIN ENGINES</u>	15
<u>SHUTTLE RANGE SAFETY SYSTEM</u>	15
<u>ORBITER SUBSYSTEMS PERFORMANCE</u>	16
<u>Main Propulsion System</u>	16
<u>Reaction Control Subsystem</u>	17
<u>Orbital Maneuvering Subsystem</u>	17
<u>Power Reactant Storage and Distribution Subsystem</u> .	18
<u>Fuel Cell Powerplant Subsystem</u>	18
<u>Auxiliary Power Unit Subsystem</u>	22
<u>Hydraulics/Water Spray Boiler Subsystems</u>	23
<u>Electrical Power Distribution and Control Subsystem</u> .	23
<u>Pressure Control Subsystem</u>	23
<u>Atmospheric Revitalization Subsystem</u>	24

STS-83 Table of Contents

<u>Title</u>	<u>Page</u>
<u>Active Thermal Control Subsystem</u>	24
<u>Supply and Waste Water Subsystem</u>	24
<u>Waste Collection Subsystem</u>	25
<u>Airlock Support System</u>	25
<u>Smoke Detection and Fire Suppression Subsystem</u>	25
<u>Flight Data Systems</u>	25
<u>Flight Software</u>	25
<u>Flight Control Subsystem</u>	25
<u>Displays and Controls Subsystem</u>	26
<u>Communications and Tracking Subsystems</u>	27
<u>Operational Instrumentation/Modular</u>	
<u>Auxiliary Data System</u>	27
<u>Structures and Mechanical Subsystems</u>	28
<u>Integrated Aerodynamics, Heating and Thermal</u>	
<u>Interfaces</u>	29
<u>Thermal Control Subsystem</u>	29
<u>Aerothermodynamics</u>	30
<u>Thermal Protection Subsystem and Windows</u>	30
<u>GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW</u>	
<u>EQUIPMENT</u>	33
<u>CARGO INTEGRATION</u>	34
<u>DEVELOPMENT TEST OBJECTIVE/DETAILED SUPPLEMENTARY</u>	
<u>OBJECTIVES</u>	35
DEVELOPMENT TEST OBJECTIVES	35
DETAILED SUPPLEMENTARY OBJECTIVES	36
<u>PHOTOGRAPHY AND TELEVISION ANALYSIS</u>	38
LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS	38
ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS	38
LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSIS	38

List of Tables

TABLE I - STS-83 SEQUENCE OF EVENTS	39
TABLE II - STS-83 ORBITER IN-FLIGHT ANOMALY LIST	41
TABLE III - STS-83 GOVERNMENT FURNISHED EQUIPMENT	
PROBLEM TRACKING LIST	44

Appendixes

A - <u>DOCUMENT SOURCES</u>	A-1
B - <u>ACRONYMS AND ABBREVIATIONS</u>	B-1

INTRODUCTION

This Space Shuttle Program Mission Report presents a discussion of the Orbiter subsystem operation and the in-flight anomalies that were identified. The report also summarizes the activities of the STS-83 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-third mission of the Space Shuttle Program. STS-83 was the fifty-eighth flight since the return to flight, and the twenty-second flight of the OV-102 (Columbia) Orbiter vehicle.

The flight vehicle consisted of the OV-102 Orbiter; an ET that was designated ET-84; three Phase II SSMEs that were designated as serial numbers (S/N) 2012, 2109, and 2019 in positions 1, 2, and 3, respectively; and two SRBs that were designated BI-086. The two RSRMs were designated RSRM 059 with one installed in each SRB. The individual RSRMs were designated 360T059A for the left SRB, and 360T059B for the right SRB.

The STS-83 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-83 flight was to successfully perform the planned operations of the First Microgravity Science Laboratory (MSL-1). The Orbital Acceleration Research Experiment (OARE) provided supplementary data for the MSL-1 microgravity experiments. Secondary objectives of this flight were to perform the operations of the Cryogenic Flexible Diode Experiment (CRYOFD); perform the requirements of the Shuttle Amateur Radio Experiment-II (SAREX-II); and as a payload of opportunity, perform the requirements of the Midcourse Space Experiment (MSX).

The STS-83 mission was a planned 16-day plus two-contingency-day mission during which experiments were to be conducted in the MSL-1. The two contingency days were available for bad weather avoidance for landing, or other Orbiter contingency operations. However, fuel cell 2 was shut down after approximately two days of operation because of a high cell differential voltage reading in substack 3, and the mission was shortened to four days. A discussion of the problem and accomplishments of this shortened mission are contained in this report.

The STS-83 sequence of events is shown in Table I, and the Orbiter In-Flight Anomaly List is shown in Table II. The Government Furnished Equipment/Flight Crew Equipment (GFE/FCE) Problem Tracking List is shown in Table III. Table

IV shows the Marshall Space Flight Center (MSFC) in-flight anomaly that was identified in the SRB during the postflight inspection . 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 using in this report. All times are given in Greenwich mean time (G.m.t.) and mission elapsed time (MET).

The seven-person crew of the STS-83 mission consisted of James Halsell, Jr., Lt. Col., United States Air Force, Commander; Susan Leigh Still, Lt. Cdr., United States Navy, Pilot; Janice Voss, Ph. D., Civilian, Payload Commander/Mission Specialist 1; Michael L. Gemhardt, Ph. D., Civilian, Mission Specialist 2; Donald A. Thomas, Ph. D., Civilian, Mission Specialist 3; Roger K. Crouch, Ph. D., Civilian, Payload Specialist 1; and Gregory T. Linteris, Ph. D., Civilian, Payload Specialist 2. STS-83 was the third space flight for the Commander, Mission Specialist 1 and Mission Specialist 2; the second space flight for Mission Specialist 3; and the first space flight for the Pilot, Payload Specialist 1 and Payload Specialist 2.

MISSION SUMMARY

The STS-83 mission was launched at 094:19:20:32.019 G.m.t. (2:20 p.m. e.s.t.) on April 4, 1997. The launch was delayed approximately 20 ½ minutes and the cause is discussed in later paragraphs. The launch phase was satisfactory in all respects. The original planned launch date was April 3, 1997, but the requirement to install thermal protection around the floodlight coldplate in the payload bay caused a rescheduling of the launch to April 4 at 2:00 p.m. e.d.t.

When fuel cell start-up was initiated during prelaunch operations, the fuel cell 2 substack 3 differential voltage [as measured by the cell performance monitor (CPM)] remained above the Operations and Maintenance Requirements and Specification Document (OMRSD) limit of 150 mV for an unusually long period of time. After the pre-start reactant purge, the differential voltage (ΔV) dropped from 500 mV to 160 mV. When fuel cell 2 was connected to the main bus, the ΔV increased to over 400 mV and then began a gradual decrease. Typically, the substack ΔV values drop below 100 mV early in the start-up sequence. Prior to the fuel cell high-load calibration test, a purge of fuel cell 2 was performed in an attempt to sweep away any inert material that may have been the cause of the high ΔV reading. This purge had no effect on the rate of decrease. The high-load test (250 amperes) was performed and this caused the ΔV to shift down to less than 100 mV in response to the load change. The ΔV shifted back up to above 100 mV at the conclusion of the test. The ΔV reading then continued its gradual decrease and was below 50 mV prior to liftoff. An OMRSD waiver was processed to accept this condition for flight.

During the prelaunch cabin-leak checks, a problem was noted with a seal at the port used to pressurize the cabin (Flight Problem STS-83-V-06). The seal was replaced and the cabin-leak check was completed nominally. However, the work associated with this problem caused a 20-minute 32-second launch delay.

During ascent, the flash evaporator system (FES) high-load duct temperatures dropped off sharply. The inboard-duct temperature dropped to approximately 62 °F (normally remains above 190 °F) (Flight Problem STS-83-V-02). The heaters were reconfigured from system-A-only to systems A and B at approximately 12 minutes MET, and the temperatures eventually recovered. Throughout the occurrence, the evaporator outlet temperatures were stable. No further problems with the FES were noted during the remainder of the flight.

An evaluation of the ascent vehicle propulsive 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 the start of 3g throttling was 452.6 seconds as compared to a main propulsion system (MPS) tag value of 452.56 seconds.

The orbital maneuvering subsystem (OMS) 1 maneuver was not required because of the direct ascent trajectory flown. The OMS 2 maneuver was performed 094:20:00:27.0 G.m.t. (00:00:39:55.0 MET). The maneuver was 143.2 seconds in duration and a differential velocity (ΔV) of 222 ft/sec was imparted to the vehicle. The vehicle was inserted in the planned circular orbit.

The payload bay door opening sequence was completed at 094:21:08:48 G.m.t. (00:01:48:16 MET). Nominal dual motor times were recorded for the door opening operations.

Spacelab activation was completed on April 4, 1997, at 6:15 p.m. c.s.t. (approximately five hours after launch), and it was followed by successful payload and experiment activation. Nominal payload timeline activities continued until flight day 3 when the minimum duration flight (MDF) was called by the Mission Management Team (MMT) because of the fuel cell 2 anomaly.

The fuel cell 2 substack 3 differential voltage began trending upward shortly after on-orbit operations began (approximately 00:02:00 MET). A two-minute fuel cell purge was initiated at 095:06:17 G.m.t. (00:10:56 MET) in an attempt to stop the differential-voltage upward trend. The substack 3 ΔV increase was not halted, and the level continued to rise at approximately 1 mV/hr. An analysis team was formed to investigate the anomaly, and a decision was made to shut down fuel cell 2 if the substack 3 differential voltage value reached 150 mV.

In an attempt to improve the performance of fuel cell 2, a 10-minute purge was performed at 095:15:09 G.m.t. (00:19:49 MET). Fuel cell 3 was purged simultaneously with fuel cell 2 since the current levels from the two fuel cells were being compared. Since early in the mission, main bus B (fuel cell 2) and main bus 3 (fuel cell 3) were tied for Spacelab operations.

Following the 10-minute purge, the fuel cell 2 substack 3 ΔV measurement continued to exhibit a trend towards the upper limit of 150 mV. A 30-minute purge of fuel cell 2 was initiated at 096:01:48 G.m.t. (01:06:27 MET) to improve the performance. Fuel cell 3 was purged for 30 minutes at 096:02:20 G.m.t. (01:06:59 MET). The CPM reading on the fuel cell 2 ΔV decreased, but when the purge stopped the value continued to increase. The main B-and-C bus tie was removed at approximately 096:05:27 G.m.t. (01:10:06 MET) and busses A and C were tied together. The removal of the bus tie reduced the load on fuel cell 2 and reduced the rate of change of the substack 3 ΔV . In the A-to-C bus tie configuration, the hydraulic circulation pumps were configured to be powered by main bus C instead of main bus B. The hydraulic system thermal limit was lowered to -20 °F for all surfaces. The lower limit reduced the number of circulation pump runs required during this period of limited vehicle power.

Due to the continued high substack 3 differential-voltage value and the predictions that the condition would worsen, fuel cell 2 (S/N 119), was shutdown

and safed at 096:19:30 G.m.t. (02:00:09 MET) to prevent the possibility of a crossover condition occurring (Flight Problem STS-83-V-01). During the fuel cell shutdown sequence, the H₂ reactant valve did not give a closed indication (Flight Problem STS-83-V-08). However, the H₂ flow was terminated since the fuel cell regulator shuts off both reactant supplies to the fuel cell even if only one reactant supply valve is closed. Another command to close this valve was attempted at 097:01:22 G.m.t. (02:06:01 MET) and the valve closed immediately. Fuel cells 1 and 3 continued to carry the total Orbiter load and performed nominally. The Orbiter operated under the constraints of the Group B and Group 2 priority power-down protocols.

The fuel cell shut down and attendant reduction in available power to the Microgravity Science Laboratory (MSL) -1 payload resulted in the premature termination of several experiments including the Expedite the Processing of Experiments to the Space Station (EXPRESS) rack, the Orbital Acceleration Research Experiment (OARE), the Physics of Hard Spheres Experiment (PHaSE), the Quasi-Steady Acceleration Measurement (QSAM), the Space Acceleration Measurement System (SAMS), and the Electromagnetic Containerless Processing Facility (TEMPUS). Remaining experiment objectives were reprioritized in an effort to obtain critical science and stay within the remaining on-orbit time and power constraints. Spacelab deactivation was completed at 098:04:48 G.m.t. (03:09:28 MET).

The flight control system (FCS) checkout was performed at 097:15:27 G.m.t. (02:20:07 MET) using APU 1. FCS performance was nominal. APU 1 was started at 097:15:33 G.m.t. (2:20:13 MET) and ran for 6 minutes 44 seconds. The fuel consumption during this run was 17 lb. The APU and hydraulics subsystems performed nominally during the checkout. No water spray boiler operation occurred because of the short APU run time.

The navigational aids (NAVAIDS) sensors self-test was performed as part of FCS checkout at 097:15:46 G.m.t. (02:20:26 MET). All NAV AIDS self-test results were good. As a result of the power conservation protocol due to the failure of fuel cell 2, the NAV AIDS were not repowered until the 15,000-ft/sec point during the entry phase.

The reaction control subsystem (RCS) hot-fire was performed at 097:16:30 G.m.t. (02:21:10 MET). All but one thruster fired satisfactorily. Forward RCS thruster F3F was deselected by the redundancy management (RM) software when the chamber pressure reached only 11.6 psia with no leakage apparent (Flight Problem STS-83-V-03). The most likely cause of the failure was improper operation of the thruster fuel or oxidizer valve. The loss of this thruster did not impact mission operations.

Following a reactivation of the -Z star tracker at approximately 097:18:04 G.m.t. (02:22:44 MET), a pressure built-in-test-equipment (BITE) was annunciated for

approximately 11 minutes (Flight Problem STS-83-V-04). After the BITE cleared, the star tracker functioned nominally. The star tracker is pressurized to prevent moisture and contamination intrusion during entry and ground operations. There is no impact to flight operations from the pressure BITE indication.

Approximately 12 minutes after star tracker reactivation, at 097:18:16 G.m.t. (02:22:56 MET), the -Y star tracker was bypassed by the primary avionics software system (PASS) (Flight Problem STS-83-V-05). The crew performed the malfunction procedure, but the -Y star tracker was not recovered.

Prior to both of these star tracker occurrences, both star trackers had been powered off due to the loss of fuel cell 2.

A bus reconfiguration from a Main A-B bus tie to a Main B-C bus tie occurred at 098:04:46 G.m.t. (003:09:25 MET). Main busses B and C were then powered by fuel cell 3 which was the healthier of the two remaining fuel cells.

The payload bay doors were closed and latched at 098:14:56:33 G.m.t. (03:19:36:01MET) in preparation for landing. Acceptable weather conditions existed at the Kennedy Space Center (KSC) Shuttle Landing Facility (SLF) for a landing on the first opportunity. The dual-engine deorbit maneuver for the landing at the SLF was performed on orbit 63 at 098:17:31:18.1 G.m.t. (03:22:10:46.1 MET). The maneuver was 202.4 seconds in duration with a ΔV of 324.8 ft/sec.

The video mini-camera used to show video data through the Heads Up Device (HUD) during landing operations was out-of-focus (Flight Problem STS-83-V-07). The camera is normally used for other video during the mission, and the camera must be refocused to infinity prior to entry.

Entry was completed satisfactorily, and main landing gear touchdown occurred on KSC concrete runway 33 at 098:18:33:11 G.m.t. (03:23:12:39 MET) on April 8, 1997. The Orbiter drag chute was deployed at 098:18:33:15.4 G.m.t. and the nose gear touchdown occurred 8 seconds later. The drag chute was jettisoned at 098:18:33:48 G.m.t. with wheels stop occurring at 098:18:34:11 G.m.t. The rollout was normal in all respects. The flight duration was 3 days 23 hours 12 minutes and 39 seconds. The APUs were shut down 17 minutes 38 seconds after landing.

PAYLOADS

The primary payload was the MSL, which was a collection of microgravity experiments housed in a European Spacelab long module. The MSL featured 19 materials science investigations in five major facilities. These facilities were the Large Isothermal Furnace, the EXPRESS rack; the TEMPUS; the Coarsening in Solid-Liquid Mixtures (CSLM) facility; and the Combustion Module-1 facility. Additional technology experiments were also to be performed in the Middeck Glovebox (MGBX), using the High-Packed Digital Television (HI-PAC DTV) system for multi-channel real-time analog science video.

Experiments that measured microgravity included the SAMS, the Microgravity Measurement Assembly by the QSAM and the OARE.

The MGBX facility will supported the Bubble and Drop Nonlinear Dynamics (BDND) Experiment, the Study of the Fundamental Operation of a Capillary-driven Heat Transfer (CHT) Device in the Microgravity Experiment, the Internal Flows in a Free Drop (IFFD) experiment, and the Fiber Supported Droplet Combustion experiment.

SPACELAB SYSTEMS OPERATION

Space Station EXPRESS Rack

The Space Station EXPRESS rack hardware operated satisfactorily until flight day 3 when it was deactivated to conserve power because of the fuel cell 2 anomaly. During the attempt to shutdown the EXPRESS using commands from a payload general support computer (PGSC), the SIR-2 drawer could not be initially powered off. The drawer supplies power to the EXPRESS rack. The EXPRESS rack was reactivated and then an immediate deactivation was successfully performed.

Spacelab Command and Data Management System

A series of experiment computer (EC) processing halts and EC operating system (ECOS) problems interrupted experiment operations. An EC reconfiguration prevented further problems. Initial indications were that an anomaly existed between the EC and EC input/output unit that was preventing the ECOS from cycling through its normal operation.

Mission Peculiar Equipment

The HI-PAC television system experienced a failure in the MPEG1 video encoder assembly (MVEA) 4. Indications were that circuit breaker 4 (CB4) had

opened, and data analysis indicated a one ampere current increase on the circuit breaker.

An in-flight maintenance (IFM) procedure that was to exchange MVEA 4 with the spare JPEG encoder was deferred because of time constraints resulting from the decision to perform a MDF. Nominal operation of the HI-PAC television system was exhibited with the other five prime encoders.

COMBUSTION SCIENCE RESULTS

Although experiment operations were curtailed, unparalleled data were obtained from the Combustion Module-1 (CM-1) and Droplet Combustion Experiment (DCE) that will improve the fundamental understanding of fuel combustion. The operations on flight day 3 are regarded as the most important day in combustion history.

Three test points (01E, 1, and 3) of the Laminar Soot Process (LSP) were conducted and resulted in very steady burns. Two test points (4a and 8a) were completed with excellent data on the Structure of Flame Balls at Low Lewis-number (SOFBALL); however, a reburn of test point 8a was not successful as it resulted in only a spark.

Four sample bottles (2, 3, 21, and 22) of the DCE were used to conduct burns. Video data of these excellent burns were downlinked to the ground, and these burns are expected to improve the understanding of the behavior of fuel combustion.

MATERIALS SCIENCE

Physics of Hard Spheres Experiment

Unattended PHaSE operations continued in the module EXPRESS rack until the experiment was powered down on flight day 3 to conserve power. During the experiment operations, the science team reported excellent data. A touch-screen lockup problem was resolved using a preplanned recovery procedure.

Large Isothermal Furnace

Sample processing in the Large Isothermal Furnace (LIF) for the Diffusion in Liquid Lead-Tin-Telluride investigation was successfully completed. Likewise, experiment runs for the Measurement of Impurity Coefficients in Ionic Melts were nominally completed. The science team used the downlinked data to perform real-time analysis.

The unattended runs of sample cartridges 1, 3, and 4 were completed for the Liquid Phase Sintering II investigation. The runs were made at temperatures as high as 1500 °C, and data from these runs will be used to improve existing

theoretical models. The samples for the Measurement of Diffusion Coefficient by Shear Cell Method were heated and two shear-cell rotations were performed. The test samples are tin, and the shear-cell method is an important tool for determining the rate of diffusion in a variety of materials.

Electromagnetic Containerless Processing Facility

The German-sponsored Electromagnetic Containerless Processing Facility (TEMPUS) used electromagnetic levitation to provide an ultra-clean, containerless environment for processing metallic samples in microgravity.

The Nucleation in Different Flow Regimes investigation using Bayuzick Zirconium (FO₂) determined quantitatively the temperatures of solid nucleation from melts of pure zirconium and the number of nucleations at each temperature as the melts are cooled below their equilibrium freezing points. The investigation was initiated ahead of schedule and the tests on nucleation in different flow regimes were completed. The science team ended the tests early after two samples hit the sample cage wall. The crew confirmed the levitating and heating coils were not bent or embedded in the sample.

The Thermophysical Properties of Advanced Materials in the Undercooled State experiment measured the specific heat of undercooled metallic melts and provided data for understanding how glass forms in Zirconium-based alloys. One sample was loaded and activated for a 35-minute run in the Large Isothermal Furnace. This sample provided data on surface tension, viscosity and electrical conductivity of liquid and undercooled alloys.

BIOTECHNOLOGY

Four crystal and plant growth experiments, all of which were unattended, operated satisfactorily throughout the mission. The experiments were:

- a. Protein Crystal Growth Using the Protein Crystallization Apparatus for Microgravity;
- b. Protein Crystal Growth Using the Second Generation Vapor Diffusion Apparatus;
- c. Protein Crystal Growth Using the Hand-Held Diffusion Test Cells: and
- d. Astro/Plant Generic Bioprocessing Apparatus.

MIDDECK GLOVEBOX

Two experiments were performed partially during the course of the mission. However, operations were curtailed because of the fuel cell 2 anomaly.

Six of the CSLM sample runs (1, 2, 4, 5, 6, and 7) were processed. With the fact that the CSLM operation replaced the Internal Flows in a Free Drop (IFFD) operation in the timeline, the crew was able to successfully complete and videotape seven of the nine nominally planned science objectives. Before curtailment of the IFFD operations, the Drop Translational and Rotational Control experiment was completed in which 0.2, 0.4 and 0.6 drops were deployed and rotated/positioned by varying acoustic alignment parameters.

ACCELEROMETERS

Microgravity Measurement Assembly

The Microgravity Measurement Assembly (MMA) monitored the microgravity environment in the range of 0.1 to 100 Hertz inside the Spacelab. The MMA heads were deployed in the Spacelab racks where gravity-sensitive investigations were conducted. The MMA was deactivated for landing.

Space Acceleration Measurement System

The SAMS sensor heads were placed in three locations in the Spacelab and the Orbiter middeck. The SAMS measured accelerations from 0.1 to 25 Hertz. The SAMS was deactivated prematurely to conserve power because of the fuel cell 2 anomaly.

Quasi-Steady Acceleration Measurement

The QSAM was located in rack 3 of the Spacelab and was used to measure accelerations between 0 and 0.02 Hertz. The QSAM was prematurely deactivated to conserve power and this action was necessary because of the fuel cell 2 anomaly.

Orbital Acceleration Research Experiment

The OARE measured very-low-frequency accelerations in the payload bay of the Orbiter. The OARE had a real-time data interface with the Spacelab high-rate multiplexer (HRM), which was used to downlink OARE data to the science community using the Ku-band along with MSL-1 high-rate data. It was necessary to remove power from the OARE because of the power conservation that was required in support of the fuel cell 2 anomaly.

Midcourse Space Experiment

No MSX activities were performed during the mission because of the lack of opportunities. The need for power conservation because of the fuel cell 2 anomaly also impacted this experiment.

CRYOGENIC FLEXIBLE DIODE EXPERIMENT

Overall, the CRYOFD was successful in demonstrating the first microgravity operation of a cryogenic flexible diode heat pipe and an American-made loop heat pipe.

The CRYOFD heat pipe experiment operated for two periods during the shortened mission. The first period was approximately 14 hours in length and the second was approximately 2 ½ hours in length. The CRYOFD was able to operate the oxygen flexible diode (OFD) for a total of 10 hours, the methane flexible diode (MFD) for a total of 4 hours, and the American loop heat pipe with ammonia (ALPHA) for a total of 6 hours. CRYOFD accomplished approximately 10 percent of the minimum timelined MFD objectives, and approximately 75 percent of the minimum timelined ALPHA objectives. The minimum mission timeline delineated 48 hours of operation for both the OFD and the MFD, and 8 hours for the ALPHA.

The OFD was successful in cooling down, operating between 70 and 84 Kelvin (K), and performing one diode-reversal demonstration of 100 K. Each of these tests demonstrated nominal OFD performance. The objectives not accomplished by the OFD were operation between 60 and 70 K, operation between 85 and 105 K, dry-out or maximum transport capacity at any temperature, diode-reversal between 60 and 80 K, calibration of diode reversal, and restart using the trap heater.

The MFD experiment demonstrated nominal operation in successfully cooling down and priming the heat pipe. Objectives not accomplished were operation at any temperature, dry-out or maximum transport capacity at any temperature, diode-reversal at any temperature, calibration of diode-reversal, restart using the trap heater, and BETSU characterization.

The ALPHA experiment was successful in demonstrating start-up and power-cycling (0-300 W) operations, repeatable start-ups, fluid-flow stops, and recovery from being deprived.

SHUTTLE AMATEUR RADIO EXPERIMENT

The test pass of the Shuttle Amateur Radio Experiment (SAREX) by Mission Specialist 3 with a ground ham station was completed approximately 22 hours into the mission. However, further SAREX operations were suspended because of the MDF.

RISK MITIGATION EXPERIMENT

Wireless Data Acquisition System

The Wireless Data Acquisition System (WDAS) Risk Mitigation Experiment (RME) 1330 was activated and warmed up in accordance with the planned timeline. Also one of the three planned operations was completed. Temperature sensor data were successfully retrieved via the network control unit and stored on a PGSC. The data were downlinked to the ground via the Orbiter communications adapter (OCA). The WDAS was also activated for entry; however, the results of that operation have not been reported.

VEHICLE PERFORMANCE

SOLID ROCKET BOOSTERS

All Solid Rocket Booster (SRB) systems performed normally, and one in-flight anomaly was identified from the data analysis. The in-flight anomaly concerns the gap that was found between the right SRB External Tank Attachment (ETA) ring cover and the upper strut ethylene propylene diene monomer (EPDM) cover on both the ring cap and the inboard side of the cover (Flight Problem STS-83-B-01). This anomaly had no affect on the performance of the SRB.

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

Both SRBs were separated from the External Tank (ET) at approximately T+123.0 seconds. Visual reports indicated that the deceleration subsystems performed as designed. STS-83 was also the first flight of the recoverable pilot parachutes and the drogue parachute deployment bags. Both of the pilot parachutes and both of the drogue parachute deployment bags were recovered as planned. The SRBs were recovered and returned to Cape Canaveral and in turn to Kennedy Space Center where the SRB disassembly and refurbishment activities were begun.

REUSABLE SOLID ROCKET MOTOR

The Reusable Solid Rocket Motors (RSRMs) performed satisfactorily throughout the first stage of ascent. No RSRM LCC or OMRSD violations occurred during the countdown, nor were any in-flight anomalies identified from the data analysis.

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.

Data indicate that the flight performance of both RSRMs was well within the contractor end item (CEI) performance limits and was typical of the performance observed on previous flights. The RSRM propellant mean bulk temperature (PMBT) was 72 °F at liftoff. The maximum trace shape variation of pressure versus time was calculated to be 1.30 percent at 80 seconds (left motor) and 0.95 percent at 80 seconds (right motor). These values were well within the 3.2 percent allowable limits. The table on the following page shows pertinent propulsion performance data.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 72 °F		Right motor, 72 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10 ⁶ lbf-sec	66.09	66.23	66.06	66.27
I-60, 10 ⁶ lbf-sec	175.98	176.79	175.89	176.75
I-AT, 10 ⁶ lbf-sec	296.97	297.17	296.79	297.04
Vacuum Isp, lbf-sec/lbm	268.5	268.7	268.5	268.8
Burn rate, in/sec @ 60 °F at 625 psia	0.3696	0.3710	0.3697	0.3705
Event times, seconds ^a				
Ignition interval	0.232	N/A	0.232	N/A
Web time ^b	109.0	108.3	109.0	108.5
50 psia cue time	118.7	118.0	118.7	118.0
Action time ^b	120.8	120.2	120.8	120.2
Separation command	123.6	123.1	123.6	123.1
PMBT, °F	72	72	72	72
Maximum ignition rise rate, psia/10 ms	90.4	N/A	90.4	N/A
Decay time, seconds (59.4 psia to 85 K)	2.8	3.1	2.8	3.0
Tailoff Imbalance Impulse differential, Klbf-sec	Predicted		Actual	
	N/A		498.7	

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

^aAll times are referenced to ignition command time except where noted by a ^b

^bReferenced to liftoff time (ignition interval).

The postflight inspection revealed abnormal impact damage on the left-hand forward nose and aft inlet rings; a gas path through the polysulfide in the left-hand nozzle-to-case joint with the wiper O-ring affected by the heat (in-family heating characteristics); and insulation edge debonding (0.250 in. deep) on the left-hand igniter inner joint. None of these items were classified as in-flight anomalies.

EXTERNAL TANK

All objectives and requirements associated with the ET propellant loading and flight operations were met. All ET electrical equipment and instrumentation operated satisfactorily. ET purge and heater operations were monitored and all performed properly. No ET LCC or OMRSD violations were identified nor were any in-flight anomalies identified from the data analysis.

No unexpected ice/frost formations were observed on the ET during the countdown. No frost or ice was observed on the acreage areas of the ET. Normal quantities of ice or frost were present on the liquid oxygen (LO₂) and

liquid hydrogen (LH₂) feedlines, the pressurization line brackets, and along the LH₂ protuberance air load (PAL) ramps. These observations were acceptable per NSTS 08303. The Ice/Frost team did not record any anomalous thermal protection system (TPS) conditions.

The ET pressurization system functioned properly throughout engine start and flight. The reshimmed flow control valves (FCVs) were flown for the second time on the OV-102 vehicle, and the number of FCV cycles was reduced from a minimum of 43 cycles on any previous flight to 13 cycles while the pressures were maintained well within the required limits. The minimum LO₂ ullage pressure experienced during the ullage-pressure slump was 13.2 psid, which was the lowest experienced on the OV-102 vehicle but still within the Interface Control Document (ICD) limits.

Postflight evaluation of the in-flight photography from the umbilical well as well as the crew compartment revealed no anomalies; however, eight divots were noted in the intertank to LH₂ splice closeout area. The in-depth discussion of the photographic results is included in the Development Test Objective section of this report under the heading of DTO 312.

ET separation occurred at 530.483 seconds after liftoff and was confirmed following main engine cutoff (MECO). ET entry and breakup occurred within the footprint approximately 27 nmi. uprange of the preflight predicted impact point.

SPACE SHUTTLE MAIN ENGINES

All Space Shuttle main engine (SSME) parameters were within normal limits throughout the prelaunch countdown and were typical of prelaunch parameters observed on previous flights. Engine ready was achieved at the proper time; all LCC were met; and engine start and thrust build-up were normal. There were no in-flight anomalies or significant SSME problems revealed during the data review and analysis.

Flight data indicate that the SSME performance during mainstage, throttling, shut down, and propellant dump operations were normal. The high pressure oxidizer turbopump (HPOTP) and the high pressure fuel turbopump (HPFTP) temperatures were well within specification throughout engine operation. Likewise, controller and software performance was satisfactory with no problems noted. Cutoff times for SSME 1, 2, and 3 were 516.77, 516.90, and 517.00 seconds, respectively. The I_{sp} was rated as 452.6 seconds based on trajectory data. Space Shuttle MECO occurred at T + 510.45 seconds.

SHUTTLE RANGE SAFETY SYSTEM

The Shuttle Range Safety System (SRSS) operated as expected throughout the countdown and flight, and no in-flight anomalies were identified from the data

analysis. The SRSS closed-loop testing was completed as scheduled during the countdown. All SRSS safe and arm (S&A) devices were armed and system inhibits were turned off at the appropriate times. All SRSS measurements indicated that the system operation was normal.

As planned, the SRB S&A devices were safed, and SRB power was turned off prior to SRB separation. The ET System was deleted from the vehicle.

ORBITER VEHICLE PERFORMANCE

Main Propulsion System

The overall performance of the main propulsion system (MPS) was as expected. LO₂ and LH₂ loading were performed with no stop-flows or reverts. There were no LCC or OMRSD violations, nor were there any in-flight anomalies identified from the data review and analysis.

Throughout the period of preflight operations, no significant hazardous gas concentrations were detected. The maximum hydrogen concentration level in the Orbiter aft compartment, which occurred after the start of fast-fill, was 158 ppm and this compares favorably with previous data from this vehicle.

The LH₂ loading operations were normal, and based on an analysis of the loading data, the LH₂ load at the end of replenish was 231,289 lbm. A comparison of the calculated propellant loads at the end of replenish, versus the inventory (planned) loads resulted in a difference of -0.02 percent, which is well within the required loading accuracy of ± 0.37 percent.

The LO₂ loading operations were normal, and based on an analysis of the loading data, the LO₂ load at the end of replenish was 1,387,915 lbm. A comparison of the calculated propellant loads at the end of replenish, versus the inventory (planned) loads resulted in a difference of -0.03 percent, which is well within the required loading accuracy of ± 0.43 percent.

Ascent MPS performance was completely normal and all requirements were satisfied. Data indicate that the LO₂ and LH₂ pressurization and feed systems performed nominally and satisfied all tank ullage pressure and SSME inlet net positive suction pressure (NPSP) requirements. The overall gaseous hydrogen (GH₂) system in-flight performance was nominal, and the gaseous oxygen (GO₂) fixed orifice pressurization system performed as predicted. All three FCVs performed nominally. The propellant dump operations were nominal as were the vacuum inerting operations. The helium system performance was also nominal with entry helium usage of 54 lb.

The data review and analysis showed that the pneumatic-regulator outlet-pressure decay after isolation was 3 psi/min, which is 0.6 psi/min over the

allowable File IX requirement. The leak rate equates to a 35-scim size leak. During the ground checkout following landing, the decay was approximately 1.7 psi/min, which tracked the STS-80 in-flight decay. While this leak rate meets the maximum allowable rate, individual solenoid leak checks were performed. The liquid oxygen POGO 2 valve was found to be leaking 10.4 scims, which violates the specification allowable for a three-way solenoid de-energized leakage of 7.4 scims. Current signature traces showed no binding was present, and since the valve is acceptable with 100 scim of leakage, the valve is acceptable for flight. This leak did not impact entry operations, nor will it impact future entry operations.

Reaction Control Subsystem

The overall performance of the reaction control subsystem (RCS) was nominal. One in-flight anomaly was noted and that subject is discussed in the following paragraph. No LCC violations occurred. A total of 4050 lbm propellants (2479 lbm - oxidizer, 1571 lbm - fuel) were used during the mission. No propellants were consumed by the RCS from the OMS during this shortened mission. There was a total of 2,915 primary RCS thruster firings and 8,873 vernier thruster firings during the mission.

The RCS hot-fire was performed at 097:16:30 G.m.t. (02:21:10 MET). All but one thruster fired satisfactorily. Forward RCS thruster F3F was deselected by the RM software (failed off) when the chamber pressure reached only 11.6 psia with no leakage apparent (Flight Problem STS-83-V-03). The loss of this thruster for the remainder of the flight did not impact mission operations. The thruster had not been fired during the mission, and it failed off during the first hot-fire pulse of 320 milliseconds. The oxidizer injector temperature dropped from 86 °F to 70 °F, indicating some propellant flow through both the fuel and oxidizer valves. The most likely cause of the failure was an iron nitrate induced failure of the oxidizer valve or an extruded fuel valve pilot seat (fuel valve failure) as experienced on STS-81. The forward RCS module was removed, and thruster F3F as well as the other three thrusters on that manifold were removed and replaced.

Orbital Maneuvering Subsystem

The orbital maneuvering subsystem (OMS) performed flawlessly in accomplishing all of the requirements for this shortened mission. No deviations from the OMRSD or LCC requirements occurred during prelaunch operations. One minor problem was identified from the data review and analysis. The problem is discussed in a following paragraph. Two OMS firings were performed, and the propellants consumed were 8303.5 lbm of oxidizer and 4937.6 lbm of fuel. The table on the following page presents pertinent parameters from the two OMS maneuvers.

OMS FIRINGS

OMS firing	Engine	Ignition time, G.m.t./MET	Firing duration, seconds	ΔV , ft/sec
OMS-2	Both	094:20:00:27.0 G.m.t. 00:00:39:55.0 MET	143.2	222
Deorbit	Both	098:17:31:18.1 G.m.t. 03:22:10:46.1 MET	202.4	324.8

The engine inlet pressures, chamber pressures, and regeneration jacket temperature for both engines were nominal. The OMS firing times and propellant consumption were consistent with predictions, thus verifying nominal performance.

The right orbital maneuvering engine (OME) GN₂ accumulator exhibited a slight GN₂ low-pressure system leak. The OME GN₂ accumulator has had a slight leak on seven of its last nine flights. The GN₂ accumulator was repressurized at 097:21:36 G.m.t. (03:02:13 MET). This condition did not impact the flight.

Power Reactant Storage and Distribution Subsystem

The power reactant storage and distribution subsystem (PRSD) performed satisfactorily throughout the shortened mission. No in-flight anomalies or significant problems were identified. This mission was the tenth flight of the Extended Duration Orbiter (EDO) pallet. Oxygen tank 9 was only loaded to 90.4 percent because of the inadvertent closure of the oxygen tank 3 ground support equipment (GSE) vent valve during the EDO pallet loading of oxygen. The PRSD subsystem supplied 1201 lbm of oxygen and 151 lbm of hydrogen to the fuel cells for the production of electricity. In addition, 17 lbm of oxygen were provided to the environmental control and life support system (ECLSS) for cabin pressurization and crew breathing. At landing, the reactants remaining were adequate to support the planned mission plus extension day at the mission average power level. At an extension-day average power level of 13.1 kW, a 570-hour mission extension could have been supported.

At approximately 095:18:00 G.m.t. (00:22:34 MET), the new procedure for current-level-detector checkout was performed successfully. The advantage of the new procedure was that it gave a positive indication that the sensor will shut off its corresponding O₂ tank heater. This procedure is only performed once per mission rather than the once-per-day frequency of the previous procedure.

Fuel Cell Powerplant Subsystem

Performance of the fuel cell powerplant subsystem was marred by the shut down of fuel cell 2 (Flight Problem STS-83-V-01), which caused the mission to be

declared a MDF. The fuel cell 2 substack 3 CPM reading continued an upward trend on-orbit towards the upper limit of 150 mV. Flight rule A9.1.1-1J calls for a fuel cell to be shutdown when the CPM exceeds 150 mV. The CPM is used to detect cell failure within the fuel cell. A crossover failure, reactant mixing, within a fuel cell could be catastrophic. Even though additional purging and reducing the load on the fuel cell was performed, it was apparent that the value was going to reach 150 mV. The decision was thus made to safe and shut down fuel cell 2 (Flight Problem STS-83-V-01). All other fuel cell 2 parameters were nominal. As a result, landing occurred after only four days of the flight were completed. The remaining two fuel cells performed nominally throughout the mission, even though fuel cell 1 had exceeded its certified operating life of 2400 hours during the course of the mission. Fuel cell 1 was still operating 0.5 V above the launch minimum curve at shutdown. Fuel cell 1 was removed from the vehicle because it exceeded its certified operating life of 2400 hours. Fuel cell 2 was removed from the vehicle and sent to the fuel cell manufacturer for failure analysis.

The postflight failure analysis of the fuel cell did not reveal a root cause for the fuel cell anomaly. The analysis did reveal that 20 adjacent cells have some amount of degradation, thus showing that the CPM was operating properly. The analysis also showed that crossover did not occur. As a result of the analysis and investigation, the Launch Commit Criteria (LCC) was revised to not launch with a fuel cell showing similar prelaunch CPM readings.

During the four days of flight, the fuel cells produced 1709 kWh of electrical energy and 1352 lbm of potable water. The fuel cells used 1201 lbm of oxygen and 151 lbm of hydrogen in the production of electrical energy and water. The average electrical power level and load was 17.9 kW and 599 amperes. The normal purge schedule was not followed because of the extra purges performed in an attempt to correct the fuel cell 2 operation. The overall thermal performance of the fuel cell water relief, water line, and reactant purge systems was nominal. The fuel cell purge vent line heaters operated nominally in both the auto and manual mode. The actual fuel cell voltages at the end of the mission were 0.1 V above predicted for fuel cell 1, and 0.2 V above predicted for fuel cell 3. When fuel cell 2 was shut down, its voltage was 0.2 V above the predicted performance curve.

The fuel cell 2 substack 3 reading was unusual from the beginning of the fuel cell start-up operations. After the reactant pulse purge was completed (80 minutes before the pre-start purge), the ΔV slowly decayed from the full-scale value of 500 mV to 150 mV at the beginning of the pre-start purge. The value increased to 160 mV during the two-minute purge, then jumped to 460 mV when the start command (pumps and heaters on) was issued. The CPM value quickly decreased to 370 mV before increasing back up to 460 mV, then decreased to 370 mV again when the ready-for-load indication was received, at which time the CPM values suddenly fell to 260 mV. The 24 minutes 16 seconds required for the ready indication was nominal. The CPM reading

then quickly rose to 310 mV, then decayed to 270 mV before the fuel cell was connected to main bus B (150 amperes), when the value jumped to 500 mV. By the time the start-up purge was terminated, the value had decreased to 280 mV. Typically, CPM values drop rapidly after the flow-through purge and level off at nominal steady-state readings.

A decision was made to continue with the start-up of fuel cell 3 and observe fuel cell 2 performance. An OMRSD waiver was written for the fuel cell 2 substack 3 reading remaining above the 150 mV limit after the fuel cell was connected to the main bus. The value kept decreasing throughout the prelaunch period, and it was anticipated that it would stabilize at a nominal value near its final value at the end of the previous flight (34 mV at landing and 14 mV at pumps off). The CPM value fell below the 150 mV LCC limit just before the high-load calibration test (270 amperes for 45 minutes) and decayed to 40 mV during the high-load, but the value rose to 108 mV when the high-load was removed. A purge was performed prior to the high-load test in an attempt to sweep away any inert material that may have been the cause of the high CPM reading. The purge did not have any effect on the rate of decrease.

The CPM reading continued a steady decrease to 2 mV until the time when the prelaunch conditioning loads were applied (260 amperes). The CPM passed through zero (note that the CPM output is an absolute value) and jumped to 36 mV. From this point on, the value had a slow but steadily increasing trend. The decision to go ahead and launch based on the fact that the CPM reading was not near the LCC limit and appeared to be stabilizing in the 40 mV range. At launch, the CPM value was 38 mV.

At 094:21:27 G.m.t. (00:02:06 MET), main busses B and C were tied as part of the planned procedure, which is typical for Spacelab missions. The CPM continued to increase, but the rate of the increase was slowing. A two-minute purge was performed at 095:05:28 G.m.t. (00:10:07 MET) when the CPM was at 94 mV, but this purge failed to halt the upward trend.

The first nominal on-orbit purge was performed as a manual purge, beginning at 095:15:08 G.m.t. (00:20:47 MET), with main busses B and C still tied. Fuel cell 1 was purged for two minutes, then fuel cell 2 was purged for 10 minutes with the substack 3 CPM at 120 mV. The increased purge time had no effect, as the CPM reading continued to increase. Fuel cell 3 was then purged for two minutes. When the fuel cell 2 substack 3 CPM reading reached 140 mV, the fuel cell was purged again, beginning at 096:01:48 G.m.t. (01:06:27 MET) for 30 minutes. Fuel cell 3 was then purged for 30 minutes to maintain similar conditions in both fuel cells because the difference in their current reading (differential amperes) is a backup method to detect crossover for a failed CPM. The CPM reading on fuel cell 2 decreased some, but when the purge stopped the value again began increasing. The purge was coincident with a lower load

on the fuel cell which causes the CPM reading to decrease because changes in fuel cell current correspond directly to changes in the CPM.

At 096:05:28 G.m.t. (01:10:07 MET), main busses B and C were untied and busses A and C were tied. This change left fuel cell 2 connected to an untied bus and allowed it to operate at a lower load, down from 216 amperes to 164 amperes. The change also caused a corresponding step-change downward in the substack 3 CPM reading from 134 mV to 120 mV. This reduction provided more time to evaluate the trending of the CPM, which up to this point had been increasing but at a decreasing rate. In the A-to-C bus tie configuration, the hydraulic circulation pumps were configured to be powered by main bus C instead of main bus B. The hydraulic system thermal limit was lowered to -20°F for all surfaces. The lower limit reduced the number of circulation pump runs required during the limited vehicle-power operations.

The CPM appeared to be stable in the 126 to 134 mV range for the next several hours, but during this time the fuel cell current also had a downward trend which masked the continuing upward trend of the CPM. The consensus of the fuel cell community was that the fuel cell should be shut down, since it was inevitable that the CPM would reach the Flight Rules limit of 150 mV. Also, this type of signature had not been seen previously and it was unknown what could be causing the continued upward trend in the CPM. Safing of the fuel cell was performed to consume the hydrogen and oxygen in the reactant chambers.

Before fuel cell 2 was shut down, main bus B was tied to bus A at 096:19:04:51 G.m.t. (01:23:44:19 MET). This change caused the current on fuel cell 2 to increase from 168 to 224 amperes, and the CPM to increase from 134 to 152 mV. Bus C was untied at 096:19:04:58 G.m.t. (01:23:44:26 MET), and this allowed the fuel cell 2 current to decrease to 172 amperes. The CPM reading then fell back to 134 mV, and the fuel cell 3 current increased from 220 amperes to 304 amperes. Fuel cell 2 was disconnected from bus B at 096:19:06:55 G.m.t. (01:23:06:23 MET) with the current at 176 amperes and the CPM reading at 136 mV. The fuel cell 1 substack 1 CPM level was at 20 mV and substack 2 was at 64 mV. Each of these readings had steadily decayed about 10 mV from launch to main bus disconnect. Fuel cell 1, after picking up the main bus B load, changed from 136 amperes at 30.7 V to 286 amperes at 29.3 V. Fuel cell 3 changed from 304 amperes at 29.6 V to 336 amperes at 29.4 V.

To safe the fuel cell, the reactant shutoff valves were commanded closed at 096:19:07:24 G.m.t. (01:23:46:52 MET). The oxygen valve responded with a closed talkback, but the hydrogen valve did not (Flight Problem STS-83-V-08). The oxygen supply was shut off at the valve, and the regulator closed and vented down the hydrogen side. There were two sustaining heater cycles which consumed the oxygen and hydrogen in the reactant chambers. The coolant pressure ramped down to 8 psia at 096:19:26:14 G.m.t. (02:00:05:42 MET). The

stop command was sent at 096:19:30:17 G.m.t. (02:00:09:45 MET). The fuel cell 2 hydrogen shutoff valve subsequently closed nominally when the crew cycled the cockpit switch to close at 097:01:23 G.m.t. (02:06:02 MET). The Orbiter operated under the constraints of the Group B and Group 2 priority power-down protocols until entry.

A nominal 2-minute duration purge of fuel cells 1 and 3 was successfully performed at 097:10:26 G.m.t. (02:15:06 MET). This was a 43-hour purge interval for fuel cell 1 and a 32-hour purge interval for fuel cell 3. It was expected that a shorter purge interval would be required, since the rate of fuel cell degradation is faster under the higher per-fuel-cell power levels required since the safing of fuel cell 2. The performance degradation in fuel cell 1 was 0.21 V over 43 hours. After the purge, fuel cell 1 recovered all but 0.07 V of its 0.21 V performance drop. The performance degradation in fuel cell 3 was 0.22 V over 32 hours. After the purge, fuel cell 3 recovered all but 0.08 V of its 0.23 V performance drop.

The fuel cell 3 alternate water-line temperature increased to over 125 °F, indicating a slight leakage of warm water through the check valve. This condition has been seen on other flights and did not impact system operations.

Auxiliary Power Unit Subsystem

The auxiliary power unit (APU) subsystem performance was nominal throughout the mission. No in-flight anomalies or significant problems were noted. The APU run-times and fuel consumption are summarized in the following table.

APU RUN TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (S/N 401)		APU 2 (S/N 303)		APU 3 (S/N 403)	
	(a) (b) Time, min:sec	Fuel consumption, lb	(a) Time, min:sec	Fuel consumption, lb	(a) Time, min:sec	Fuel consumption, lb
Ascent	20:20	48	20:41	54	20:57	53
FCS checkout	06:44	17				
Entry ^a	62:07	115	84:37	184	62:33	127
Total	89:11	180	105:18	238	83:30	180

^a APUs were shut down 17 minutes 36 seconds after landing.

^b APU 1 was used for the FCS checkout.

The FCS checkout was performed at 097:15:27 G.m.t. (02:20:07 MET) using APU 1. APU 1 was started at 097:15:33 G.m.t. (2:20:13 MET) and ran for 6 minutes 44 seconds. The APU subsystem performed nominally during the checkout.

The APU 1 and 2 injector water line system A and B heater exhibited a narrow operating band. These heaters have had a history of a narrow operating band over the last six missions. The thermostats are located in a relatively benign environment (low vibration). These thermostats and heaters should continue to operate in this same manner on future missions.

Hydraulics/Water Spray Boiler Subsystems

The overall hydraulics/water spray boiler subsystems operation was nominal. No in-flight anomalies or significant problems were noted during the mission.

During prelaunch activities, the water spray boiler (WSB) 2 vent temperature, although acceptable for flight, was lower than expected (dropping to the 130 °F range). It was noted that the temperature signature was almost identical to that seen during the previous flight (STS-80) of this vehicle. The vent heaters performed nominally throughout the mission.

WSB system 3 experienced a slight over-cooling condition during entry. The lubrication oil temperature dropped from 255 °F to 237 °F, and the file IX requirement is no greater than a 15°F difference. This same condition occurred on STS-80, and both occurrences are being evaluated. However, this performance does not impact mission operations.

The hydraulics subsystem performed nominally during the FCS checkout. No water spray boiler operation occurred because of the short APU run time.

The hydraulic system 1 reservoir quantity dropped 18 percent at landing gear deployment. The amount of drop in quantity is not a violation of any requirement, although the expected drop is no more than 15 percent. This same condition occurred on the last flight of this vehicle when the quantity also dropped 17.8 percent. Postflight leak checks did not reveal any leakage.

Electrical Power Distribution and Control Subsystem

The electrical power distribution and control (EPDC) subsystem performed satisfactorily throughout the mission, meeting all electrical requirements for this shortened mission. The average electrical power level and load were 17.9 kW and 599 amperes. A discussion of the fuel cell problem is contained in the Fuel Cell Powerplant Subsystem section of this report.

Pressure Control Subsystem

The pressure control subsystem (PCS) performed normally throughout the duration of the mission, and no in-flight anomalies were identified in the data or

analysis. The Orbiter pressure control subsystem 2 was activated the last day of the mission and exhibited normal operation.

Atmospheric Revitalization Subsystem

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

The regenerative carbon dioxide removal system (RCRS) was activated at 094:20:36 G.m.t. (00:01:16 MET) and operated satisfactorily. The RCRS, which when cycling has an average power consumption of 110 watts, was deactivated at 096:18:50 G.m.t. (01:23:30 MET) to conserve power due to the shut down of fuel cell 2. Lithium hydroxide (LiOH) canisters were used for carbon dioxide control for the remainder of the mission.

Active Thermal Control Subsystem

The active thermal control subsystem performed nominally throughout the mission. One in-flight anomaly was identified and it is discussed in the following paragraph.

During ascent, the flash evaporator system (FES) high-load duct temperatures dropped off sharply. The inboard-duct temperature dropped to approximately 62 °F (normally remains above 190 °F) (Flight Problem STS-83-V-02). The heaters were reconfigured from system-A-only to systems A and B at approximately 12 minutes MET, and the temperatures eventually recovered. Throughout the occurrence, the evaporator outlet temperatures were stable. No further problems with the FES were noted during ascent. No hardware changes were made postflight. The plan is to enable the A and B heaters just prior to liftoff on STS-94.

Supply and Waste Water Subsystem

The supply and waste water subsystem performed satisfactorily throughout the mission. No in-flight anomalies or significant problems were identified from the data.

Supply water was managed through the use of the FES. No supply water dumps were made because of the shortened mission. The supply water dump line temperature was maintained between 77 °F and 103 °F throughout the mission with the operation of the line heater.

Waste water was gathered at approximately the predicted rate. One waste water dump was performed with an average dump rate of 1.93 percent/minute

(3.18 lb/min). The waste water dump line temperature was maintained between 55 °F and 80 °F throughout the mission. The vacuum vent line temperature was maintained between 59 °F and 75 °F with the vacuum vent nozzle between 106 °F and 157 °F.

At 094:20:48 G.m.t. (00:01:28 MET), a preflight-planned command was uplinked to change the water coolant loop (WCL) 1 pump cycle time to 2 hours from the nominal time of 4 hours. The increased cycle frequency was instituted to prevent the floodlight coldplate water lines on the 576 bulkhead from getting too cold. The first WCL 1 cycle occurred at 094:22:54 G.m.t. (00:03:34 MET).

Waste Collection Subsystem

The waste collection subsystem performed satisfactorily throughout the mission. No in-flight anomalies or significant problems were identified by the crew.

Airlock Support System

Use of the airlock support system was not required because no extravehicular activity (EVA) was planned, and none was required for a contingency situation. The active system monitor parameters indicated normal outputs throughout the duration of the flight.

Smoke Detection and Fire Suppression Subsystem

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

Flight Data Systems

The flight data systems performed satisfactorily with no in-flight anomalies or significant problems identified.

Flight Software

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

Flight Control Subsystem

FCS performance was nominal. The on-orbit and entry inertial guidance navigation and control (IGN&C) performance was nominal. Aileron trim data indicated the presence of an asymmetric boundary layer transition in the Mach 13.5 region. IGN&C performance during terminal area energy management (TAEM), and approach and landing were nominal.

Data from the external sources were incorporated into the onboard navigation states at their expected region of operations. Drag measurement processing started at approximately 229,700 ft and ended at 4,600 ft. Tactical air navigation (TACAN) station acquisition occurred at 149,500 ft. Air data transducer assembly (ADTA) data incorporation started at approximately 79,400 ft and continued to 16,300 ft. All external sensor data measurement residuals were nominal.

Following a reactivation of the -Z star tracker at approximately 097:18:04 G.m.t. (02:22:44 MET), a pressure built-in-test-equipment (BITE) was annunciated for approximately 11 minutes (Flight Problem STS-83-V-04). The star tracker is normally pressurized to 17.58 psia to prevent moisture and contamination from entering the star tracker during entry and ground operations. After the BITE cleared, the star tracker functioned nominally. There was no impact to flight operations from the BITE indication.

Approximately 12 minutes after star tracker reactivation, at 097:18:16 G.m.t. (02:22:56 MET), the -Y star tracker was bypassed by the primary avionics software system (PASS) (Flight Problem STS-83-V-05). The crew performed the malfunction procedure, but the -Y star tracker was not recovered.

Prior to both of these star tracker occurrences, both star trackers had been powered off due to the loss of fuel cell 2.

The inertial measurement unit (IMU) performance was nominal throughout the flight. One uplink of accelerometer compensation values was made during the flight. Gyro drift performance showed no signs of degradation from previous signatures.

Displays and Controls Subsystem

The displays and controls subsystem performed nominally with only one problem identified. The problem is discussed in the following paragraph.

Contact A of the Pilot's speedbrake/throttle switch on panel F2 failed the switch redundancy management (RM) upon transition to the OPS 3 mode of operation for entry at approximately 098:17:48 G.m.t. (03:22:27:28 MET). This condition appears to be left-over from the FCS checkout switch check. The RM failure status is inactive and invisible during OPS 8 (FCS checkout) and becomes active in OPS 3. This condition did not impact the flight since two of the three contacts did make which is sufficient for the proper functioning of the switch. Ground troubleshooting found no anomalies, and the cause was determined to most likely occur because of switch tease. Postflight discussions with the crew revealed that nothing was seen during FCS checkout.

Communications and Tracking Subsystems

The communications and tracking subsystems performed nominally throughout the mission.

The Ku-Band system failed self-test twice during activation. A data review determined that the failure was caused by a "hot receiver", a known self-test failure condition. The signature was consistent with the documented performance of the S/N 109 deployed assembly and is not considered a degradation of the operational capabilities of the system. The condition did not impact Ku-Band usage as it operated satisfactorily throughout the mission.

The navigational aids (NAVAIDS) sensors self-test was performed as part of FCS checkout at 097:15:46 G.m.t. (02:20:26 MET). All NAV AIDS self-test results were satisfactory. As a result of the power conservation protocol due to the failure of fuel cell 2, the NAV AIDS were not repowered until the 15,000-ft/sec point during the entry.

Low-level cross-talk was heard between air-to-ground (A/G) -1 and A/G-2 when network signal processor (NSP) -2 was selected. The condition has been experienced on previous Spacelab flights and it did not interfere with communications. Testing for this phenomenon has determined that the system was operating within specification.

The discussion of the failure of the Commander's audio interface unit (AIU) (Flight Problem STS-83-F-01) is presented in the Government Furnished Equipment/Flight Crew Equipment section of this report.

Operational Instrumentation/Modular Auxiliary Data System

A payload data interleaver (PDI) wrap test failure was annunciated at 096:20:04 G.m.t. (02:00:43 MET), and the CRYOFD experiment personnel reported a loss of downlink telemetry. The pulse code modulation master unit (PCMMU) 1 to PDI interface was the suspected cause of the failure. The PCMMU 1 was deselected, and the PCMMU 2 was selected. Troubleshooting included the reselection of PCMMU 1 with telemetry format load (TFL) 179 loaded. The PDI wrap was still present when PCMMU 1 was selected. The Orbiter general purpose computer (GPC) and operational instrumentation (OI) data busses were not affected. The PDI wrap was caused by a logic hang that resulted when transient bad data were placed on the data bus at the time that the experiment computer operating system (ECOS) crashed. The logic hang caused the PDI to no longer respond to the wrap pattern turnaround as required to confirm I/O. Following the PDI power cycle, the input/output (I/O) between the PCMMU 1 and PDI was recovered. PCMMU 1 was fully capable of supporting entry; however, PCMMU 2 was reselected for end-of-mission (EOM) operations with PCMMU 1 available, if needed.

The MADS recorder was not operated during entry due to power concerns resulting from the fuel cell 2 failure.

Structures and Mechanical Subsystems

The structures and mechanical subsystems performed nominally. One in-flight anomaly was identified and it is discussed in the following paragraph.

During the prelaunch cabin-leak checks, a problem was noted with the nose seal at the end of the test port fitting used to pressurize the cabin (Flight Problem STS-83-V-06). The seal came off when the pressurization probe was removed. The seal was replaced and the cabin-leak check was completed nominally. Because seal replacement caused an additional cabin leak check, there was excessive oxygen in the midbody. The high reading and the ensuing discussion to clear the vehicle for flight caused a 20-minute 32-second launch delay.

The star tracker doors were opened, and Ku-Band deployed assembly was deployed simultaneously at 094:21:22 G.m.t. (00:02:01 MET). The Ku-Band deployed in nominal dual motor time, while the star tracker doors were opened with a single motor using system 1. Switch scans show that only the system 1 switch was used for opening the star-tracker doors. The star tracker door closures and Ku-band antenna stowage were completed nominally.

The tires and brakes were in good condition for a landing on the KSC concrete runway. Some ply under-cutting was noted on two of the main landing gear tires. The landing and braking parameters are shown in the table on the following page.

The ET/Orbiter separation devices EO-1, EO-2, and EO-3 functioned normally. No ordnance fragments were found on the runway beneath the umbilical cavities. Virtually no umbilical closeout foam or white room temperature vulcanizing (RTV) material adhered to the umbilical plate near the LH₂ recirculation line disconnect. The EO-2 and EO-3 retainer springs were bent, a condition that has been observed on previous missions.

Bent metal, approximately 1 inch in length by ¼ inch wide, was visible on the trailing edge of a spacer between two bolt heads on the inside surface of the LO₂ ET/Orbiter door near the forward outboard corner. This same condition has been noted after the last three flights on different Orbiter vehicles.

LANDING AND BRAKING PARAMETERS

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	3174	197.2	1.0	N/A
Nose gear touchdown	6679	151.5	N/A	-4.7
Brake initiation speed		83.6 knots		
Brake-on time		29.6 seconds		
Rollout distance		8,622.9 feet		
Rollout time		58.6 seconds		
Runway		33 (Concrete) KSC		
Orbiter weight at landing		235,285 lb		
Brake sensor location	Peak pressure, psia	Brake assembly	Gross energy, million ft-lb	
Left-hand inboard 1	840	Left-hand inboard	9.94	
Left-hand inboard 3	804			
Left-hand outboard 2	744	Left-hand outboard	10.26	
Left-hand outboard 4	804			
Right-hand inboard 1	1104	Right-hand inboard	13.46	
Right-hand inboard 3	1032			
Right-hand outboard 2	1140	Right-hand outboard	14.78	
Right-hand outboard 4	1068			

Integrated Aerodynamics, Heating, and Thermal Interfaces

The prelaunch thermal interface purges were nominal. The ascent aerodynamics and plume heating was also normal.

The entry aerodynamic heating to the SSME nozzles was nominal. The lack of Modular Auxiliary Data System (MADS) data during entry significantly affected the understanding of the heating on the SSME nozzles. The heating that was caused by the forward center-of-gravity (c.g.) as well as data from the early transition were to be used to update the nozzle-heating models. The lack of these data may affect the extended forward c.g. efforts.

Thermal Control Subsystem

The thermal control subsystem performance was nominal throughout the STS-83 mission with all subsystem temperatures being maintained within acceptable limits.

During the prelaunch period, the WSB 2 vent temperature, although acceptable for flight, fell below normal into the 130 °F range with the heater operating on a 100-percent duty cycle. The heater remained operational; consequently, there was no interruption of the prelaunch activities. The WSB 2 vent heater performed nominally throughout the mission.

During ascent, the FES high-load inboard-duct (zone A) temperature dropped to approximately 62 °F while operating on the system A heater. This duct normally remains above 190 °F. This anomaly is discussed in greater detail in the Active Thermal Control Subsystem section of this report.

Aerothermodynamics

Boundary layer transition is suspected to have occurred earlier than usual, occurring at Mach 15 instead of approximately Mach 8. This condition may have been caused by protruding gap filler just inboard of the right main landing gear door. Because of the lack of MADS data during entry, this suspicion of early transition cannot be verified.

Acreage heating was above normal as a result of the early transition. Local heating was nominal.

Thermal Protection Subsystem and Windows

The thermal protection system (TPS) and windows performed nominally with no in-flight anomalies identified. Entry heating was significantly higher than expected based on lower-surface structural temperature response data. There were no MADS data to establish the actual time of transition from laminar to turbulent flow. The aft area bondline temperature data indicated moderately higher-than-usual temperature rise, which could have been caused by early transition. There was one gap filler approximately half way between the centerline and the left-hand side that protruded diagonally after landing. Exposed shiny red RTV material was noted and this indicates that the gap filler was not protruding during entry. The gap filler was most probably dislodged at nose gear slap-down. Another gap filler was protruding just inboard of the right main landing gear door and it may have caused early transition in the aft area.

Prior to launch, the closeout crew reported difficulty when installing a TPS carrier panel on the crew ingress/egress hatch. The carrier panel covers the cabin pressure port, the hatch seal leak check port, and the emergency latch actuator access. The panel is attached with six screws, and the closeout crew reported that installing the last screw was difficult. It is believed that some or all of the five screws previously installed were torqued prior to installation of the sixth screw. After loosening the other screws, the sixth screw was installed and all six screws were torqued to required values.

The TPS sustained a total of 81 hits (damage sites) from debris impact, and 13 of these 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 flame arrestment sparkler system as well as exhaust plume recirculation and SSME vibration acoustics. A comparison of these numbers to statistics from 67 previous missions of similar configuration indicates that both the total number of damage sites and the number of hits 1-inch or larger were less than average. The following table shows the distribution of these damage sites by area of the Orbiter.

TPS DAMAGE SITES

Orbiter Surfaces	Hits > 1 Inch	Total Hits
Lower Surface	7	38
Upper Surface	6	36
Right Side	0	0
Left Side	0	0
Right OMS Pod	0	2
Left OMS Pod	0	5
Total	13	81

As shown in the table, the lower surface had a total of 38 hits of which 7 had a major dimension greater than 1 inch or larger. The largest lower surface damage site was located on the body flap and measured 2 inches long by 1 inch wide by 0.125 inch maximum depth. The damage was caused probably by an impact from ET/Orbiter umbilical ice.

Tile damage sites aft of the LO₂ and LH₂ ET/Orbiter umbilicals were typical in size and quantity. The damage was most likely caused by impacts from umbilical ice or shredded pieces of umbilical purge-barrier material that was flapping in the airstream. Both of these conditions were observed in the launch films.

The SSME dome-mounted heat shield (DMHS) closeout blankets were in excellent condition. The numerous damage sites on the base heat shield that are attributed to the flame arrestment sparkler system as well as exhaust plume recirculation and SSME vibration acoustics were typical. A corner was missing from a tile in the area between SSME 2, SSME 3, and the body-flap hinge. Tiles on the vertical stabilizer "stinger" and around the drag chute cavity were undamaged. No significant tile damage occurred on the leading edges of the OMS pods or vertical stabilizer.

None of the documented TPS damage sites resulted from micrometeorites or on-orbit debris.

Hazing and streaking of forward-facing windows was typical. Damage sites on the window perimeter tiles appeared to be greater than usual in quantity and size. Two damage sites that were greater than 1 inch in size were noted in a cluster of 11 damage sites that were present in the black tile area between windows 3 and 4. These damage sites are believed to have resulted from excessive RTV material used to attach paper covers over the forward RCS thrusters.

GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

The government furnished equipment/flight crew equipment (GFE/FCE) performed nominally. One in-flight anomaly was identified and it is discussed in the following paragraph.

The Commander reported at 095:11:20 G.m.t. (01:16:00 MET) that his audio interface unit (AIU), which is located on panel O5, stopped functioning (Flight Problem STS-83-F-01). Multiple headsets and frequencies were checked but none would provide communications. The leg units continued to work on other AIUs.

The Spacelab video cassette recorder (VCR) 2 did not change to the standby mode after a tape was rewound to the beginning of tape (BOT). A standby command was manually sent and the mode changed properly. However, the same problem occurred with a second tape. These problems did not affect the video quality. Troubleshooting of the problem will be performed postflight.

CARGO INTEGRATION

The cargo integration hardware performance was nominal throughout the mission with no in-flight anomalies or significant problems identified.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DEVELOPMENT TEST OBJECTIVES

DTO 255 - Wrap-Around Digital Autopilot Flight Test Verification - This DTO was performed with all programmed test inputs (PTIs) completed. 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 (Method 4) - Fifteen photographs of the External Tank (ET) were acquired after ET separation using a 35 mm camera with a 400 mm lens and a 2X extender. The +Z axis of the ET was imaged. The first picture was taken approximately 18 minutes after liftoff, and the final picture was taken 2 minutes 21 seconds later. Backlighting from the Sun degraded the views. No anomalies were noted on the ET. The normal scars were visible. The ET was approximately 3.1 kilometers from the Orbiter when frame 5 was taken. There was no camcorder video taken of the ET.

Two rolls of umbilical well camera film of the ET were reviewed: the 16 mm films (5 mm lens and 10 mm lens) from the LH₂ umbilical. The coverage of the left SRB was good; however, backlighting from the Sun did degrade the ET views. No anomalous conditions were observed during the review of the 16 mm film. The 35 mm camera in the LO₂ umbilical did not operate, and the cause is being determined.

DTO 416 - Water Spray Boiler Quick Restart Capability - Development Test Objective (DTO) 416 was performed to verify the ability of the water spray boilers (WSBs) to support second-orbit abort and Abort-Once-Around (AOA) conditions. This was the sixth of seven flights planned for this DTO. The APU lubrication oil return temperature was approximately 245 °F for each of the three systems at the initiation of the DTO. The system 1 vent heater was activated approximately 19 minutes 35 seconds after APU shutdown, and the time required for the vent temperature to increase above 122 °F was 1 hour 22 minutes. System 2 was activated approximately 19 minutes 5 seconds after APU shutdown, and the time required for the vent temperature to increase to 122 °F was 50 minutes. The system 3 vent heater was activated 13 minutes 59 seconds after APU shutdown, and the time required for the vent temperature to increase to 122 °F was 39 minutes. The vent heaters were left on for approximately 7¼ hours for post-ascent bake-out.

DTO 623 - Cabin Air Monitoring - The planned activities in support of this DTO were completed and the data have been given to the sponsor. After evaluation, the results will be published in separate documentation.

DTO 663 - Acoustic Noise Dosimeter Data - Data for this DTO were recorded and have been given to the sponsor for evaluation. The results of the evaluation will be published in a separate document.

DTO 665 - Acoustic Noise Sound Level Data - Data for this DTO were recorded and have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DTO 667 - Portable In-Flight Landing Operations Trainer - Training was provided to the Commander and Pilot on the Portable In-Flight Landing Operations Trainer (PILOT).

DTO 677 - Evaluation of Microbial Capture Device in Microgravity - Data were obtained for this DTO on the use of the capture device. These data have been given to the sponsor for evaluation, and the results of that evaluation will be reported in separate documentation.

DTO 684 - Radiation Measurement in Shuttle Crew Compartment - Data for this DTO were collected until the equipment was stowed at approximately 094:19:05 G.m.t. (02:23:45 MET). The data were given to the sponsor for evaluation, and the results of that evaluation will be published in separate documentation.

DTO 805 - Crosswind Landing Performance - Initial indications during the entry phase were that this DTO would be accomplished. However, the wind direction changed just prior to landing and the crosswind decreased to 7 knots, which was not adequate to meet the requirements of this DTO.

DETAILED SUPPLEMENTARY OBJECTIVE

DSO 331 - The Interaction of the Space Shuttle Launch and Entry Suit and Sustained Weightlessness on Egress Locomotion - Data were obtained from the crewmembers, and these data have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DSO 487 - Immunological Assessment of Crew Members - Data were obtained from the assessment of the crewmembers, and these data have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DSO 493 - Monitoring of Latent Virus Reactivation and Shedding in Astronauts - The planned activities in support of this Detailed Supplementary Objective (DSO) were completed and the data were given to the sponsor for

evaluation. The results of the evaluation will be reported in separate documentation.

PHOTOGRAPHY AND TELEVISION ANALYSES

LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS

On launch day, 24 of the expected 24 launch videos were received and screened. No anomalous conditions were noted; however, the SSME Mach diamonds appeared to form out of sequence with SSME 3 occurring prior to SSMEs 1 and 2.

Following the launch day screening, a total of twelve 16 mm films and nine 35 mm films were also reviewed. No anomalous events or conditions were noted that would affect entry or landing. A bolt hang-up was noted on the left SRB hold-down post M-7 at liftoff.

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

Eleven videos of the landing were received and screened. No anomalous events were found in any of the films.

TABLE I.- STS-83 SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
APU Activation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	094:19:15:45.237 094:19:15:49.893 094:19:15:51.126
SRB HPU Activation ^a	LH HPU System A start command LH HPU System B start command RH HPU System A start command RH HPU System B start command	094:19:20:04.089 094:19:20:04.249 094:19:20:04.409 094:19:20:04.569
Main Propulsion System Start ^a	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	094:19:20:25.458 094:19:20:25.577 094:19:20:25.706
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	094:19:20:32.019
Throttle up to 104 Percent Thrust ^a	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	094:19:20:35.850 094:19:20:35.867 094:19:20:35.873
Throttle down to 67 Percent Thrust ^a	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	094:19:20:57.610 094:19:20:57.627 094:19:20:57.634
Maximum Dynamic Pressure (g)	Derived ascent dynamic pressure	094:19:21:23
Throttle up to 104 Percent ^a	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	094:19:21:28.650 094:19:21:28.668 094:19:21:28.674
Both RSRM's Chamber Pressure at < 50 psi ^a	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	094:19:22:29.939 094:19:22:29.979
End RSRM ^a Action ^a Time	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	094:19:22:32.479 094:19:22:32.479
SRB Separation Command	SRB separation command flag	094:19:22:35.
SRB Physical Separation ^a	LH rate APU A turbine speed - LOS RH rate APU B turbine speed - LOS	094:19:22:35.099 094:19:22:35.099
Throttle Down for 3g Acceleration ^a	ME-3 command accepted ME-1 command accepted ME-2 command accepted	094:19:28:05.615 094:19:28:05.634 094:19:28:05.638
3g Acceleration	Total load factor	094:19:28:07.5
Throttle Down to 67 Percent Thrust ^a	ME-3 command accepted ME-1 command accepted ME-2 command accepted	094:19:28:56.175 094:19:28:56.195 094:19:28:56.198
SSME Shutdown ^a	ME-3 command accepted ME-1 command accepted ME-2 command accepted	094:19:29:02.455 094:19:29:02.475 094:19:29:02.478
MECO	MECO command flag MECO confirm flag	094:19:29:03 094:19:29:04
ET Separation	ET separation command flag	094:19:29:23
APU Deactivation	APU-1 GG chamber pressure APU 2 GG chamber pressure APU 3 GG chamber pressure	094:19:36:05.739 094:19:36:30.633 094:19:36:47.925

**TABLE I.- STS-83 SEQUENCE OF EVENTS
(Concluded)**

Event	Description	Actual time, G.m.t.
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	094:20:00:27.0 094:20:00:27.0
OMS-2 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	094:20:02:50.2 094:20:02:50.2
Payload Bay Doors (PLBDs) Open	PLBD right open 1 PLBD left open 1	094:21:07:26 094:21:08:48
Flight Control System Checkout APU Start APU Stop	APU 3 GG chamber pressure APU 3 GG chamber pressure	097:15:33:13.513 097:15:39:57.950
Payload Bay Doors Close	PLBD left close 1 PLBD right close 1	098:14:53:36 098:14:55:33
APU Activation for Entry	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	098:17:26:10.363 098:17:48:23.770 098:17:48:27.077
Deorbit Burn Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	098:17:31:18.1 098:17:31:18.2
Deorbit Burn Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	098:17:34:40.5 098:17:34:40.6
Entry Interface (400K feet)	Current orbital altitude above	098:18:01:18
Blackout end	Data locked (high sample rate)	No blackout
Terminal Area Energy Management	Major mode change (305)	098:18:26:48
Main Landing Gear Contact	LH main landing gear tire pressure 1 RH main landing gear tire pressure 2	098:18:33:11 098:18:33:11
Main Landing Gear Weight on Wheels	LH MLG weight on wheels RH MLG weight on wheels	098:18:33:11 098:18:33:11
Drag Chute Deployment	Drag chute deploy 1 CP volts	098:18:33:15.4
Nose Landing Gear Contact	RGA 1 pitch rate	098:18:33:23
Nose Landing Gear Weight On Wheels	NLG weight on wheels 1	098:18:33:23
Drag Chute Jettison	Drag chute jettison 1 CP Volts	098:18:33:48.0
Wheel Stop	Velocity with respect to runway	098:18:34:11
APU Deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	098:18:50:30.951 098:18:50:47.345 098:18:50:59.607

TABLE II.- STS-82 ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-83-V-01	Fuel Cell 2 Substack 3 Delta V High	094:07:35 G.m.t. Prelaunch CAR 83RF01 IPR 87V-0001 PR FCP-0336	<p>When the fuel cell start-up was initiated during prelaunch operations, the fuel cell 2 substack 3 differential voltage (ΔV) remained above the OMRSD limit of 150 mV for an unusually long period of time. After the pre-start reactant purge, the ΔV value dropped from 500 mV to 160 mV. At the beginning of the fuel cell 2 start-up, the value increased to over 400 mV and then began a gradual decrease. Prior to the fuel cell high-load calibration test, a purge was performed on fuel cell 2 in an attempt to sweep away any inert material that may have been the cause of the high ΔV reading. This purge had no effect on the rate of decrease. The high-load test (250 amperes) was performed and this caused the value to rapidly decrease to 100 mV, but when the load was returned to 150 amperes, the ΔV increased to above 100 mV. The ΔV reading continued to decrease and was below 50 mV prior to flight. A waiver (WK03629) was processed to accept this condition for flight.</p> <p>The fuel cell 2 substack 3 ΔV began to increase on-orbit. Analysis of the data determined that the health of the fuel cell was suspect. The fuel cell 2 substack 3 ΔV data indicated that a cell in the substack had a performance degradation approaching 300 mV, which could lead to the failure of the fuel cell. The decision was made to shutdown and safe the fuel cell and terminate the mission early. Fuel cell 2 shutdown and safing was initiated at approximately 096:19:07 G.m.t. (01:23:46 MET).</p> <p>KSC: The fuel cell was removed and replaced postflight.</p>
STS-83-V-02	High-Load FES Inboard Duct Temperature Low During Ascent	094:19:32 G.m.t. 00:00:12 MET CAR 83RF02 IPR 87V-0012	<p>During ascent, the FES high-load duct temperatures dropped off sharply. The inboard duct temperature dropped to approximately 62 °F (normally remains above 190 °F) by 094:19:32 G.m.t. (approximately 12 minutes MET). The heaters were reconfigured from system-A to system-B at approximately 12 minutes MET, and the temperatures eventually recovered. Throughout the occurrence, the evaporator outlet temperatures were stable. No further FES problems were noted during the flight.</p> <p>KSC: Troubleshooting will investigate to determine if the heater has become debonded.</p>
STS-83-V-03	Primary RCS Thruster F3F Failed Off	097:16:38 G.m.t. 02:21:17 MET CAR 83RF05 PR FRC2-0524	<p>During the RCS hot-fire test, primary RCS thruster F3F failed off on its first attempted firing. The thruster had a good driver out but the chamber pressure (P_c) reached only 11 psia. There was no indication of leakage. The P_c tube blockage is considered to be an unlikely cause of the fail-off condition but can be ruled out by postflight inspection. The most likely cause of the failure is improper operation of the thruster fuel or oxidizer valve. The</p>

TABLE II.- STS-82 ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-83-V-03 (Continued)	Primary RCS Thruster F3F Failed Off (Continued)	097:16:38 G.m.t. 02:21:17 MET	thruster was deselected for the remainder of the mission. KSC: The forward RCS pod will be removed and the thruster, along with the other three thrusters on that manifold, will be removed and replaced.
STS-83-V-04	-Z Star Tracker Pressure BITE	097:18:04 G.m.t. 02:22:44 MET CAR 83RF06 PR GNC-0133	Following the reactivation of the -Z star tracker at approximately 097:18:04 G.m.t. (02:22:44 MET), a pressure BITE was annunciated for approximately 11 minutes. After the BITE cleared, the star tracker functioned nominally, successfully acquiring stars. The star tracker is normally pressurized with argon gas to 17.58 psia to prevent moisture and contamination from entering the star tracker during entry and ground operations. There was no impact to flight operations.
STS-83-V-05	-Y Star Tracker BCE Bypass	097:18:16 G.m.t. 02:22:56 MET CAR 84RF07 IPR 87V-0006	At 097:18:16 G.m.t. (02:22:56 MET), the -Y star tracker (S/N 11) was bypassed by the PASS. The crew performed the malfunction procedures, which included an I/O reset, port mode and power cycle of MDM FF3, as well as a power switch and circuit breaker cycle of the -Y star tracker. The -Y star tracker was not recovered. Note that prior to this occurrence, both star trackers had been powered off due to the loss of fuel cell 2. The star trackers had been powered on for approximately 12 minutes when the bypass occurred. KSC: Troubleshooting revealed a failed power supply in the star tracker. The star tracker was removed and replaced with S/N 5.
STS-83-V-06	Side Hatch Test Port Seal Leak/Damage Prelaunch	094:18:15 G.m.t. Prelaunch CAR 83RF04 IPR 83V-0144	During the prelaunch cabin-leak check, the closeout crew reported a problem with the KkC103-16 nose seal at the end of the test-port fitting used to pressurize the cabin. The seal came off when the pressurization probe was removed. The seal was replaced and the cabin leak check was completed nominally. Because seal replacement caused an additional cabin leak check, there was excessive oxygen in the midbody. This high reading and the ensuing discussion to clear for flight caused a 20 minute 32 second launch delay.
STS-83-V-07	HUD Camera Out of Focus During Entry	098:18:28 G.m.t. 02:23:08 MET	The mini-camera used to show landing video through the HUD was out-of-focus during landing operations. This camera, one of two mini-cameras flown, is used for other video purposes during the flight and must be refocused to infinity prior to entry. The camera will be inspected at the Flight Equipment Packing Facility.
STS-83-V-08	Fuel Cell 2 Hydrogen Reactant Valve Failed to Close	096:19:07 G.m.t. 01:23:46 MET CAR 83RF09	At 096:19:07 G.m.t. (01:23:46 MET), when the fuel cell 2 reactant valves were closed to shut down and safe fuel cell 2, the fuel cell 2 hydrogen reactant valve failed to close. The fuel cell 2 oxygen reactant valve closed and the shut down and safing were completed. Approximately 6 1/2 hours later, the crew cycled the

TABLE II.- STS-82 ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-83-V-08 (Continued)	Fuel Cell 2 Hydrogen Reactant Valve Failed to Close (Continued)	096:19:07 G.m.t. 01:23:46 MET (Continued)	fuel cell 2 hydrogen reactant valve and the valve closed nominally. KSC: No action required.

TABLE III.- GOVERNMENT FURNISHED EQUIPMENT PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-83-F-01	Commander's AIU A Failed	095:11:20 G.m.t. 01:16:00 MET	The Commander reported that his audio interface unit (AIA) A, located on panel 05, had stopped functioning. Multiple headsets and frequencies were tried, but none provided communications. The leg units worked on other AIUs.

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-82 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.

ADTA	air data transducer assembly
AIU	audio interface unit
ALPHA	American Loop Heat Pipe with Ammonia
AOA	abort once around
APU	auxiliary power unit
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
BDND	Bubble and Drop Nonlinear Dynamics
BITE	built-in test equipment
BOT	beginning of tape
CB	circuit breaker
CEI	contract end item
CHT	Capillary-driven Heat Transfer Device
CM	Combustion Module
CO ₂	carbon dioxide
CPM	cell performance monitor
CRYOFD	Cryogenic Flexible Diode Experiment
CSLM	Coarsening in Solid-Liquid Mixtures
DCE	Droplet Combustion Experiment
DMHS	dome-mounted heat shield
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
ΔV	differential velocity/differential voltage
EC	experiment computer
ECLSS	environmental control and life support system
ECO	engine cutoff
ECOS	experiment computer operating system
EDO	Extended Duration Orbiter
EI	entry interface
EMI	electromagnetic interference
EOM	end-of-mission
EPDC	electrical power distribution and control subsystem
EPDM	ethylene propylene diene monomer
e.s.t.	eastern standard time
ET	External Tank
ETA	External Tank Attachment
EVA	extravehicular activity
EXPRESS	Expedite the Processing of Experiments to the Space Station.
FCE	flight crew equipment
FCS	flight control system
FCV	flow control valve
FES	flash evaporator system
FO ₂	Bayuzick Zirconium
ft/sec	feet per second

g	gravity
GFE	Government furnished equipment
GH ₂	gaseous hydrogen
G.m.t.	Greenwich mean time
GN ₂	gaseous nitrogen
GO ₂	gaseous oxygen
GPC	general purpose computer
H ₂	hydrogen
HIPAC DTV	high-packed digital television
HPFTP	high pressure fuel turbopump
HPOTP	high pressure oxidizer turbopump
HRM	high-rate multiplexer
ICD	Interface Control Document
IFFD	Internal Flows in a Free Drop Experiment
IFM	in-flight maintenance
IMU	inertial measurement unit
I/O	input/output
I _{sp}	specific impulse
keas	knots estimated air speed
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt hour
lb	pound
lbm	pound-mass
LCC	Launch Commit Criteria
LH ₂	liquid hydrogen
LIF	Large Isothermal Furnace
LiOH	lithium hydroxide
LMSMS&S	Lockheed Martin Space Mission Systems and Services
LO ₂	liquid oxygen
LSP	laminar soot process
MADS	modular auxiliary data system
MDF	minimum duration flight
MECO	main engine cutoff
MET	mission elapsed time
MFD	methane flexible diode
MGBX	Middeck Glovebox
MMA	Microgravity Measurement Assembly
MMT	Mission Management Team
MPS	main propulsion system
MSL-1	Microgravity Science Laboratory -1
MSX	Midcourse Space Experiment
mV	millivolts
MVEA	MPEG1 video encoder assembly
NAVAIDS	navigation aids
nmi.	nautical miles
NPSP	net positive suction pressure
NSP	network signal processor
NSTS	National Space Transportation System (i.e., Space Shuttle Program)
OARE	Orbital Acceleration Research Experiment

OCA	Orbiter Communications Adapter
OFD	oxygen flexible diode
OI	Operational Instrumentation
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
PAL	protuberance air load
PASS	primary avionics software system
PCMMU	pulse code modulation master unit
PDI	payload data interleaver
PGSC	payload and ground support computer
PHaSE	Physics of Hard Spheres Experiment
PILOT	Pilot Operated Landing Operations Trainer
PMBT	propellant mean bulk temperature
POGO	longitudinal oscillation
ppm	parts per million
PPOV-CAM	Pilot Point of View Camera
PRSD	power reactant storage and distribution
PTI	programmed test input
QSAM	Quasi-Steady Acceleration Measurement
RCRS	regenerative CO ₂ removal system
RCS	reaction control subsystem
RF	radio frequency
RM	redundancy management
RSRM	Reusable Solid Rocket Motor
RTV	room temperature vulcanizing
SAMS	Shuttle Acceleration Measurement System
SAREX-II	Shuttle Amateur Radio Experiment-II
S&A	safe and arm
scch	standard cubic centimeters per hour
scim	standard cubic inches per minute
SLF	Shuttle Landing Facility
S/N	serial number
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSME	Space Shuttle main engine
TACAN	Tactical Air Navigation
TAEM	Terminal Area Energy Management
TEMPUS	Electromagnetic Containerless Processing Facility
TPS	thermal protection subsystem
V	Volts
VCR	video cassette recorder
WCL	water coolant loop
WCS	Waste Collection System
WDAS	Wireless Data Acquisition System
WSB	water spray boiler