

STS-96 SPACE SHUTTLE MISSION REPORT

July 1999



**National Aeronautics and
Space Administration**

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

NOTE

The STS-96 Space Shuttle Mission Report was prepared from inputs received from the Flight Projects Office as well as other organizations. The following personnel may be contacted should questions arise concerning the technical content of this document.

Kenneth L. Brown
713-483-3891

Orbiter and Subsystems

James Yeager, MSFC
205-544-3963

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

Anne Patterson
713-483-3367

Payloads/Experiments

Ralph V. Anderson, JSC
713-483-1271

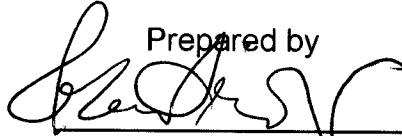
FCE and GFE

STS-96

SPACE SHUTTLE

MISSION REPORT

Prepared by



Robert W. Fricke, Jr.

LMSO/Mission Evaluation Room Support Section

Approved by



Kenneth L. Brown

STS-96 Lead Mission Evaluation Room Manager
Space Shuttle Vehicle Engineering Office



Ralph R. Roe

Manager, Space Shuttle Vehicle Engineering Office



Ronald D. Dittmore

Space Shuttle Program Manager

Prepared by

Lockheed Martin Space Operations
for the

Space Shuttle Vehicle Engineering Office

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

July 1999

STS-96 Table of Contents

<u>Title</u>	<u>Page</u>
<u>INTRODUCTION</u>	1
<u>MISSION SUMMARY</u>	2
<u>PAYLOADS AND EXPERIMENT OPERATIONS</u>	8
SPACEHAB.....	8
STUDENT TRACKED RESEARCH SATELLITE FOR HEURISTIC INTERNATIONAL NETWORKING EXPERIMENT PAYLOAD.....	8
<u>VEHICLE PERFORMANCE</u>	10
SOLID ROCKET BOOSTERS.....	10
REUSABLE SOLID ROCKET MOTORS.....	10
EXTERNAL TANK.....	11
SHUTTLE RANGE SAFETY SYSTEM.....	12
SPACE SHUTTLE MAIN ENGINES.....	13
ORBITER SUBSYSTEMS PERFORMANCE.....	13
<u>Main Propulsion System</u>	13
<u>Reaction Control Subsystem</u>	14
<u>Orbital Maneuvering Subsystem</u>	15
<u>Power Reactant Storage and Distribution Subsystem</u>	16
<u>Fuel Cell Powerplant Subsystem</u>	16
<u>Auxiliary Power Unit Subsystem</u>	17
<u>Hydraulics/Water Spray Boiler Subsystem</u>	18
<u>Electrical Power Distribution and Control Subsystem</u>	18
<u>Orbiter Docking System</u>	18
<u>Atmospheric Revitalization Pressure Control System</u>	19
<u>Atmospheric Revitalization Subsystem</u>	20
<u>Active Thermal Control Subsystem</u>	20
<u>Supply and Waste Water Subsystem</u>	21
<u>Waste Collection Subsystem</u>	22
<u>Airlock Support System</u>	22
<u>Smoke Detection and Fire Suppression Subsystem</u>	22
<u>Flight Data Subsystem</u>	22
<u>Flight Software</u>	22
<u>Flight Control System</u>	22
<u>Displays and Controls Subsystem</u>	23
<u>Communications and Tracking Subsystems</u>	23
<u>Operational Instrumentation/Modular</u>	
<u>Auxiliary Data System</u>	23
<u>Structures and Mechanical Subsystems</u>	24
<u>Integrated Vehicle Heating and Thermal</u>	
<u>Interfaces</u>	24

STS-96 Table of Contents (Concluded)

<u>Page</u>	<u>Title</u>
	<u>Thermal Control Subsystem</u> 25
	<u>Aerothermodynamics</u> 25
	<u>Thermal Protection Subsystem and Windows</u> 25
	<u>Gas Sample Bottle Analysis</u> 27
	<u>EXTRAVEHICULAR OPERATIONS</u> 28
	<u>REMOTE MANIPULATOR SYSTEM OPERATION</u> 30
	<u>GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW</u>
	<u>EQUIPMENT</u> 31
	<u>CARGO INTEGRATION</u> 32
	<u>POSTLAUNCH PAD INSPECTION</u> 33
	<u>DEVELOPMENT TEST OBJECTIVE/DETAILED SUPPLEMENTARY</u>
	<u>OBJECTIVES</u> 34
	DEVELOPMENT TEST OBJECTIVES 34
	HUMAN EXPLORATION AND DEVELOPMENT OF SPACE
	TECHNOLOGY DEMONSTRATION 35
	<u>PHOTOGRAPHY AND TELEVISION ANALYSIS</u> 36
	LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS 36
	ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS 36
	LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSIS 37

List of Tables

TABLE I - STS-86 SEQUENCE OF EVENTS	38
TABLE II - STS-86 SPACE SHUTTLE VEHICLE ENGINEERING	
OFFICE IN-FLIGHT ANOMALY LIST	41
TABLE III - EVA EQUIPMENT PROBLEM TRACKING LIST	43
A - <u>DOCUMENT SOURCES</u>	A-1
B - <u>ACRONYMS AND ABBREVIATIONS</u>	B-1

INTRODUCTION

The STS-96 Space Shuttle Program Mission Report presents a discussion of the Orbiter subsystem operation and the in-flight anomalies that were identified during the mission. The report also summarizes the mission activities 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 ninety-fourth mission of the Space Shuttle Program. STS-96 was the sixty-ninth flight since the return to flight, and the twenty-sixth flight of Orbiter 103 (Discovery) vehicle.

The flight vehicle consisted of the OV-103 Orbiter; an ET that was designated ET-100, which was the fourth super lightweight tank (SLWT); three Block IIA SSMEs that were designated as serial numbers (S/N) 2047, 2051, and 2049 in positions 1, 2, and 3, respectively; and two SRBs that were designated BI-098. The two RSRMs were designated RSRM 70 with one installed in each SRB. The individual RSRMs were designated 360L070A for the left SRB, and 360L070B for the right SRB. For this mission, the vehicle was erected on Mobile Launch Platform (MLP) 2 and the launch was completed from launch pad 39B.

The primary objective of the STS-96 mission was to provide the International Space Station (ISS) Program with logistics capability for transfer to the Orbiting ISS Stage 2A, utilizing a double Spacehab module and Integrated Cargo Carrier (ICC) and the Orbiter crew compartment. Prior to undocking, one scheduled extravehicular activity (EVA) was performed for external equipment transfer. In addition, the secondary objectives of this flight included performing the requirements for the Student Tracked Atmospheric Research Satellite for Heuristic International Networking Experiment (STARSHINE) and Shuttle Vibration Forces (SVF).

The STS-96 mission was a planned 10 day plus 1 day plus 2-contingency-day mission during which items listed in the previous paragraph will be performed. The two contingency days were available for bad weather avoidance for landing, or other Orbiter contingency operations. The STS-96 sequence of events is shown in Table I, and the Space Shuttle Vehicle Engineering Office (SSVEO) In-Flight Anomaly List is shown in Table II. Appendix A lists the sources of data, both informal and formal, that were used in the preparation of this report. Appendix B provides the definitions of all acronyms and abbreviations used in this report. All times from liftoff to landing are given in Greenwich mean time (G.m.t.) and mission elapsed time (MET).

The seven crewmembers of the STS-96 mission consisted of Kent V. Rominger, CDR, U. S. Navy, Commander; Rick D. Husband, Lt. Col., U. S. Air Force, Pilot; Tamara E. Jernigan, Ph.D., Civilian, Mission Specialist 1; Ellen Ochoa, Ph.D., Civilian, Mission Specialist 2; Daniel T. Barry, Ph.D. Civilian, Mission Specialist 3; Julie Payette, Civilian, Canadian Astronaut, Mission Specialist 4; and Valery Tokarev, Colonel, Russian Air Force, Mission Specialist 5. STS-96 was the fifth Space Shuttle flight for Mission Specialist 1, the fourth Space Shuttle flight for the Commander, the third Space Shuttle flight for Mission Specialist 2, the second Space Shuttle flight for Mission Specialist 3, and the first Space Shuttle flight for the Pilot, Mission Specialist 4 and Mission Specialist 5.

MISSION SUMMARY

The STS-96 Space Shuttle vehicle was launched on a 51.6-degree inclination at 147:10:49:42.021 G.m.t. (6:49:42 a.m. e.d.t. on May 27, 1999) and began the second U. S. mission to the International Space Station (ISS). The countdown was satisfactory with no unplanned holds. All subsystems operated satisfactorily. Following a flawless rendezvous, the first direct docking with the ISS Pressurized Mating Adapter -2 (PMA-2) was completed very successfully. The launch occurred seven days later than planned because of repairs that were required to the External Tank insulation as a result of hail damage while on the launch pad.

A minor problem was noted during the countdown with forward Reaction Control Subsystem (RCS) thruster F1U when the temperature of the oxidizer decreased over a 40-minute period and then began recovering. An analysis revealed that the worst case of this condition was acceptable for the mission, and no further concerns arose during the countdown.

An evaluation of vehicle performance was made using the vehicle acceleration and preflight propulsion prediction data. The average flight-derived engine specific impulse was 452.9 seconds compared to the MPS tag value of 453.50 seconds.

An Orbital Maneuvering Subsystem (OMS) assist maneuver was performed during ascent following Solid Rocket Booster (SRB) separation. The ignition time for the maneuver was 147:10:51:56.8 G.m.t. [00:00:02:14.8 mission elapsed time (MET)], and the maneuver was 102.2 seconds in duration. At the start of the OMS assist maneuver, the right OMS engine ball valve 2 displayed sluggish behavior, although the valve did not fail the File IX requirement of opening to at least 98-percent in no more than 0.8 second. The sluggish performance was considered an in-flight anomaly (Flight Problem STS-96-V-02). Valve performance during the subsequent OMS maneuvers was improved. Aside from the sluggish ball valve performance, the OMS performance was nominal.

RCS thruster F4R was deselected by the Redundancy Management (RM) as fail-leak at 147:11:18:45 G.m.t. (00:00:29:03 MET) when the fuel injector temperature reached 20 °F (Flight Problem STS-96-V-01). The temperature returned to normal, and the thruster was reselected at 148:00:54 G.m.t. (00:14:05 MET) but placed in second priority. After undocking and the separation maneuver, thruster F4R was manually deselected for the remainder of the mission.

The OMS-1 maneuver was not required. The OMS-2 maneuver was performed at 147:11:32:52.8 G.m.t. (00:00:43:10.8 MET). The maneuver was 164.2 seconds in duration and a differential velocity (ΔV) of 255.2 ft/sec was imparted to the vehicle. The resulting orbit was 177 by 183 nmi.

The payload bay doors were opened at 147:12:24:36 G.m.t. (00:01:34:54 MET). Dual motor times were recorded during the opening operations.

The Ku-band antenna was deployed in nominal dual motor times at 147:12:34 G.m.t. (00:01:45 MET). The self-test was completed with a passed indication 16 minutes later. The OMS 3 NC1 rendezvous maneuver was performed at 147:13:49:24.3 G.m.t. (00:02:59:42.3 MET) with nominal performance from both engines. The engine firing imparted a ΔV of 42.6 ft/sec to the vehicle.

The OMS-4 rendezvous maneuver was performed at 147:14:35:53.5 G.m.t. (00:03:46:11.5 MET) with nominal performance from both engines. The engine firing was 18.8 seconds in duration and imparted a ΔV of 29.6 ft/sec to the vehicle.

The RCS NC2 rendezvous maneuver was performed at 148:03:02:53 G.m.t. (00:03:46:11.5 MET) with nominal subsystem performance. The firing was 19.5 seconds in duration and a ΔV of 4.6 ft/sec was imparted to the vehicle.

The Remote Manipulator System (RMS) was powered up at 147:15:14 G.m.t. (00:04:25 MET). On-orbit initialization was successfully completed and the arm was powered down and placed in the temperature monitor mode. The RMS was powered up at 148:07:14 G.m.t. (00:20:25 MET) to perform the on-orbit checkout, which was completed at 148:08:55 G.m.t. (00:22:06 MET). The payload bay survey was completed satisfactorily, and all RMS operations were nominal.

During a video downlink at 147:17:07 G.m.t. (00:06:18 MET), the image from payload bay camera D became unusable. Numerous power cycles of the camera did not correct the problem, and camera D was considered failed for the remainder of the mission. A check of the camera later in the mission showed that the camera video was still unusable.

The Extravehicular Mobility Unit (EMU) checkout was performed beginning at 148:03:55 G.m.t. (00:22:06 MET). All suits checks were completed satisfactorily and the EMUs were ready to support the extravehicular activity (EVA). The communications checkout with the Space-to-Space Orbiter Radio (SSOR) and Space-to-Space EMU Radio (SSER) was satisfactory.

The NC3 rendezvous maneuver was performed with the RCS at 148:19:18:54.8 G.m.t. (00:23:29:12.8 MET). The maneuver was approximately 14 seconds in duration and a ΔV of 3.2 ft/sec was imparted to the vehicle. The RCS performed satisfactorily.

Crew compartment depressurization to 10.2 psia for prebreathing prior to the planned EVA was completed satisfactorily.

At 148:12:19 G.m.t. (01:01:30 MET), during the humidity separator in-flight checkout, the crew observed an accumulation of water below the middeck floor at the outlet screen of humidity separator B (Flight Problem STS-96-V-04). The crew removed the water and switched to humidity separator A, which performed nominally. Humidity separator A performed satisfactorily for the remainder of the mission.

The RCS NC4 rendezvous maneuver was performed at 148:23:49:31 G.m.t. (01:12:59:49 MET) with nominal subsystem performance. The firing imparted a ΔV of 4.6 ft/sec to the vehicle.

The RCS corrective combination (NCC) rendezvous maneuver was performed at 149:00:37:35 G.m.t. (01:13:47:53 MET) with nominal subsystem performance. The multi-axis firing imparted a ΔV of 1.4 ft/sec to the vehicle.

The left OMS engine was used to perform the terminal phase initiation (TI) rendezvous maneuver at 149:01:35:17 G.m.t. (01:14:45:35 MET) with nominal performance. This engine firing was 10.2 seconds in duration and imparted a ΔV of 7.85 ft/sec to the vehicle.

The RCS midcourse correction (MC) -1 maneuver was performed at 149:01:55:17 G.m.t. (01:15:05:35 MET) with nominal subsystem performance. The firing imparted a ΔV of 0.7 ft/sec to the vehicle.

The RCS MC-2 maneuver was performed at 149:02:28:17 G.m.t. (01:15:38:35 MET) with nominal subsystem performance. The firing imparted a ΔV of 1.1 ft/sec to the vehicle.

The RCS MC-3 maneuver was performed at 149:02:45:17 G.m.t. (01:15:55:35 MET) with nominal subsystem performance. The firing imparted a ΔV of 0.7 ft/sec to the vehicle.

The RCS MC-4 maneuver was performed at 149:02:55:17 G.m.t. (01:16:05:35 MET) with nominal subsystem performance. The firing imparted a ΔV of 2.0 ft/sec to the vehicle.

Docking of the Discovery vehicle with the ISS in a 205 nmi. orbit was successfully completed at 149:04:37:37 G.m.t. (01:17:47:55 MET), and all docking systems performing nominally. The crewmembers ingress the ISS PMA-2 at approximately 149:07:00 G.m.t. (01:20:10 MET).

The Trajectory Control Sensor (TCS) performance in support of rendezvous and docking was satisfactory. The unit was powered at a range of approximately 3700 feet and powered off about 20 minutes after docking was completed.

While depressurizing the airlock in preparation for the EVA, a leakage of gas (2.7 lb, which was equivalent to 23 percent of PMA -2/ vestibule atmosphere) was measured from the vestibule to the airlock (Flight Problem STS-96-V-03). The leakage began when the differential pressure (ΔP) reached 8.97 psid because of airlock depressurization for the EVA, and the leakage stopped when the ΔP reached 8.0 psid. The vestibule pressure at that time was 10.4 psi. This was the first flight of the Space Shuttle Program where a negative pressure was present across the D hatch. The most probable cause of the airlock D hatch leakage was that the sealing surfaces separated slightly because of the high negative ΔP , which exceeded the capability of the latches as rigged.

The RMS was powered up at 150:00:34 G.m.t. (02:13:45 MET), and checkout was performed in preparation for supporting the planned EVA. The arm was used to perform a survey of the starboard Early Communications System (ECOMM) on the ISS and an evaluation of the RMS Situational Awareness Display (RSAD) single-joint drive

operations. The arm supported the planned EVA tasks with nominal performance. The planned RMS inspection of the Space Vision System (SVS) targets was canceled due to time limitations, but the inspection was rescheduled later in the mission.

The scheduled EVA began when the EMUs were transitioned to battery power at 150:02:56 G.m.t. (02:16:07 MET) and ended at the start of airlock repressurization at 150:10:51 G.m.t. (03:00:02 MET) for a total EVA time of 7 hours and 55 minutes. All of the EVA objectives were met including an additional task of installing a trunnion pin cover.

The Space-to-Space Communications System supported the EVA; however, a known problem was experienced. There were four occurrences of audio malfunctions, each of which was cleared by power cycling. The communication recovery procedures worked well. In addition, the EV2 crewmember reported a full volume high pitch squeal on three occasions. The ground also noted many instances during the EVA in which communications between the EVA personnel and the intravehicular personnel degraded to choppy, then garbled, and finally total loss of the signal (Flight Problem STS-96-V-05). The communication upsets did not impact EVA operations.

The Spacehab module was activated at 150:00:24 G.m.t. (03:13:35 MET), and the mated ISS/Space Shuttle vehicle was repressurized to 14.7 psia.

Flight day 4 consisted mainly of activities in the ISS, as Unity and Zarya were ingressed by the crew and several installation and replacement tasks were successfully performed. The crew performed an In-Flight Maintenance (IFM) procedure on the ISS ECOMM during which normal operation of the ECOMM was restored.

STS-96 is the first flight of the forward RCS after the replacement of the 10-watt heaters with 18-watt heaters on the vernier thrusters. As a result, the temperatures remained well above the 130 °F leak detection limit, and the in-flight tasks of managing the thruster temperatures was significantly reduced.

The crew performed a successful data retrieval that was downlinked in support of the Single-String Global Positioning System (GPS) Detailed Test Objective (DTO) 700-14. This DTO evaluates the performance and operation of the GPS as a Space Shuttle navigation aid during all phases of the mission.

Logistics transfers from the Orbiter to the ISS were completed. A total of 98 items (2881 lb) of dry cargo and 686 lb of water were transferred from the Orbiter during intravehicular operations, and 661 lb of cargo were transferred during EVA. Also, 18 items (197 lb) of cargo were transferred from the ISS to the Orbiter for return.

The ISS was pressurized to the desired level, and the activities in the ISS were completed with the final closure of the hatches between the Orbiter and the ISS.

The RMS was used to perform a survey of the ECOMM port antenna assembly. In addition, a survey was made of the Node 1 SVS targets.

The reboost maneuver was initiated at 154:09:36:53.6 G.m.t. (06:22:47:11.6 MET) with the first of 17 five-second pulses of the 2 +X aft RCS thrusters (L1A and R1A). The

interval between each pulse was approximately 125 seconds. In addition, the aft down-firing thrusters (L5D and R5D) were fired on a duty cycle of 90 seconds on and 40 seconds off. The maneuver was completed at 154:10:11:40 G.m.t. (06:23:21:58 MET). The ISS orbit was raised approximately 6 nmi. The RCS was in right OMS interconnect during the maneuver and approximately 977 lbm of OMS propellants were expended.

The Orbiter Docking System (ODS) performed satisfactorily as the Orbiter successfully undocked from the ISS at 154:22:36:47 G.m.t. (07:11:47:05 MET). The Orbiter then maneuvered to approximately 430 feet away from the ISS and performed a 2 ½-circle fly-around survey of the ISS before establishing a fixed separation position. The Ku-Band radar acquired the ISS at a range of 150 ft and operated satisfactorily throughout the fly-around and separation operations.

The TCS operation was nominal, starting almost immediately after undocking at a distance of 5 ft. Satisfactory tracking continued to a separation distance of 2666 ft after which the TCS was powered off.

The RCS was in straight feed for the -X axis separation maneuver, which was performed at 155:00:53:19 G.m.t. (07:14:03:37 MET). The maneuver was 11.7 seconds in duration and imparted a ΔV of 2.9 ft/sec. Total propellant usage by the RCS from the OMS up to this time in the mission was 9.1 percent from the left OMS and 11.6 percent from the right OMS.

The flight control system (FCS) checkout was performed using Auxiliary Power Unit (APU) 1. APU 1 was started at 156:00:01:55 G.m.t. (08:13:12:13 MET) and ran for 4 minutes and 47 seconds with a fuel consumption of 16 lb. APU 1 and hydraulic system 1 performed nominally during the checkout.

The RCS hot-fire commenced at 156:01:06:04 G.m.t. (08:14:16:22 G.m.t.) and was completed 15 minutes later. Vernier RCS thruster F4R was deselected during the hot fire. Performance was nominal, and all 38 primary thrusters were fired on this mission.

The multi-mirrored payload Student Tracked Atmospheric Research Satellite for Heuristic International Networking Experiment (STARSHINE) was deployed from the payload bay at 156:07:21 G.m.t. (08:20:32 MET). The development of STARSHINE involved the work of thousands of students worldwide, and it will be used for daily orbit observations and calculations, and to determine atmospheric density changes over time.

Ku-band antenna stowage was accomplished at about 156:09:40 G.m.t. (08:22:51 MET).

The payload bay doors were closed and latched for landing at 157:02:14:20 G.m.t. (09:15:24:38 MET). The dual-engine deorbit maneuver for the first landing opportunity at the Kennedy Space Center (KSC) Shuttle Landing Facility (SLF) was performed on orbit 153 at 157:04:54:09.38 G.m.t. (09:18:04:27.36 MET). The maneuver was 219.41 seconds in duration with a ΔV of 372.8 ft/sec imparted to the vehicle.

Entry interface occurred at 157:05:30:49 G.m.t. (09:18:41:07 MET). Entry was completed satisfactorily, and main landing gear touchdown occurred on SLF concrete runway 15 at 157:06:02:45 G.m.t. (09:19:13:03 MET) on June 6, 1999. The nose gear touchdown occurred at 157:06:02:57 G.m.t. The drag chute was jettisoned at 157:06:03:18 G.m.t., with wheels stop occurring at 157:06:03:35 G.m.t. The rollout was normal in all respects. The flight duration was 9 days 19 hours 13 minutes 3 seconds. The APUs were shut down 17 minutes 20 seconds after landing.

PAYLOADS AND EXPERIMENT OPERATIONS

The STS-96 mission, which was an International Space Station (ISS) -2A.1 Logistics mission, was completed very successfully with all objectives accomplished. Following a flawless rendezvous and docking, the planned Extravehicular Activity (EVA) was completed to transfer the U. S. Orbital Replacement Unit (ORU) Transfer Device (OTD) and Russian Strela cranes as well as the transfer of EVA pre-positioning hardware to be used for subsequent ISS assembly tasks. This mission also highlighted the maiden voyage of the Spacehab Integrated Cargo Carrier (ICC) which consists of an Unpressurized Cargo Pallet (UCP) that was mounted on a Keel Assembly on which was carried the external transfer items.

During the docked operations, all preflight planned on-orbit task priorities were completed including the transfer of over 4,000 lb of equipment and water during the EVA and Intravehicular Activity (IVA). In addition to accomplishing all 27 of the ISS flight objectives, 8 additional on-orbit inspection tasks were completed by the crew.

The Human Exploration and Development of Space (HEDS) Technology Demonstration (HTD) -1402 entitled Integrated Vehicle Health Monitoring (IVHM) was activated for approximately one hour daily during the pre-sleep period to record Power Reactant Storage and Distribution (PRSD) valve cycling.

Following undocking, the crew successfully deployed the Student Tracked Atmospheric Research Satellite for Heuristic International Networking Experiment (STARSHINE) satellite.

SPACEHAB

The Spacehab double module was flown and carried approximately 2881 lb of cargo that was transferred to the ISS. The Spacehab module was activated at 150:00:24 G.m.t. (03:13:35 MET), and the mated ISS/Space Shuttle vehicle was repressurized to 14.7 psia.

Logistics transfers from the Orbiter to the International Space Station were completed. A total of 98 items of dry cargo and 686 lb of water were transferred from the Orbiter during intravehicular operations, and 661 lb of cargo were transferred during EVA. Also, 18 items (197 lb) of cargo were transferred from the ISS to the Orbiter for return.

STUDENT TRACKED RESEARCH SATELLITE FOR HEURISTIC INTERNATIONAL NETWORKING EXPERIMENT PAYLOAD

The multi-mirrored payload STARSHINE was deployed from the payload bay at 156:07:20 G.m.t. (08:20:31 MET). The STARSHINE team was able to observe the satellite from the ground while outside the Goddard Space Flight Center Payload Operations Control Center (POCC). The satellite was covered by almost 1,000 evenly distributed mirrors that had been polished by participating pre-college students. The development of STARSHINE involved the effort of thousands of students worldwide, and it will be used for daily observations and orbit calculations by the pre-

college students who will use the orbital decay data to derive atmospheric density changes over time.

VEHICLE PERFORMANCE

All elements of the Space Shuttle Vehicle performed satisfactorily throughout the mission. No anomalies were identified in the Marshall Space Flight Center (MSFC) elements and only five Orbiter anomalies and three EVA anomalies were identified in the Johnson Space Center (JSC) element. The overall performance of the subsystems of the various elements are discussed in this section of the report.

SOLID ROCKET BOOSTERS

All Solid Rocket Booster (SRB) subsystems performed satisfactorily during the prelaunch testing and countdown as well as during the flight. No SRB Launch Commit Criteria (LCC) or Operations and Maintenance Requirements Document (OMRSD) violations or in-flight anomalies occurred.

The heated ground-supplied aft-skirt purges had a cumulative activation time of 5 hours and 6 minutes during the period of the countdown from T-6 hours to T-5 minutes. All of the purges were conducted at the high range to maintain the case/nozzle joint and flex bearing temperatures within the required LCC ranges.

STS-96 was the second flight for the ET Thermal Protection System (TPS) observation cameras, which were flown to support the investigation of TPS loss from the ET thrust panel area). The cameras were flown on both SRBs and were located in the unused Range Safety Crossover cutout area of both SRB forward skirts. Likewise, this was the second flight on which all main parachutes were equipped with Sea Water Activated Release (SWAR) links (eight per parachute). All links operated properly.

Evaluation of the Thrust Vector Controller (TVC) data showed that the TVC subsystem responded as expected to the Space Shuttle main engine (SSME) trim modifications that were made to enhance the performance of the vehicle.

Both SRBs were successfully separated from the vehicle at 124.444 seconds after liftoff. The SRBs were recovered and towed back to Port Canaveral and returned to Kennedy Space Center (KSC) for inspection, disassembly and refurbishment. The open inspections of the SRBs revealed no significant damages or anomalous conditions.

REUSABLE SOLID ROCKET MOTORS

The Reusable Solid Rocket Motors (RSRMs) performed satisfactorily with no in-flight anomalies noted in the data. Also, no LCC or OMRSD violations occurred during the countdown.

The power-up of the igniter and field joint heaters was accomplished routinely. The field-joint heaters operated for 12 hours 47 minutes during the launch countdown. Power was applied to the heating elements 26-percent of the time during the LCC time frame to maintain the joints within the nominal operating temperature range. For this launch, uneven heating on the field joints was experienced, and as a result, the set

point temperature was lowered from 98 °F to 90 °F. Igniter joint heaters operated for 12 hours 37 minutes during the countdown. Power was applied to the heating elements 48-percent of the time to maintain nominal igniter joint temperatures.

The aft skirt purge operated prior to and during the LCC time frame for a total of 5 hours 6 minutes to maintain the nozzle/ case joint temperatures within the nominal operating range. The calculated flex bearing mean bulk temperature was a nominal 80 °F.

Flight data indicate that the performance of the RSRMs was well within the allowable performance envelopes and was typical of the performance observed on previous flights. The RSRM propellant mean bulk temperature was a nominal 75 °F at liftoff.

The propulsion performance is shown in the following table.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 75 °F		Right motor, 79 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10 ⁶ lbf-sec	65.31	65.23	65.45	65.44
I-60, 10 ⁶ lbf-sec	174.25	174.51	174.55	175.19
I-AT, 10 ⁶ lbf-sec	296.93	296.31	296.91	296.78
Vacuum Isp, lbf-sec/lbm	268.6	268.0	268.6	268.5
Burn rate, in/sec @ 60 °F at 625 psia	0.3662	0.3678	0.3667	0.3680
Event times, seconds ^a				
Ignition interval	0.232	N/A	0.232	N/A
Web time ^b	110.3	109.4	110.0	109.1
50 psia cue time	120.0	119.5	119.8	119.7
Action time ^b	122.1	121.4	121.9	121.9
Separation command	124.9	124.0	124.9	124.0
PMBT, °F	75	75	75	75
Maximum ignition rise rate, psia/10 ms	90.4	N/A	90.4	N/A
Decay time, seconds (59.4 psia to 85 K)	2.8	2.8	2.8	3.0
Tailoff Imbalance Impulse differential, Klbf-sec	Predicted N/A		Actual 467.4	

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).

EXTERNAL TANK

All External Tank (ET) subsystems performed satisfactorily and all flight objectives were satisfied. No in-flight anomalies were noted in the data review, and no LCC or OMRSD

violations occurred during the countdown. STS-96 was the fourth flight of the Super Lightweight Tank (SLWT) and the first flight of the modified hazardous gas detection system (HGDS).

STS-96 was the first flight of the modified HGDS which sampled the ET intertank during the last three minutes of the countdown. No oxygen or hydrogen leakage concentrations were measured in the tank areas.

All objectives and requirements were met during the propellant loading and flight operations. All ET electrical equipment and instrumentation operated satisfactorily. Purge and heater operations were monitored and no off-nominal operation was noted.

Prelaunch hail damage repairs to the TPS foam were successful. No unexpected ice/frost formations or pockets were observed during the prelaunch inspection and video monitoring. No ice or frost was noted on the acreage areas of the ET. Normal quantities of ice or frost was present on the Liquid Hydrogen (LH₂) and Liquid Oxygen (LO₂) feed-lines, the pressurization line brackets, and along the LH₂ Protuberance Air Load (PAL) ramps. These observations were acceptable per NSTS-08303.

Propellant loading was delayed from the planned start time with LH₂ chill-down starting approximately 50 minutes later than planned. The primary cause of the delay was resolving an Interim Problem Report (IPR) that occurred. During preparations for opening the LO₂ 17-inch disconnect, the LO₂ manifold was to be vented. Procedures were not followed in the closing of the overboard bleed valve, and a concern for possible moisture in the ET and MPS from atmospheric intrusion existed. An evaluation showed that no moisture had entered the system because no negative internal pressure was present that could cause this condition to occur. Loading operations were initiated following this resolution.

The pressurization system functioned properly throughout engine start and flight. The minimum LO₂ ullage pressure experienced during the ullage pressure slump was 13.6 psid.

ET separation was confirmed at the expected time followed by entry and breakup, which occurred within the predicted footprint. The postflight predicted ET intact impact point was approximately 85 nmi. uprange from the preflight prediction.

SHUTTLE RANGE SAFETY SYSTEM

The Shuttle Range Safety System (SRSS) closed-loop testing was completed as scheduled during the launch countdown. All SRSS Safe and Arm (S&A) devices were armed and system inhibits turned off at the appropriate times. As planned, the SRB S&A devices were safed and SRB system power was turned off prior to SRB separation. The SRSS operated nominally throughout the countdown and flight.

The SRSS signal strength of the right SRB B system exceeded the range safety minimum requirement of -85 dBm when tracking with the Cape command site. The lowest observed signal strength was -94.5 dBm at liftoff plus 108.2 seconds. This level did not exceed the demonstrated command sensitivity of the receivers (-109 dBm), and

system operation was not affected. This condition is expected on high inclination angle flights and is caused by plume attenuation and right SRB shading.

SPACE SHUTTLE MAIN ENGINES

The SSMEs flown on STS-96 were of the Block IIA design, and the overall performance was satisfactory, and no in-flight anomalies were noted in the data. The SSME preflight parameters were nominal throughout the countdown and were typical of the parameters observed on previous flights. Engine ready was achieved at the proper time, and thrust buildup was normal. All LCC or OMRSD requirements were met during prelaunch operations.

The flight data indicate that the SSME performance during mainstage, throttling, shutdown and propellant dump operations was normal. The high pressure turbine pump temperatures were well within specification throughout engine operation. Main engine cutoff (MECO) occurred 508.89, 508.61, and 508.73 seconds after ignition for SSMEs 1, 2, and 3, respectively.

ORBITER SUBSYSTEMS PERFORMANCE

Main Propulsion Subsystem

The overall in-flight performance of the Main Propulsion Subsystem (MPS) was nominal. No LCC or OMRSD violations occurred during the countdown. A minor problem occurred during the countdown when it was discovered that a valve on the LO₂ tank had been left open following the venting of the LO₂ tank. Concerns including ingestion of contaminants and possible moisture through the ET vent valve or from the ground support equipment through the valve that was left open. An evaluation showed that no moisture or contaminant intrusion was possible, and as a result, loading of the ET proceeded nominally.

No significant hazardous gas concentrations were detected prior to liftoff. The maximum hydrogen concentration level in the Orbiter aft compartment was 110 ppm. This level compares favorably with previous launch countdown data from this Orbiter.

The ascent MPS performance was nominal in all aspects with no in-flight anomalies noted. Data indicate that the LO₂ and LH₂ pressurization systems performed as planned, and the engine-inlet net positive suction pressure requirements were met throughout the flight. The overall Gaseous hydrogen (GH₂) system in-flight performance was nominal, as was the operation of the flow control valves. The Gaseous Oxygen (GO₂) fixed orifice pressurization system performed as predicted. The reconstructed data from the engine and MPS parameters closely matched the actual ET ullage pressure measurements. Helium system performance for the SSME and pneumatic helium systems was nominal as was the entry helium usage of 62.3 lbm.

Reaction Control Subsystem

The Reaction Control Subsystem (RCS) performed nominally throughout the mission with the exception of one in-flight anomaly, which did not impact satisfactory mission operations. This anomaly is discussed in a following paragraph. The following table lists the significant RCS maneuvers performed during the mission.

RCS MANEUVERS

RCS Maneuver	Ignition Time, day:hr:min:sec	Differential Velocity, ft/sec	Firing Time, seconds
NC1 RCS Trim	147:13:49:52 G.m.t. 00:03:00:10 MET	0.1	0.5
NC2	148:03:02:53 G.m.t. 00:16:13:11 MET	4.4	18.6
NC3	148:10:18:55 G.m.t. 00:23:29:13 MET	3.1	13.4
NC4	148:23:49:31 G.m.t. 01:12:59:49 MET	4.5	19.2
NCC	149:00:37:35 G.m.t. 01:13:47:53 MET	1.0	4.2
MC1	149:01:55:17 G.m.t. 01:15:05:35 MET	0.5	2.0
MC2	149:02:28:17 G.m.t. 01:15:38:35 MET	0.9	4.0
MC3	149:02:45:17 G.m.t. 01:15:55:35 MET	0.5	2.0
MC4	149:02:55:17 G.m.t. 01:16:05:35 MET	1.6	7.0
ISS Reboost	154:09:36:53.6 G.m.t. 06:22:47:11.6 MET	21.8	93.8 _a
Undocking and Fly-Around	154:22:39:32 G.m.t. 07:11:49:50 MET	N/A	N/A
Separation	155:00:53:19 G.m.t. 07:14:03:37 MET	2.9	11.7

Note a: The ISS reboost maneuver consisted of 17 +X firings, each lasting 5.52 seconds. Each firing provided a differential velocity of 1.28 ft/sec.

No LCC or OMRSD limits were violated; however, a minor problem was noted during the countdown with forward RCS thruster F1U. The temperature of the oxidizer decreased approximately 7 °F over a 40-minute period and then began recovering. An analysis revealed that the worst case of this condition was acceptable for the mission, and no further concerns arose during the countdown. The thruster performed nominally throughout the mission.

Following the ET separation, RCS thruster F4R was deselected by the Redundancy Management (RM) as fail-leak at 147:11:18:45 G.m.t. (00:00:29:03 MET) when the fuel

injector temperature reached 20 °F (Flight Problem STS-96-V-01). The temperature returned to normal, which indicates the leak had stopped, and the thruster was reselected for rendezvous and docking at 148:00:53 G.m.t. (00:14:04 MET), but the thruster was placed in second (last) priority. After undocking and the separation maneuver, thruster F4R was manually deselected at 155:21:57 G.m.t. (08:11:08 MET) for the remainder of the mission.

The reboost maneuver consisted of seventeen 5-second pulses of the two +X aft RCS thrusters (L1A and R1A). The interval between each pulse was approximately 125 seconds. In addition, the aft down-firing thrusters (L5D and R5D) were fired on a duty cycle of 90 seconds on and 40 seconds off. The maneuver was completed at 154:10:11:40 G.m.t. (06:23:21:58 MET). The RCS was in right OMS interconnect during the maneuver and approximately 977 lbm of OMS propellants were expended. The ISS orbit was raised approximately 6 nmi., and the resultant orbit of the ISS/Shuttle was 206.2 by 212.1 nmi.

During the undocking and subsequent fly-around, thruster R1U exhibited fuel sensor temperature fluctuations ranging between 90 °F and 72 °F and the temperature cycled 16 times in 35 minutes. This condition is normally caused by fuel valve bounce when two or more thrusters on the same manifold fire simultaneously. The condition has been seen previously and does not impact flight operations.

The RCS hot-fire commenced at 156:01:06:04 G.m.t. (08:14:16:22 G.m.t.) and was completed 15 minutes later. Thruster F4R was deselected during the hot fire. Performance was nominal, and all 38 primary thrusters were fired on this mission. During entry, a two-thruster 73.9-second forward RCS propellant dump firing was performed.

In addition to the 2686.5 lbm of OMS propellants consumed by the RCS during interconnect operations, a total of 4007.3 lbm of RCS propellants were consumed. The vernier thrusters had 16,367 firings and the firing time was 30,229.3 seconds. The primary thrusters had 3680 firings and a total firing time of 1236.8 seconds.

Orbital Maneuvering Subsystem

The Orbital Maneuvering Subsystem (OMS) performed nominally with only the exception discussed in a following paragraph. No LCC or OMRSD violations were noted during the mission. The table on the following page lists the pertinent parameters for each OMS maneuver during the mission. A total of 23,326 lbm of OMS propellants (14,508 lbm of oxidizer and 8818 lbm of fuel) were consumed, and of this total, 2688 lbm was consumed by the RCS during interconnect operations. The direct insertion ascent trajectory resulted in the OMS 1 maneuver not being required.

An OMS assist maneuver was performed during ascent following Solid Rocket Booster (SRB) separation. At the start of the OMS assist maneuver, the right OMS engine ball valve 2 displayed sluggish behavior, although the valve did not fail the File IX requirement of opening to at least 90 percent in no more than 0.8 second. Because of the sluggish performance, the item has been deemed an in-flight anomaly (Flight Problem STS-96-V-02). Valve performance during the subsequent OMS maneuvers

was improved. This problem had no affect on the mission, but will result in the replacement of the OMS engine.

OMS MANEUVERS

OMS Maneuvers	Engine Configuration	Ignition Time, day:hr:min:sec	Firing time, seconds	Differential Velocity, ft/sec
Assist	Dual-engine	147:10:51:56.8 G.m.t. 00:00:02:14.8 MET	99.6	N/A
OMS-1		Not required		
OMS-2	Dual-engine	147:11:32:52.8 G.m.t. 00:00:43:10.8 MET	164.0	255.2
OMS-3 (NC-1)	Dual-engine	147:13:49:24 G.m.t. 00:02:59:42 MET	26.2	42.6
OMS-4	Dual-engine	147:14:35:53.5 G.m.t (00:03:46:11.5 MET	18.8	29.6
OMS-5 (TI)	Left-engine	149:01:35:17 G.m.t. 01:14:45:35 MET	10.2	7.9
Deorbit	Dual-engine	157:04:54:09 G.m.t. (09:18:04:27 MET	219.4	372.8

The dual-engine deorbit maneuver for the first landing opportunity at the Kennedy Space Center (KSC) Shuttle Landing Facility (SLF) was performed on orbit 153.

Power Reactant Storage and Distribution Subsystem

The Power Reactant Storage and Distribution (PRSD) subsystem performed nominally throughout the mission with no in-flight anomalies identified. There were no LCC violations noted during the prelaunch operations. The subsystem provided the fuel cells with 2500 lbm of oxygen and 315 lbm of hydrogen for the production of 3648 kWh of electricity. In addition, the Environmental Control and Life Support System (ECLSS) was supplied 127 lbm of oxygen.

The Orbiter landed with 1288 lbm of oxygen and 141 lbm of hydrogen remaining in the PRSD subsystem. A 92-hour mission-extension capability existed at touchdown at the average mission power level of 15.5 kW, and at an extension-day power level of 13.2 kW, a 107-hour mission extension was available.

Fuel Cell Powerplant Subsystem

Performance of the fuel cell powerplant subsystem was nominal throughout the STS-96 mission with no in-flight anomalies identified from the data. The average electrical power level and load for the mission was 14.2 kW and 466 amperes. The fuel cells produced 4025 kWh of electrical energy and 3130 lbm of by-product potable water while using 2780 lbm of oxygen and 350 lbm of hydrogen.

Four purges of the fuel cells were performed satisfactorily during the mission using both the automatic and manual systems. The actual fuel cell voltages at the end of the mission were 0.10 Vdc above predicted for fuel cell 1, 0.05 Vdc above predicted for fuel cell 2, and 0.10 Vdc above predicted for fuel cell 3. The fuel cell operating times for the mission were 260 hours 12 minutes for fuel cell 1, 259 hours 36 minutes for fuel cell 2, and 259 hours 05 minutes fuel cell 3.

The overall thermal performance of the fuel cell water relief, water line and reactant purge systems was nominal. Both system A and system B heaters were exercised during the flight, and all in-flight checkout requirements were met.

The Fuel Cell Monitoring System (FCMS) performed satisfactorily while monitoring individual cell voltages prelaunch, on-orbit and postlanding. All of the data were nominal with the exception of fuel cell 3, cells 41 and 42. A total of 12 minutes of full-rate data were recorded during the on-orbit portion of the flight. The full rate data showed that the cell 41 voltage measurement was reading low, usually below 100 mV, and the cell 42 voltage was reading full-scale high at 1298 mV. During the prelaunch operations, these cells were reading nominally in the low 970 mV range at 150 amperes. This condition did not cause any problem during the mission.

Auxiliary Power Unit Subsystem

The Auxiliary Power Unit (APU) subsystem performed nominally with no in-flight anomalies noted in the data. The following table provides data concerning the run times and fuel consumption of the APUs during the mission.

APU RUN TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (S/N 310) (a) (b)		APU 2 (S/N 204) (a)		APU 3 (S/N 404) (a)	
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	20:55	52	21:03	52	21:08	55
FCS checkout	04:47	16				
Entry ^a	62:00	117	90:47	166	62:11	137
Total	87:42	185	111:50	218	83:19	192

^a APUs were shut down 17 minutes 20 seconds after landing.

^b APU 1 was used for the FCS checkout.

The only problem of any significance was the APU 1 Exhaust Gas Temperature (EGT) measurement, which was erratic for 1 minute during ascent, 4 minutes during FCS checkout and 15 minutes during the entry phase. As a result, this temperature sensor will be replaced during the turnaround activities.

The Flight Control System (FCS) checkout was performed using APU 1, which was started at 156:00:01:55 G.m.t. (08:13:12:13 MET) and ran for 4 minutes and

47 seconds. APU 1 and hydraulic system 1 performed nominally during the checkout. Likewise, all three APUs performed nominally during entry and landing.

Hydraulics/Water Spray Boiler Subsystem

The overall performance of the hydraulics and Water Spray Boiler (WSB) subsystem was nominal. No LCC or OMRSD violations occurred during the prelaunch operations, and no in-flight anomalies were noted.

During ascent, a minor over-cooling condition on WSB 2 and a slightly higher WSB relief valve cracking pressure were noted in the data. Neither condition caused any concern for the successful completion of all mission objectives and the flight because they are understood and are no cause of concern.

In a successful attempt to minimize system 1 circulation pump run-time during the on-orbit phase, the thermal control set-points were lowered on all three aerosurfaces (body flap, rudder speedbrake and elevons). This action resulted from the fact that during STS-88, the previous mission to the ISS, the system 1 circulation pump run time was approximately 27 hours compared to a total of 3 hours for system 2 and 3. As a result of the lower set-points, system 1 run-time was reduced to 2.3 hours, but system 2 run-time increased to 18.5 hours and system 3 ran approximately 3.5 hours. Data evaluation is in progress to lower the thermal set-points on some of the measurements but not all on each hydraulic system for the next flight to ISS. Data review will continue for a better evaluation of all circulation pump parameters with the ultimate goal to reduce circulation pump run-time and thereby reduce cryogenics consumption.

The hydraulic system and WSB performance was satisfactory during the FCS checkout. Because of the short run time of the APU, lubrication oil spray cooling was not required. Likewise, hydraulic and WSB operation during entry was satisfactory.

Electrical Power Distribution and Control Subsystem

The Electrical Power Distribution and Control (EPDC) subsystem performed satisfactorily throughout the flight, and no in-flight anomalies noted. All File IX in-flight checkout requirements were also met.

Orbiter Docking System

The Orbiter Docking System (ODS) performed satisfactorily throughout the STS-96 mission. No in-flight anomalies were identified during the review and analysis of the data.

Docking of the Discovery vehicle with the ISS in a 205 nmi. orbit was successfully completed at 149:04:37:37 G.m.t. (01:17:47:55 MET), and all docking systems performed nominally. The crewmembers ingress the ISS PMA-2 at approximately 149:07:00 G.m.t. (01:20:10 MET).

The ODS valves were used during the docked operation and for EVAs and the valves performed nominally. After docking, the vestibule/PMA-2 pressurization and leak check

was performed with satisfactory results. The air inlet screen of one of the equalization valves on the top hatch of the external airlock was gray-taped as well as was one of the two assembly holes to minimize flow and maintain the ΔP across the PMA-2 hatch below 0.7 psid and thereby protecting the hatch from being lifted off of its seal and allowing some pressure loss (phenomenon called "burping"). The ΔP reached 1.58 psid during the initial stage of the pressurization, but data indicate that no burping of the hatch occurred.

While depressurizing the airlock in preparation for the EVA, a leakage of gas (2.7 lb, which was equivalent to 23 percent of PMA -2/vestibule atmosphere) was measured from the vestibule to the airlock (Flight Problem STS-96-V-03). The leakage began when the ΔP reached 8.97 psid because of airlock depressurization for the EVA, and the leakage stopped when the ΔP reached 8.0 psid. The vestibule pressure at that time was 10.4 psi. This was the first flight of the Space Shuttle Program where a negative pressure was present across the D hatch. The most probable cause of the airlock D hatch leakage was that the sealing surfaces separated slightly because of the high negative ΔP which exceeded the capability of the latches as rigged.

After the EVA, the Orbiter/ISS stack [PMA-2, Node 1, PMA-1 and Functional Cargo Block (FGB)] pressures were equalized at 12.96 psia and then the pressure was raised to 14.96 psia in preparation for the planned activities in the ISS. The vestibule depressurization valves were used to depressurize the vestibule and PMA 2 to space prior to undocking from the ISS.

The ODS performed satisfactorily as the Orbiter successfully undocked from the ISS at 154:22:36:47 G.m.t. (07:11:47:05 MET). The Orbiter then maneuvered to approximately 430 feet away from the ISS and performed a 2 1/2-circle fly-around survey of the ISS before establishing a fixed separation position.

Atmospheric Revitalization Pressure Control Subsystem

The primary and alternate Atmospheric Revitalization Pressure Control Subsystem (ARPCS) operated satisfactorily throughout the flight, and the system-monitor parameters indicated normal outputs throughout the flight. Crew compartment depressurization to 10.2 psia for prebreathing prior to the planned EVA was completed satisfactorily. Following the EVA, the Orbiter cabin pressure was equalized with the ISS pressure at 12.98 psia. After the equalization, the overall pressure of the ISS/Orbiter was raised to 14.7 psia using the Orbiter repressurization procedures. The overall Orbiter/ISS pressure was further raised to 14.96 psia. The 14.7-psia regulators switched to low-flow at 14.56 psia. This was caused by the oxygen flow panel becoming very cold with frost present at the regulator ports. This condition is expected during long-duration high-flow conditions and the transition to the low-flow condition was nominal.

The vacuum vent line temperature dropped off-scale low (<25 °F) for about 30 minutes during the cabin repressurization of the Orbiter/ISS to 14.7 psia and then recovered. Data evaluation for possible sources indicate that a leak did not exist to cause the temperature drop. The most plausible explanation is water from the wet trash vent

(caused by towels used for the water cleanup from the humidity separator) migrating to the vacuum vent line as a result of the cabin pressure rising.

While depressurizing the airlock in preparation for the EVA, a leakage of gas (2.7 lb, which was equivalent to 23 percent of PMA -2/vestibule atmosphere) was measured from the vestibule to the airlock (Flight Problem STS-96-V-03). The leakage began when the differential pressure ΔP reached 8.97 psid because of airlock depressurization for the EVA, and the leakage stopped when the ΔP reached 8.0 psid. The vestibule pressure at that time was 10.4 psi. This was the first flight of the Space Shuttle Program where a negative pressure was present across the D hatch. The most probable cause of the airlock D hatch leakage was that the sealing surfaces separated slightly because of the high negative ΔP which exceeded the capability of the latches as rigged.

Atmospheric Revitalization Subsystem

The Atmospheric Revitalization Subsystem (ARS) performed nominally for this mission.

While performing the prelaunch 2-psid cabin integrity check, the avionics bay 3A fan ΔP peaked and operated at 4.4 inches of water for approximately 5 minutes, violating both the LCC and OMRSD limits of 4.3 inches of water. After a review of the data, a decision was made to fly with this condition but raise the onboard limit to 4.4 inches of water. The fan ΔP remained below the newly established limit for this vehicle for the remainder of the flight, and the preflight excursion had no impact on the flight operations.

At 148:12:26 G.m.t. (01:01:37 MET), during the humidity separator in-flight checkout, the crew observed an accumulation of water below the middeck floor at the outlet screen of humidity separator B (Flight Problem STS-96-V-04). The crew removed the water and switched to humidity separator A, which performed nominally for the remainder of the mission. STS-96 was the fifth flight of this humidity separator. The unit had passed the OMRSD checks in the last turnaround, but this is done in a non-flight configuration (humidity separator detached from cabin heat exchanger). The data review showed that the B fan separator was performing below its expected level during the flight. As a result, a decision was made to remove and replace the humidity separator during the STS-96 postflight turnaround activities. A boroscope inspection of the heat exchanger will also be made during this process to determine the condition of the interior coating and the presence of debris.

The Partial Pressure Carbon Dioxide (PPCO₂) peaked at a nominal 4.28 mmHg on flight day 4 while at a cabin pressure of 14.7 psia. During the 10.2 -psia cabin pressure operations, the PPCO₂ peaked at 2.7 mmHg, which was also satisfactory. The average PPCO₂ level for the entire flight was a satisfactory 1.94 mmHg.

Active Thermal Control Subsystem

The Active Thermal Control Subsystem (ATCS) operation was satisfactory throughout the mission. No in-flight anomalies were identified from the data analysis.

Ascent performance was nominal. Radiator flow was initiated at 147:12:23 G.m.t. (00:01:34 MET) and the payload bay doors were fully open approximately 10 minutes later. The radiators were not deployed on this flight. Both Freon loop Flow Proportioning Valves (FPVs) remained in the interchanger position for the entire flight to aid in the cabin cooling at 10.2 psia. The Spacehab heat loads were very low during the flight and, therefore, FPV operation in the payload position was not required.

The radiator cold-soak prior to entry resulted in cooling being provided throughout entry. The radiators started to lose control two minutes after landing and the temperature continued to climb until landing plus four minutes when the radiators were taken to the high set point. Ammonia Boiler System (ABS) B was activated at 157:00:08 G.m.t., approximately 6 minutes after landing. System B provided cooling for 41 minutes until the tank pressure blew-down. System A was operated for approximately 3.5 minutes until ground cooling was activated.

Supply and Waste Water Subsystem

The supply water and waste management system performed nominally throughout the mission. All in-flight checkout requirements were satisfied with the exception of the vacuum vent line temperature problem that is discussed in a following paragraph. Seven Contingency Water Containers (CWCs), containing a total of 670 lb of technical water, were transferred to the ISS.

Supply water was managed through the use of the Flash Evaporator system (FES) She water dump system and transfer to the ISS. Two supply-water dumps were made at a nominal average dump rate of 1.62 percent/minute (2.67 lb/min). Both dumps were made simultaneously with the waste water. The supply water dump line was maintained between 60.0 °F and 95.8 °F throughout the mission with the operation of the line heater, except for a momentary drop to 56.8 °F when the heat exchange Development Test Objective (DTO) 686 was first installed. This DTO is discussed in detail in the Development Test Objective section of this report.

Waste water was gathered at about the predicted rate. Four waste water dumps were completed at an average dump rate of 1.88 percent/minute (3.10 lb/min). The waste water dump line temperature was maintained between 55.5 °F and 87.0 °F throughout the mission.

At 151:05:22 G.m.t. (03:18:33 MET), the vacuum vent nozzle temperature dropped from 129 °F to 83 °F at a rate of approximately 0.8 deg/min. Six minutes later, the vacuum vent line temperature dropped from 64 °F to off-scale low (25 °F) at a rate of approximately 1.2 deg/min. This condition indicated the presence of water in the line, possibly from the wet trash compartment because of the wet towels being placed in that compartment as a result of the humidity separator anomaly. This anomaly is discussed in the Active Thermal Control Subsystem section of this report. This event coincided with the end of the 14.7 psia repressurization of the ISS/Orbiter stack. The line temperature began recovering approximately five minutes after the temperature drop began and reached 40 °F within 15 minutes. The nozzle temperature also recovered at about the same time. Line heater A cycled normally before and after this problem, and heater B cycled normally throughout the second half of the flight.

Waste Collection Subsystem

The waste collection subsystem (WCS) performed nominally during STS-96.

Airlock Support System

The active airlock support system monitor parameters indicated normal operation throughout the flight during which one EVA was performed.

During the EVA, the first-time operation of the OV-103 external airlock water-line higher set-point "C" thermostats occurred. Each time the liquid cooling garment (LCG) flow was stopped, the heater systems were activated to ensure that the chilled water lines in the payload bay would remain well above freezing. The heaters operated satisfactorily in maintaining the water line above the freezing level.

The nominal airlock repressurization following the EVA began at 150:02:56 G.m.t. (02:16:07 MET). A very successful 7 hour and 55 minute EVA was completed.

Smoke Detection and Fire Suppression Subsystem

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

Flight Data Subsystem

The flight data system performed satisfactorily throughout the mission. The Global Positioning System (GPS) performance was nominal during ascent and entry.

The Inertial Measurement Units (IMU's) performed satisfactorily throughout the mission. The preflight calibrations performed during the countdown resulted in good calibrations of the IMU parameters. As a result, only one adjustment of the IMU accelerometer compensations was required for all three of the IMU's. Also, one gyro-drift compensation was required for IMU 1 and IMU 3. Based on the analysis of the IMU data, this ship-set of IMUs is flight worthy for the next mission of this vehicle.

The star tracker performance during this mission was satisfactory with no in-flight anomalies identified in the data. This ship-set of star trackers is flight worthy for the next flight of this vehicle.

Flight Software

The overall performance of the flight software was satisfactory. Two minor issues were noted during the mission and were resolved with no impact to the mission.

Flight Control System

The flight control system performance was nominal throughout the mission. On-orbit flight control system performance during payload-extended operations was nominal.

The loss of the forward RCS F4R thruster early in the flight did not impact on-orbit operations other than the loss of redundancy. There were no known violations of the flight control constraints. The data analysis indicates that the preflight mass properties and structural model accuracy's were within the requirements. No dynamic interaction stability concerns were observed.

STS-96 was the first flight where docking with the ISS was performed rather than berthing. After vehicle contact, the crew commanded the Post Contact Thrusting (PCT), which provided the necessary translational acceleration for mating followed by moding the Orbiter digital autopilot to free drift. The docking was nominal. Upon completion of the docking, the vernier RCS was reinitialized and a rotational maneuver was commanded to reorient the vehicle to the desired attitude.

Mated vehicle rotational control was nominal. The Orbiter was commanded to an inertial attitude with the X-Axis Perpendicular to the Orbital Plane (XPOP), and the vernier RCS was used to maintain rotational control of the ISS/Orbiter vehicle. The vernier RCS propellant usage in the XPOP attitude was very close to preflight estimates in not only the totals but also in the forward-to-aft usage ratio.

The flight control system also performed satisfactorily during the vehicle reboost maneuver, with the final altitude increase within 57 feet of the planned target.

The entry guidance, navigation and control operations were performed nominally. All baseline navigation external sensor data were incorporated into the onboard navigation state vector. However, because of a long period of data dropouts, the go was not given by ground control for TACAN incorporation in the state vector until after an altitude of 135,000 ft had been reached. As expected, the condition resulted in the annunciation of a "Nav Edit TAC" message. The postflight analysis showed that all external measurement residuals and residual ratio values were nominal with no navigation editing observed after data incorporation.

Displays and Control Subsystem

The displays and control subsystem performance was nominal throughout the flight.

Communications and Tracking Subsystems

The communications and tracking subsystems performed satisfactorily throughout the mission. The Ku-Band radar acquired the ISS at a range of 150 ft and operated satisfactorily throughout the fly-around and separation operations.

Operational Instrumentation/Modular Auxiliary Data System

The Operational Instrumentation (OI) subsystem and Modular Auxiliary Data System (MADS) performed satisfactorily throughout the mission.

Structures and Mechanical Subsystems

The structures and mechanical subsystems performed satisfactorily throughout the mission. The landing and braking parameters for this flight are shown in the following table.

LANDING AND BRAKING PARAMETERS

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	3290.7	196.6	-2.3	N/A
Nose gear touchdown	6038.3	157.7	N/A	-5.20
Brake initiation speed		151.8 knots		
Brake-on time		36.04 seconds		
Rollout distance		11612 feet		
Rollout time		47.8 seconds		
Runway		15 (Concrete) KSC		
Orbiter weight at landing		201,606.1 lb		
Brake sensor location	Peak pressure, psia	Brake assembly	Gross energy, million ft-lb	
Left-hand inboard 1	1637	Left-hand inboard	30.33	
Left-hand inboard 3	1637			
Left-hand outboard 2	1575	Left-hand outboard	29.45	
Left-hand outboard 4	1575			
Right-hand inboard 1	1975	Right-hand inboard	33.34	
Right-hand inboard 3	1975			
Right-hand outboard 2	1829	Right-hand outboard	30.26	
Right-hand outboard 4	1829			

The main landing gear tires were reported to be in excellent condition for a crosswind landing on the KSC concrete runway.

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. The EO-2 and EO-3 fitting retainer springs were bent. A total of seven clips were missing from the EO-3 "salad bowl". No umbilical closeout foam or white Room Temperature Vulcanizing (RTV) material adhered to the umbilical plate near the LH₂ recirculation line disconnect.

Integrated Vehicle Heating and Thermal Interfaces

The prelaunch thermal interface purges were normal with no problems noted. The ascent aerodynamic and plume heating was normal. The entry aerodynamic heating on the SSME nozzles was also normal. A postflight inspection showed that the damage was similar on the last two missions.

The acreage heating on the vehicle was nominal with the lower surface structural temperatures typical for this vehicle. Localized heating was normal.

Thermal Control Subsystem

The thermal control subsystem (TCS) performance was satisfactory for the STS-96 mission. All TCS temperatures were maintained within acceptable limits. The docked phase attitudes consisted of low beta angle with the ISS XPOP attitudes that resulted in the Sun initially 8 degrees above the Orbiter wing plane and then transitioning to below the wing plane by the end of the docked phase.

During the EVA, the first-time operation of the OV-103 external airlock water-line higher set-point "C" thermostats occurred. Each time the Liquid Cooling Garment (LCG) flow was stopped, the heater systems were activated to ensure that the chilled water lines in the payload bay would remain well above freezing. The heaters operated satisfactorily in maintaining the water line above the freezing level.

The hydraulic system 1 loop control sensors for the rudder speed brake Power Drive Unit (PDU) and the elevons and body flap PDU were set 20 to 25 °F lower than the nominal set-points to investigate potential cryogenic consumable savings for future ISS flights. The system 1 run times and frequency were significantly reduced compared to the STS-88 mission. There was no indication from the flight data that the -65 °F lower operational limit was violated. Also, model data show that all hydraulic area temperatures were above the -65 °F level, and all circulation pump inlet temperatures remained well above the lower limit of -20 °F.

STS-96 is the first flight where the forward vernier RCS 10-watt heaters were replaced with 18-watt heaters. The heaters were installed to prevent nuisance firings and unnecessary propellant usage when in stable attitudes where low firing rates allowed the leak detectors to approach the lower operational limit of 130 °F. Although most of the attitudes had significant firings, a comparison with a similar previous mission showed a 30 °F increase in the oxidizer injector temperature, and the in-flight tasks of managing the thruster temperatures was significantly reduced.

Aerothermodynamics

Data indicate that a symmetrical and normal boundary layer transition occurred, although it was the latest transition on the OV-103 vehicle. Aileron data, wing skin temperature and yaw thruster firings were all normal. Skin temperature rise data indicate a turbulent to laminar flow transition time of 1286 seconds. No protruding AMES gap fillers were reported.

Thermal Protection Subsystem and Windows

The Thermal Protection Subsystem (TPS) and windows performed nominally with no in-flight anomalies identified. Entry heating was normal based on structural temperature rise data. MADS data showed transition from turbulent to laminar flow occurred at Mach 7.5, which was 1286 seconds after entry interface and was symmetric.

The Orbiter TPS sustained a total of 199 damage sites (hits) during the mission. Of this total, 72 had a major dimension of 1-inch or larger. The total does not include the numerous damage sites on the base heat shield that are attributed to SSME vibration/acoustics, exhaust plume recirculation, and the flame arrestment sparkler system. A comparison of these numbers to 71 missions of similar configuration indicates that the total number of damage sites was much above average and the number of damage sites greater than 1-inch was significantly greater than the cumulative mission average. The table on the following page provides the data for the total number of damage sites on the STS-96 Orbiter.

TPS DAMAGE SITES

Orbiter Surfaces	Hits > 1 Inch	Total Hits
Lower Surface	66	160
Upper Surface	0	0
Right Side	4	4
Left Side	3	3
Right OMS Pod	0	4
Left OMS Pod	4	4
Window Area	4	24
Total	72	199

The initial evaluation indicates that two to three lower surface tiles will be scrapped as a result of debris damage. The largest lower surface damage site, located on the left inboard elevon, measured 6 inches long by 2 inches wide by 0.5 inch deep. Most of the lower surface damage was concentrated from the nose landing gear to the main landing gear wheel wells on both the left and right chines. The damage sites that were on the chines and outboard of the wheel wells followed a similar location/pattern that has been documented on the previous seven missions. A comparison of Orbiter lower surface tile damage statistics since STS-86 is shown in the following table.

COMPARISON OF DAMAGE SITE DATA FROM LAST EIGHT FLIGHTS

Parameter	STS -86	STS -87	STS -89	STS -90	STS -91	STS -95	STS -88	STS -96
Lower surface total hits	100	244	95	76	145	139	80	160
Lower surface hits > 1 in.	27	109	38	11	45	42	21	66
Longest damage site, in.	7	15	2.8	3.0	3.0	4.0	4.5	6.0
Deepest damage site, in.	0.4	1.5	0.2	0.25	0.5	0.4	0.5	0.5

The damage sites around and aft of the LH₂ and LO₂ ET/Orbiter umbilicals were attributed to impacts from umbilical ice or shredded pieces of umbilical purge barrier material flapping in the airstream.

Typical amounts of damage occurred on the base heat shield. All SSME Dome-Mounted Heat Shield (DMHS) closeout blankets were in excellent condition with the exception of frayed, torn, and missing material on the SSME 3 blanket between the 9:00 and 11:00 o'clock position.

Less than usual amounts of tile damage occurred on the base heat shield. All SSME DMHS closeout blankets were in excellent condition.

A somewhat unusual but favorable finding was the absence of any debris hits on the vertical stabilizer. Two large damage sites that were on the left OMS pod leading edge tiles were most likely the result of ice impacts from the overboard dump valves on the left forward fuselage.

Hazing and streaking on the forward-facing Orbiter windows was moderate. Damage sites on the window perimeter tiles were typical of old repair material falling out and were not included in the assessment.

Gas Sample Bottle Analysis

The gas sample bottles performed satisfactorily during the STS-96 ascent phase. The hardware provided the program with six excellent gas samples on this the twenty-sixth flight of the redesigned system. The data obtained during ascent was nominal with all six bottle pressures in the range expected. The hydrogen concentration was within the data base for all Space Shuttle vehicles. The oxygen data were within the bands of error as determined by the argon measurement, and the amount detected can be attributed to air.

EXTRAVEHICULAR OPERATIONS

The Extravehicular Mobility Unit (EMU) checkout was performed beginning at 148:03:55 G.m.t. (00:22:06 MET). All suits checked out satisfactorily to support the Extravehicular Activity (EVA). The communications checkout with the Space-to-Space Orbiter Radio (SSOR) and Space-to-Space EMU Radio (SSER) was satisfactory.

During the EVA prepressurization operations, the crew experienced difficulty in attaching the servicing and cooling umbilical (SCU) 1 to the EMU1 display and control module (DCM) (Flight Problem STS-96-X-01). The crew inspected the umbilical and could find no obvious cause for the problem. Postflight testing at KSC showed that SCU 1 was difficult to operate and jammed easily. Also, SCU 1 showed signs of wear and damage. The SCU was returned to Johnson Space Center (JSC) for repair.

The planned EVA was successfully executed with all scheduled tasks accomplished on schedule with one minor exception. During the Strela crane transfer activity, the crew was unable to break the torque on two of the bolts using the EVA power grip tool. The ratchet wrench and cheater bar were retrieved from the starboard stowage area, and the bolts were successfully removed. Strela was then successfully transferred to the Pressurized Mating Adapter-2 (PMA-2).

The scheduled EVA began when the EMUs were transitioned to battery power at 150:02:56 G.m.t. (02:16:07 MET) and ended at the start of airlock repressurization at 150:10:51 G.m.t. (03:99:02 MET) for a total EVA time of 7 hours and 55 minutes. The EVA was extended because the sortie cleanup required more time than expected, and the crew had difficulty attaching one of the umbilicals to the EMU during airlock ingress.

All of the EVA objectives were met including three of five additional get-ahead tasks that were identified for this mission. These additional tasks included installing the trunnion pin cover, photographing suspect areas of the Functional Cargo Block (FCB) paint and photographing the starboard Early Communications (ECOMM) antenna. Time did not permit the checkout of the U. S. Orbital Replacement Unit (ORU) Transfer Device (OTD) nor the photography of the Node 1 discoloration.

A retractable tether was lost overboard during the EVA (Flight Problem STS-96-X-02). The tether was attached to a fish stringer with an equipment hook, which came free and allowed the tether to be lost. Another retractable tether with two equipment hooks that were hooked to the EV2 crewmember "D" ring also came loose, but the tether and camera were captured before they were lost. The cause of these conditions has not yet been determined.

The Space-to-Space Communications System supported the EVA; however, a known problem was experienced. There were four occurrences of audio malfunctions, each of which was cleared by power cycling. The communication recovery procedures worked well. In addition, the EV2 crewmember reported a full volume high pitch squeal on three occasions. The ground also noted many instances during the EVA in which communications between the EVA personnel and the intravehicular personnel

degraded to choppy, then garbled, and finally total loss of the signal (Flight Problem STS-96-V-05). The communication upsets did not impact EVA operations.

During postflight processing, the simplified aid for EVA rescue (SAFER) unit that was worn by the EV1 crewmember was found to have a fired pyrotechnic valve and an open manual isolation valve (Flight Problem STS-96-X-03). Also, there was only 16 percent gaseous nitrogen in the unit. An investigation into the cause of this occurrence was in progress as this report was being written.

REMOTE MANIPULATOR SYSTEM OPERATION

The Remote Manipulator System (RMS) performance was very satisfactory throughout the mission. No in-flight anomalies were noted during the mission.

The RMS was powered up at 147:15:14 G.m.t. (00:04:25 MET). On-orbit initialization was successfully completed and the arm was powered down and placed in the temperature-monitor mode. The RMS was powered up at 148:07:14 G.m.t. (00:20:25 MET) to perform the on-orbit checkout, which was completed at 148:08:55 G.m.t. (00:22:06 MET). The payload bay survey was completed satisfactorily, and all RMS operations were nominal.

The RMS was powered up at 150:00:34 G.m.t. (02:13:45 MET), and checkout was performed to support the planned EVA. The arm was used to perform a survey of the starboard Early Communications System (ECOMM) on the ISS and an evaluation of the RMS Situational Awareness Display (RSAD) single-joint drive operations. The arm supported the planned EVA tasks with nominal performance. The planned RMS inspection of the Space Vision System (SVS) targets was canceled due to time limitations, but the inspection was rescheduled later in the mission.

Later in the mission, the RMS was used to perform a survey of the Early Communications (ECOMM) port antenna assembly. In addition, a survey was made of the Node 1 SVS targets.

GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

The overall performance of the Government Furnished Equipment/Flight Crew Equipment (GFE/FCE) was satisfactory. The one in-flight anomaly as well as the minor problem that were encountered are discussed in the following paragraphs.

During a video downlink at 147:17:07 G.m.t. (00:06:18 MET), the image from payload bay camera D became unusable. Numerous power cycles of the camera did not correct the problem, and camera D was considered failed for the remainder of the mission. A check of the camera later in the mission showed that the camera video was still unusable.

The Trajectory Control Sensor (TCS) performance in support of rendezvous and docking was satisfactory. The unit was powered at a range of approximately 3700 feet and powered off about 20 minutes after docking was completed.

The Space-to-Space Communications System supported the EVA; however, a known problem was experienced. There were four occurrences of audio malfunctions, each of which was cleared by power cycling. The communication recovery procedures worked well. In addition, the EV2 crewmember reported a full volume high pitch squeal on three occasions. The ground also noted many instances during the EVA in which communications between the EVA personnel and the intravehicular personnel degraded to choppy, then garbled, and finally total loss of the signal (Flight Problem STS-96-V-05). The communication upsets did not impact EVA operations.

The TCS operation was nominal, starting almost immediately after undocking at a distance of 5 ft. Satisfactory tracking continued to a separation distance of 2666 ft after which the TCS was powered off.

CARGO INTEGRATION

The analysis of data for the cargo integration hardware revealed satisfactory operation of all hardware with no in-flight anomalies noted.

POSTLAUNCH PAD INSPECTION

The postlaunch inspection of the launch pad showed that the damage was minimal and typical of previous launches from this complex. No flight hardware was found during the inspection.

No stud hang-up was experienced during the launch as the Orbiter lateral acceleration at liftoff was 0.11 g, which is below the threshold for stud hang-up. The hold-down post erosion exhibited typical exhaust plume damage.

Material covering the SRB flame deflector was missing from an area near the flame trench wall. The material had a 12 foot-long arc that was 12 to 18 inches wide and 4 to 6 inches thick. The pieces were scattered north of the flame trench throughout the pad acreage.

**DEVELOPMENT TEST OBJECTIVES/HUMAN EXPLORATION AND DEVELOPMENT
OF SPACE TECHNOLOGY DEMONSTRATION**

DEVELOPMENT TEST OBJECTIVES

DTO 261 - ISS On-Orbit Loads Validation (Hardware Pre-positioning Only) -

Installation of eight strain gauge cables to pre-positioned Node 1 strain gauges was completed successfully as part of the ISS-2A.1 logistics tasks. Operations of these strain gauges and collection of data are scheduled for the STS-97 (ISS-4A) mission.

DTO 686 - Heat Exchange Unit Evaluation - DTO 686 consisted of a Heat Exchange

Unit (HEU) or "chill can" that was connected to the supply water cross-tie quick disconnect and exposed to the vacuum of space for a period of 4 hours. The HEU contained approximately six ounces of water that slowly evaporated and cooled the surface of the HEU which in turn chilled the package of gelatin that was wrapped around the HEU. The DTO was performed three times, and all activities in support of this DTO were successfully completed.

DTO 690 - Urine Collection Device - The activities in support of this DTO were not included in the timeline and evaluations were made at the discretion of the crew. All activities were assumed to have been accomplished.

DTO 700-14 - Single String Miniature Air-to-Ground Receiver Global Positioning

System - The Single String Miniature Air-to-Ground Receiver (MAGR) Global Positioning System (GPS) on-orbit setup was successfully completed. The crew reported that 51 files were copied from the upper flash memory to the Payload and Ground Support Computer (PGSC) hard drive, and this was as expected for ascent. All the functions of the MAGR GPS were successfully performed and the results were nominal. This DTO evaluated the performance and operation of the GPS as a Space Shuttle navigation aid during all phases of the mission.

DTO 700-15 - Space Integrated Global Positioning System/Inertial Navigation

System - The Space Integrated GPS/Inertial Navigation System (SIGI) receiver performed satisfactorily throughout the flight. The SIGI was navigating with four satellites during ascent and entry.

DTO 805 - Crosswind Landing Performance - This DTO of opportunity was not performed because crosswind conditions did not exist at the time of landing.

DTO 847 - Solid State Star Tracker Size - This DTO of opportunity was performed and the results will be reported following the postflight evaluation of the data.

DTO 1214 - Resource Transfer Line Capability Evaluation - The crew completed the requirements of the DTO. These requirements consisted of fit-checking the PMA-2 nitrogen and oxygen recharge lines to the ISS quick disconnect and the Shuttle gaseous oxygen and gaseous nitrogen panel interfaces. The crew also performed the get-ahead task of pressure checking the nitrogen hose.

DTO 1215 - Space Station/Space Shuttle - Test of Color Printer - The printer was setup as scheduled. The printer was used for nominal operations with no anomalies reported.

HUMAN EXPLORATION AND DEVELOPMENT OF SPACE TECHNOLOGY DEMONSTRATION

HTD 1402 - Integrated Vehicle Health Monitoring - The Integrated Vehicle Health Monitoring (IVHM) technology demonstration performed very satisfactorily during the pre-mission data take with only two anomalies reported. These will be investigated during vehicle turnaround activities.

While on-orbit, the IVHM was activated approximately 1-hour daily during the pre-sleep time period to capture data during PRSD valve cycling. No verification was required from the crew, and no telemetry downlink was available from the payload to verify operation. The data will be dumped post-mission for analysis.

Two times during the mission, attitude changes were evaluated to determine thermal impact to the IVHM. Both attitude changes were minor and required no further action. This second mission of the IVHM was highly successful.

PHOTOGRAPHY AND VIDEO DATA ANALYSIS

LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS

A total of eleven 16 mm films, eight 35 mm films and 24 launch videos were reviewed. Some minor items of interest were noted in the films, but none of these events were anomalous or would affect the mission.

Film from the three umbilical well cameras [two 16 mm (one 5 mm lens and one 10 mm lens) and one 35mm] was viewed for possible anomalous conditions. The 16 mm film showed Solid Rocket Booster (SRB) separation to be normal. The wide-angle lens provided a view of the left SRB forward skirt/frustum/nose-cap during separation. The nose-cap was not recovered for postflight inspection, but it was intact and appeared to be in good condition in the film.

External Tank (ET) separation from the Orbiter appeared to be normal. The seal around the ET-Orbiter (EO) -2 fitting was properly positioned; however, the seal around the EO-3 fitting had come loose but was still attached. No anomalies were noted on the composite nose cone. The TPS repairs of the hail-damaged areas that were visible in the sunlit section of the LO₂ tank were intact and in good condition.

The views of ET after separation were poor because of the sun angle. Sunlight illuminated the far +Y side of the tank, but all areas of the -Y side of the LO₂ feedline were in shadow. Due to the graininess of the film, small divots in the +Y thrust panel were not visible. Also, both the -Y and +Y thrust struts exhibited typical erosion and very small divoting. Charring and "popcorn" divoting of the aft dome was typical.

The 35 mm film showed the hail damage repairs on the ET nose/ogive. The pattern appeared identical to that observed in the prelaunch closeout photography. No "new foam", which would be indicative of a failed or missing repair, was identified. However, several repair marks that were visible on the sunlit TPS in the -Y direction from the cable tray appeared to have shadows that would indicate depth and possible missing TPS. Kennedy Space Center (KSC) personnel indicated that the repairs were not all flat and flush with the outer mold line and the observed conditions appear to be normal. No other significant findings were noted in the analysis of the 35 mm film.

ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS

The STS-96 crew, using the hand-held 35 mm camera, exposed 38 frames of film on the ET after separation. The photographs had excellent exposure of the ET, rotating less than 1 deg/sec in full sunlight. Timing data were on the film, and the first exposure was made 14 minutes 21 seconds after liftoff with the ET calculated to be 1.6 kilometers from the Orbiter. Views of the aft dome, nose, and all sides of the ET were obtained. No evidence of significant damage was visible in the photographs.

Two divots were noted on the LH₂ tank-to-intertank closeout flange between the legs of the forward bipod. The normal SRB separation burn scars and aerodynamic heating marks were present on the intertank and nose TPS of the ET. The hail-damage repairs

were seen on the ET nose, and no indication of postlaunch damage to the repairs was visible. No venting was noted in any of the photographs.

The photographs of the +Y and -Y thrust panels were enhanced to provide more detail of those areas. Divots greater than 7 inches in size would be visible in the enhancements, but no divots were noted.

Light-colored marks were visible on the ET thrust panel and adjacent intertank TPS. Possible causes of these marks include the presence of TPS erosion and/or multiple divots too small to be resolved on the film.

In addition to the hand-held photographs, excellent quality video of the ET was also obtained, from which all aspects of the ET including the -Y and +Y thrust panels were evaluated. No significant ET damage was visible in the video.

The -Y thrust panel had fewer divots when compared with the video from the STS-95 vehicle. The first divot appeared 22 seconds after liftoff, and the second at approximately 90 seconds after liftoff. By 93 seconds after liftoff, multiple divots and discoloration and erosion of the TPS surface coating was visible.

Evaluation of the +Y thrust panel revealed a greater number of divots when compared with the -Y thrust panel. Also, the STS-96 +Y divoting appeared significantly greater than the divoting seen on the STS-95 video of the -Y panel. The view of the +Y panel was not acquired on the STS-95 mission. A minimum of 25 divots greater than 1 inch in size were counted on the +Y panel prior to SRB separation.

At approximately 60 seconds MET, discoloration and erosion of the TPS was detected on the +Y panel. The first divot that was seen on the video occurred at 92 seconds. At 95 seconds, the first divot greater than 1 inch in size was noted. By 110 seconds, multiple divots were present throughout the view of the +Y panel.

LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSIS

Seven videos of the landing sequence were reviewed and no anomalies were noted from the review. One landing film was also reviewed to obtain the sequence of landing events times.

TABLE I.- STS-96 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	147:10:44:52.284 147:10:44:53.984 147:10:44:55.441
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	147:10:49:14.101 147:10:49:14.261 147:10:49:14.421 147:10:49:14.581
Main Propulsion System Start ^a	ME-3 Start Command accepted ME-2 Start Command accepted ME-1 Start Command accepted	147:10:49:35.468 147:10:49:35.593 147:10:49:35.706
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	147:10:49:42.021
Throttle up to 104.5 Percent Thrust ^{ab}	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	147:10:49:45.905 147:10:49:45.908 147:10:49:45.912
Throttle down to 72 Percent Thrust	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	147:10:50:18.226 147:10:50:18.228 147:10:50:18.233
Maximum Dynamic Pressure (q)	Derived ascent dynamic pressure	147:10:50:42
Throttle up to 104.5 Percent Thrust ^{ab}	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	147:10:50:31.186 147:10:50:31.189 147:10:50:31.193
Both RSRM's Chamber Pressure at 50 psi ^a	LH SRM chamber pressure mid-range select RH SRM chamber pressure mid-range select	147:10:51:41.541 147:10:51:41.661
End RSRM ^a Action ^a Time	LH SRM chamber pressure mid-range select RH SRM chamber pressure mid-range select	147:10:51:43.701 147:10:51:44.151
SRB Physical Separation ^a	LH rate APU turbine speed - LOS RH rate APU turbine speed - LOS	147:10:51:46.421 147:10:51:46.425
SRB Separation Command	SRB separation command flag	147:10:51:46
OMS Assist Maneuver Ignition	Right Engine Bi-Prop Valve Position Left Engine Bi-Prop Valve Position	147:10:51:56.6 147:10:51:56.8
OMS Assist Maneuver Cutoff	Right Engine Bi-Prop Valve Position Left Engine Bi-Prop Valve Position	147:10:53:39.0 147:10:53:39.2
Throttle Down for 3g Acceleration ^a	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	147:10:57:03.509 147:10:57:03.517 147:10:57:03.521
3g Acceleration	Total load factor	147:10:57:03.4
Throttle Down to 67 Percent Thrust ^a	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	147:10:57:57.910 147:10:57:57.918 147:10:57:57.922
SSME Shutdown ^a	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	147:10:58:04.190 147:10:58:04.198 147:10:58:04.202

^aMSFC supplied data

^bSSME 1 is a Block IIA engine with a nominal power level of 104.5 percent.

**TABLE I.- STS-96 SEQUENCE OF EVENTS
(Continued)**

Event	Description	Actual time, G.m.t.	
MECO	MECO command flag	147:10:58:05	
	MECO confirm flag	147:10:58:05	
ET Separation	ET Separation Command flag	147:10:58:24	
APU Deactivation	APU-1 GG chamber pressure	147:11:05:44.860	
	APU 2 GG chamber pressure	147:11:05:53.517	
	APU 3 GG chamber pressure	147:11:06:01.861	
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	147:11:32:52.8	
	Right engine bi-prop valve position	147:11:32:52.8	
OMS-2 Cutoff	Left engine bi-prop valve position	147:11:35:37.2	
	Right engine bi-prop valve position	147:11:35:37.2	
Payload Bay Doors (PLBDs) Open	PLBD right open 1	147:12:23:19	
	PLBD left open 1	147:12:24:38	
OMS-3 Ignition	Left engine bi-prop valve position	147:13:49:24.3	
	Right engine bi-prop valve position	147:13:49:24.3	
OMS-3 Cutoff	Left engine bi-prop valve position	147:13:49:51.5	
	Right engine bi-prop valve position	147:13:49:51.7	
OMS-4 Ignition	Left engine bi-prop valve position	147:14:35:53.5	
	Right engine bi-prop valve position	147:14:35:53.6	
OMS-4 Cutoff	Left engine bi-prop valve position	147:14:36:12.6	
	Right engine bi-prop valve position	147:14:36:12.7	
Cabin Depressurization to (10.2 psi)	Cabin pressure	148:11:35	
OMS-5 Ignition	Left engine bi-prop valve position	149:01:35:18.3	
	Right engine bi-prop valve position	N/A	
OMS-5 Cutoff	Left engine bi-prop valve position	149:01:35:28.9	
	Right engine bi-prop valve position	N/A	
Airlock Depressurized - EVA	EMU battery activation	150:02:56	
Airlock Repressurized - EVA	Start Airlock Repressurization	150:10:51	
Cabin Repressurization to 14.7 psia	Cabin pressure	150:	
International Space Station RCS Reboost Maneuver			
	Start	Selected RCS thrusters firing	154:09:36:53.6
	End	Selected RCS thrusters not firing	154:10:11:40
Undocking	Undocking complete	154:22:36:47	
RCS Separation Maneuver			
	Start End	Selected RCS thrusters firing Selected RCS thrusters stop firing	155:00:53:19 155:00:53:30.7
Flight Control System Checkout APU 1 Start APU 1 Stop			
	APU 1 GG chamber pressure APU 1 GG chamber pressure	156:00:01:54.264 156:00:06:38.472	
Payload Bay Door Closure	PLBD left close 1	157:02:11:48	
	PLBD right close 1	157:02:13:22	
APU Activation for Entry	APU-2 GG chamber pressure	157:04:49:09.447	
	APU-1 GG chamber pressure	157:05:17:50.384	
	APU-3 GG chamber pressure	157:05:17:53.416	

**TABLE I.- STS-96 SEQUENCE OF EVENTS
(Concluded)**

Event	Description	Actual time, G.m.t.
OMS Deorbit Burn Ignition	Right engine bi-prop valve position	157:04:54:09.4
	Left engine bi-prop valve position	157:04:54:09.4
OMS Deorbit Burn Cutoff	Right engine bi-prop valve position	157:04:57:49.2
	Left engine bi-prop valve position	157:04:57:49.2
Entry Interface (400K feet)	Current orbital altitude above	157:05:30:49
Blackout end	Data locked (high sample rate)	No blackout
Terminal Area Energy Mgmt.	Major mode change (305)	157:05:56:18
Main Landing Gear Contact	RH MLG inboard tire pressure	157:08:02:43
	LH MLG inboard tire pressure	157:06:02:44
Main Landing Gear Weight on Wheels	RH main landing gear weight on wheels	157:06:02:45
	LH main landing gear weight on wheels	157:06:02:49
Drag Chute Deployment	Drag chute deploy 1 CP volts	157:06:02:51.1
Nose Landing Gear Contact	NLG RH tire pressure 1	157:06:02:57
Nose Landing Gear Weight On Wheels	NLG weight on wheels 1	157:06:02:57
Drag Chute Jettison	Drag chute jettison 1 CP Volts	157:06:03:18.3
Wheel Stop	Velocity with respect to runway	157:06:03:35
APU Deactivation	APU-1 GG chamber pressure	157:06:19:48.222
	APU-2 GG chamber pressure	157:06:19:55.356
	APU-3 GG chamber pressure	157:06:20:02.320

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

No.	Title	Reference	Comments
STS-96-V-01	RCS Thruster F4R Failed Leak	147:11:18 G.m.t. 00:00:29:03 MET IPR 103V-0002	<p>Shortly after a firing, RCS thruster F4R was declared fail leak, by the redundancy management (RM). The thruster pulsed five times with the fuel injector temperature dropping below the RM limit of 20 °F, reaching a minimum of 10.7 °F, then recovering to a nominal range. The temperature dropped after each firing and was recovering slowly when the last firing dropped the temperature below the RM limit. The thruster was reselected at 148:00:54 G.m.t. (00:14:05 MET) but placed in second priority. After undocking and the separation maneuver, thruster F4R was manually deselected for the remainder of the mission.</p> <p>KSC: The thruster will be removed and replaced during turnaround operations.</p>
STS-96-V-02	Right OMS Engine Ball Valve Sluggish Operation	147:10:51 56 G.m.t. 00:00:02:14 MET CAR 96RF02	<p>At the start of the OMS Assist Maneuver, shortly after SRB separation, the right OMS engine ball valve 2 displayed sluggish behavior. During the mission, the opening time was determined to be between 0.8 and 1.0 second. The File IX opening requirement is no more than 0.8 second. The subsequent OMS-2, OMS-3, and OMS-4 firings showed improved valve performance and were within the File IX requirement. The postflight review of the data determined that the File IX requirement was not violated. However, the review of the opening time data and comparison with the opening times of other OMS engines revealed that this engine opening time was out of family. With this data and the problem on STS-88, a decision was made to replace this engine.</p> <p>KSC: Remove and replace the engine during turnaround.</p>
STS-96-V-03	Vestibule Pressure Loss During the EVA	150:02:42 G.m.t. 02:15:56 MET CAR 96RF04 IPR 103V-0003	<p>During the 24-hour period prior to the EVA, when the vestibule was pressurized and isolated from the airlock, no loss of pressure from the vestibule was detected. During the subsequent airlock depressurization for the EVA, when the differential pressure (ΔP) between the airlock and the vestibule reached 8.97 psid, the leakage began. The vestibule pressure was 10.4 psi. When the ΔP decreased to 8.0 psid, the leakage stopped. These data indicate the transfer of gas across the hatch, from the vestibule into the airlock. The most probable cause of the airlock D hatch leakage was that the sealing surfaces separated slightly because of the high negative ΔP, which exceeded the capability of the latches as rigged.</p> <p>KSC: Troubleshooting will be performed.</p>
STS-96-V-04	Humidity Separator B Water Carry-Over	148:12:19 G.m.t. 01:01:30 MET CAR 96RF05	<p>At approximately 148:12:18 G.m.t. (01:01:30 MET), during the humidity separator in-flight checkout, the crew observed about one quart of water below the middeck floor at the outlet screen of the starboard (B) humidity separator. The crew cleaned up the water and switched to humidity separator A from B. Data indicate no leakage from any of the related water systems. Data also do not indicate any slugging flow (a condition resulting from either a rapid build up of condensation or a sudden jump in air flow through the heat exchanger that sweeps out excess water build up in the heat exchanger). Therefore, the most probable cause of the problem is believed to be clogging of the humidity separator's water flow path by debris. The lower than normal waste water collection rate</p>

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

No.	Title	Reference	Comments
STS-96V-04 (Continued)	Humidity Separator B Water Carry-Over	148:12:19 G.m.t. 01:01:30 MET CAR 96RF05	during the sleep period when this humidity separator was running this flight is evidence of some type of clogging. KSC: Humidity separator B will be removed and replaced..
STS-96-V-05	Space-to-Space Communication System (SCCS) EVA Communication Problems (GFE)	150:03:30 G.m.t. 002:16:41 MET	During the EVA, the EV2 crewmember reported a full volume high-pitch squeal three times. Each occurrence was heard by the ground and at least once was also reported by the EV1 crewmember. The squeal duration was between 5 and 10 seconds. The ground noted many instances during the EVA in which the communications between the EVA crewmembers and the intravehicular personnel became degraded to choppy, then garbled until at some point communications were completely lost. One case occurred near the beginning of the EVA when the EV1 crewmember was positioned on the zenith side of the ISS stack. Another case resulted in communications with significant background static noise. The condition was described to be like a signal that becomes gradually weaker, first choppy and garbled, until at some point the signal drops out completely. These two problems will be tracked in the overall corrective action plan along with the preflight predicted problem that did occur during the flight. KSC: No action required.

TABLE III - EVA EQUIPMENT PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-96-X-01	Difficulty in Attaching SCU 1 to EMU 1	150:12:44 G.m.t. 03:01:55 MET RDR B-EMU-300-FO	During EVA prepressurization operations, the crew had difficulty attaching SCU 1 to the EMU 1 DCM. An inspection of the SCU by the crew did not show any obvious cause for the problem. Post-flight testing at KSC showed that SCU1 was difficult to operate and jammed easily. SCU 1 showed signs of wear and damage. SCU 1 was returned to Houston for repair. KSC: No other additional work required.
STS-96-X-02	Lost/Loose EVA Hardware	150:03:25 G.m.t. 02:16:36 MET	During the EVA, a retractable tether which was attached to a fish stringer using an equipment hook came free from its attachment and was lost. Another retractable tether with two equipment hooks which was hooked to the EV2 crewmember's D-ring and a 35 mm camera came loose from the MWS but were captured by the EV2 crewmember before they were lost. An investigation of the problem is being conducted by JSC personnel. KSC: No KSC work required.
STS-96-X-03	SAFER postflight anomalies	161:21:17 G.m.t. Postflight	During the STS-96 post-flight processing, the SAFER unit (#1005) that had been worn by the EV1 crewmember, was found to have a fired NSJ pyrotechnic valve and an open manual isolation valve. There was 16 percent of the gaseous nitrogen in the SAFER. An investigation of this occurrence is being conducted by JSC personnel.

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. Mission Evaluation Room (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-96 Summary of Significant Events
16. Contractor Reports of Subsystem Operation

ACRONYMS AND ABBREVIATIONS

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

ABS	ammonia boiler system
APU	auxiliary power unit
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
ATCS	active thermal control system
BFS	backup flight system
CCTV	closed circuit television
CDR	Commander, U. S. Navy
CWC	contingency water container
dBm	decibel meter
DMHS	dome-mounted heat shield
DTO	Developmental Test Objective
ΔP	differential pressure
ΔV	differential velocity
ECLSS	Environmental Control and Life Support System
ECOMM	Early Communications System
EGT	exhaust gas temperature
EMU	extravehicular mobility unit
EO	ET/Orbiter
EPDC	electrical power distribution and control
e.s.t.	eastern standard time
ET	External Tank
EVA	extravehicular activity
FCE	flight crew equipment
FCMS	fuel cell monitoring system
FCS	flight control system
FGB	Functional Cargo Block
FPV	flow proportioning valve
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
GNC	guidance, navigation and control
GO ₂	gaseous oxygen
GPS	Global Positioning System
HEDS	Human Exploration and Development of Space
HEU	heat exchange unit
Hg	Mercury
HGDS	hazardous gas detection system
HPFTP	high pressure fuel turbopump
HPOTP	high pressure oxidizer turbopump

HTD	HEDS Technology Demonstration
ICC	Integrated Cargo Carrier
IFM	in-flight maintenance
IMU	inertial measurement unit
IPR	Interim Problem Report
I_{sp}	specific impulse
ISS	International Space Station
IVA	intravehicular activity
IVHM	Integrated Vehicle Health Monitoring
JSC	Johnson Space Center
km	kilometer
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt/hour
lb	pound
lbm	pound mass
lb/min	pound per minute
LCC	Launch Commit Criteria
LCG	liquid cooling garment
LH ₂	liquid hydrogen
LMSO	Lockheed Martin Space Operations
LO ₂	liquid oxygen
MADS	Modular Auxiliary Data System
MAGR	miniature airborne GPS receiver
MECO	main engine cutoff
MET	mission elapsed time
MLP	Mobile Launch Platform
mm	millimeter
MPS	main propulsion system
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NCC	rendezvous maneuver
nmi.	nautical mile
NSTS	National Space Transportation System (i.e., Space Shuttle Program)
ODS	Orbiter docking system
OI	operational instrumentation
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
ORU	Orbital Replacement Unit
OSVS	Orbiter Space Vision System
OTD	ORU Transfer Device
PAL	protuberance air load
PCT	post contact thrusting
PDU	power drive unit
PGSC	payload and general support computer
PMA	pressurized mating adapter
PMBT	propellant mean bulk temperature
POCC	Payload Operations Control Center
ppm	parts per million
PPCO ₂	partial pressure carbon dioxide

PRSD	power reactant storage and distribution
psia	pound per square inch absolute
psid	pound per square inch differential
RCS	reaction control subsystem
RM	Redundancy Management
RMS	Remote Manipulator System
RSAD	RMS Situational Awareness Display
RSRM	Reusable Solid Rocket Motor
RTV	room temperature vulcanizing (material)
S&A	safe and arm
SIGI	Space Integrated Global Positioning System/Inertial Navigation System
SLF	Shuttle Landing Facility
SLWT	super lightweight tank
S/N	serial number
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSER	Space-to-Space EMU Radio
SSME	Space Shuttle main engine
SSOR	Space-to-Space Orbiter Radio
SSVEO	Space Shuttle Vehicle Engineering Office
STARSHINE	Student Tracked Atmospheric Research Satellite for Heuristic International Networking Experiment
STS	Space Transportation System
SVF	Shuttle Vibration Forces
SVS	Space Vision System
SWAR	sea water activated release
TCS	trajectory control sensor/thermal control system
TPS	thermal protection system/subsystem
TVC	thrust vector controller
UCP	Unpressurized Cargo Pallet
Vdc	Volts direct current
WCS	waste collection system
WSB	water spray boiler
XPOP	X-axis perpendicular to orbital plane