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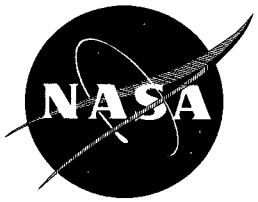
STS-103
SPACE SHUTTLE
MISSION REPORT

February 2000



**National Aeronautics and
Space Administration**

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

NOTE

The STS-103 Space Shuttle Mission Report was prepared from inputs received from the responsible Space Shuttle Program offices as well as other organizations. The following personnel may be contacted should questions arise concerning the technical content of this document.

Kenneth L. Brown 281-483-3891	Orbiter and Subsystems
James Yeager, MSFC 256-544-3963	MSFC Elements (SRB, RSRM, SSME, ET, SRSS, and MPS
Stephen G. Gaylor 281-483-1144	Payloads/Experiments
Ralph V. Anderson, JSC 281-483-1271	FCE and GFE

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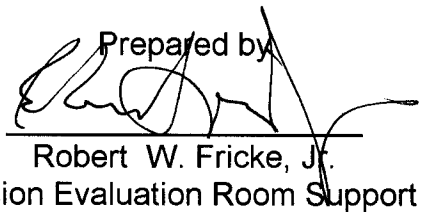
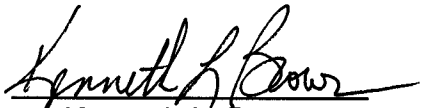
Prepared by

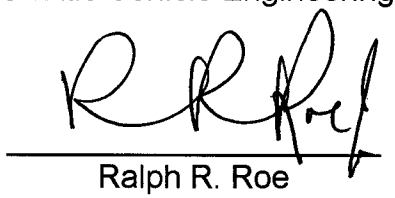


Robert W. Fricke, Jr.
LMSO/Mission Evaluation Room Support Section

Approved by



Kenneth L. Brown
STS-103 Lead Mission Evaluation Room Manager
Space Shuttle Vehicle Engineering Office



Ralph R. Roe
Manager, Space Shuttle Vehicle Engineering Office

Ronald D. Dittemore
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

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INTRODUCTION

The Space Transportation System (STS)-103 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 STS-103 flight was the third of four planned Hubble Space Telescope (HST) servicing missions that significantly upgrade the HST scientific capabilities. The remaining servicing mission is planned for 2001.

This Space Shuttle Program Mission Report presents a discussion of the Orbiter subsystem operation and the in-flight anomalies that were identified. The report also summarizes the activities of the STS-103 mission, and presents a summary of the External Tank (ET), Solid Rocket Booster (SRB), Reusable Solid Rocket Motor (RSRM), and SSME performance during this ninety-sixth mission of the Space Shuttle Program. STS-103 was the seventy-first flight since the return to flight, and the twenty-seventh flight of the OV-103 (Discovery) vehicle.

The flight vehicle consisted of the OV-103 Orbiter; an ET, which was the fifth Super Lightweight Tank (SLWT), and it was designated ET-101; three Block IIA Space Shuttle main engines (SSMEs) that were designated as serial numbers 2053, 2043, and 2049, in positions 1, 2, and 3, respectively; and two SRBs that were designated BI099. The two RSRMs were designated RSRM-73 with one installed in each SRB. The individual RSRMs were designated as 360W073A for the left SRB, and 360W073B for the right SRB.

The primary objectives of the STS-103 flight were to perform the operations necessary to fulfill the third on-orbit servicing requirements for the HST. The servicing tasks included replacement of the six gyroscopes that make up the three Rate Sensor Units (RSUs), completion of the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) valve-opening procedure, and installation of six Voltage Improvement Kits (VIKs). Additional tasks included the installation of a new computer, the installation of a fine guidance sensor, the replacement of the HST S-band Single Access Transmitter, the replacement of the Solid State Recorder, and the replacement of the worn multilayer insulation.

The STS-103 flight was planned as a 10-day plus 2-contingency-day flight. The two contingency days were available for bad weather avoidance for landing or other Orbiter contingency operations. However, because of the desire to land the vehicle prior to the end of the calendar year, a programmatic decision was made prior to launch to shorten the mission from 10 days with four extravehicular activities (EVAs) to eight days with only three EVAs. The sequence of mission events is shown in Table I, and the Orbiter In-Flight Anomaly List is shown in Table II. The EVA In-Flight Anomaly List is contained in Table III.

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

The seven-person crew of the STS-103 flight consisted of Curtis L. Brown, Lt. Col., U. S. Air Force, Commander; Scott J. Kelly, Lt. Cdr. U. S. Navy, Pilot; Steven L. Smith, Civilian, Mission Specialist 1 and Payload Commander; Jean-Francios Clervoy, European Space Agency, Civilian, Mission Specialist 2; John M. Grunsfeld, Ph. D., Civilian, Mission Specialist 3; C. Michael Foale, Ph. D., Civilian, Mission Specialist 4; and Claude Nicollier, Civilian, European Space Agency, Mission Specialist 5. STS-103 was the sixth space flight for the Commander, the fifth space flight for Mission Specialist 4, the fourth space flight for Mission Specialist 5, the third space flight for Mission Specialist 1, Mission Specialist 2 and Mission Specialist 3; and the first space flight for the Pilot.

MISSION SUMMARY

The STS-103 mission, the third Hubble Space Telescope (HST) maintenance mission, was launched at 354:00:49:59.986 G.m.t. (7:50 p.m. e.s.t.), December 19, 1999, and the Orbiter was inserted into the planned insertion orbit approximately 8 minutes 25 seconds later. The Orbiter subsystem performance during ascent and reconfiguration for the on-orbit portion of the mission was nominal in all respects.

A determination of vehicle performance during ascent was made using vehicle acceleration and preflight propulsion prediction data. The average flight-derived engine specific impulse (I_{sp}) was 452.9 seconds as compared to an main propulsion system (MPS) tag value of 452.1 seconds at the 104.5-percent power level. No in-flight anomalies were identified in any of the vehicle data during the ascent phase.

The orbital maneuvering subsystem (OMS) 2 maneuver was performed at 354:01:34:08.5 G.m.t. [00:44:08.5 mission elapsed time (MET)]. The OMS engines were fired for 152.9 seconds and the differential velocity (ΔV) was 246.8 ft/sec. The orbit following the maneuver was 170.2 by 315.4 nmi.

The payload bay doors were opened in dual motor time at 354:02:30.58 G.m.t. (00:01:40:58 MET). The Ku-band antenna was deployed at 354:02:41:27 G.m.t. (00:01:51:27 MET) in dual motor time.

The OMS 3 NC1 rendezvous maneuver was performed at 354:06:15:30.4 G.m.t. (00:05:25:04.4 MET) with nominal performance from both engines. The OMS engines were fired for 91.5 seconds imparting a ΔV of 151.4 ft/sec to the vehicle. The resulting orbit was 259 by 316 nmi.

During remote manipulator system (RMS) checkout, the end effector (EE) grapple fixture snares failed to fully open during the backup release test. During the test, power was applied for 19 seconds and downlink video showed that there were two periods of 3 to 4 seconds each where the snares tried to open (Flight Problem STS-103-V-01). When power was removed, the snares did not appear to have opened enough to allow a grapple pin to be released from the EE. The crew repeated the test and release occurred in approximately 15 seconds. The manual and auto EE release modes worked properly and there was no mission impact. Following the release of the HST, the backup release test was rerun five times. Each of the releases appeared nominal and the times were 17, 16, 16, 16 and 15 seconds.

The Orbiter cabin depressurization to 10.2 psia was initiated at 354:18:08 G.m.t. (00:17:18 MET). The depressurization was completed satisfactorily at 354:20:08:06 G.m.t. (00:19:18:16 MET).

The reaction control subsystem (RCS) NPC maneuver scheduled to occur at 354:22:16:35 G.m.t. (00:21:26:35 MET) was canceled.

It was noted at 354:23:53 G.m.t. (00:23:03 MET) that the HST turnaround plugs were not stowed for flight. These plugs are used to provide a backup method for the HST telemetry to bypass the payload signal processor (PSP) and go directly from the

payload interrogator to the payload data interleaver (PDI) and downlink to the ground. An in-flight maintenance procedure (IFM) was successfully performed to regain this backup method. A review of the documentation determined that the turnaround plugs were called out for use during the mission, but were not called out in the Orbiter stowage drawings, and consequently, were not stowed.

The OMS 4 NSR rendezvous maneuver was performed at 355:04:31:20.3 G.m.t. (01:03:41:20.3 MET) with nominal performance from both engines. The OMS engines were fired for 47.6 seconds imparting a ΔV of 79.2 ft/sec to the vehicle. The resulting orbit was 305 by 317 nmi.

The RCS NC2 rendezvous maneuver was performed at 355:05:26:49 G.m.t. (01:04:36:49 MET) with nominal subsystem performance. The firing was 31 seconds in duration and imparted 7.4 ft/sec to the vehicle. The resulting orbit was 306 by 318 nmi.

The OMS 5 rendezvous maneuver was initiated at 355:18:26:22 G.m.t. (01:17:36:22 MET). The right-engine maneuver was 19.8 seconds in duration and provided a ΔV of 16.1 ft/sec to the vehicle. The resulting orbit was 309 by 325 nmi.

The OMS 6 maneuver was performed with the left OMS engine at 355:19:14:33.6 G.m.t. (01:18:24:33.6 MET). The maneuver was 16.8 seconds in duration and a ΔV of 13.9 ft/sec was provided to the vehicle. The resulting orbit was 315 by 328 nmi.

Six RCS maneuvers were performed to complete the rendezvous with the HST. RCS performance during each of the maneuvers was nominal.

The HST rendezvous and capture was successfully conducted with the grapple completed at 356:00:34:01 G.m.t (01:23:44:01 MET). The RMS performance was nominal and berthing was accomplished at 356:01:42 G.m.t. (02:00:52 MET).

During rendezvous operations with the cabin pressure at 10.2-psia, the cabin air temperature exceeded the 80 °F limit, which is used to protect the avionics certification limit. The temperature reached a maximum of 82.4 °F, which was considered to be acceptable during the rendezvous period for this flight. Following completion of rendezvous and capture, the cabin-air temperature decreased to less than 80 °F. The contractor has been given an action to review the cabin temperature limit for 10.2 psia operations.

At 355:03:02:36 G.m.t. (01:02:12:36 MET), the Miniature Airborne Global Positioning System (GPS) Receiver (MAGR) [Development Test Objective (DTO) 700-14] performed an autonomous reset (tilt) following an extended period of degraded tracking during the single antenna tracking test. Prior to the upper-antenna-only test, which began at 35416:18 G.m.t. (00:15:28 MET), the MAGR performance appeared nominal, with the exception of erroneous antenna-in-view indications from prior to launch until 355:03:02:26 G.m.t (01:02:12:36 MET). Nominal MAGR behavior resumed following the tilt.

Crew egress on flight day 4 for the first extravehicular activity (EVA) to service the HST occurred at 356:19:01 G.m.t. (02:18:11 MET). The EVA crewmembers were Steve Smith (EV1) and John Grunsfeld (EV2). As a result of the new airlock depressurization procedure, no significant HST solar-array disturbance was observed during egress from the airlock. EVA 1 was successfully completed at 357:03:09:46 G.m.t. (03:02:19:46 MET) for an official EVA time of 8 hours and 15 minutes. Activities that the crew completed included the installation of three new HST rate sensor unit (RSU) assemblies, completion of the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) valve-opening procedure, and installation of six Voltage Improvement Kits (VIKs). The HST project reported that the initial checkout of all RSU assemblies indicated proper functioning. Functional testing of the VIK was completed during flight day 5 with satisfactory results.

During EVA 1 operations, the Power Ratchet Tool (PRT) failed to function properly and this resulted in using the Pistol Grip Tool (PGT) as a backup tool. Additionally, the roll joint jammed on one of the STS Portable Foot Restraints (PFRs) making it unusable for the remaining EVAs. However, the STS PFR from the forward bulkhead was available. Following the EVA, the crew reported that one side of extravehicular mobility unit (EMU) middeck battery charger (serial no. 1002) was not functioning properly. The spare charger (serial no. 1001) was used and a nominal recharge was performed. The crew also reported that the EV1 crewmember Communications Carrier Assembly (CCA) lost audio on one side during airlock repressurization. As a result, the EV1 crewmember used the EV4 crewmember's CCA during EVA 3.

Crew egress for the second EVA to continue servicing the HST occurred at 357:19:11 G.m.t. (03:18:21 MET). The EVA crewmembers were Michael Foale (EV3) and Claude Nicollier (EV4). EVA 2 was successfully completed at 358:03:16 G.m.t. (04:02:26 MET) for an official EVA time of 8 hours and 10 minutes. Activities that the crew completed included the changeout of telescope's central computer and the fine guidance sensor.

During EVA 2 operations, the HST PFR boot-plate pitch joint would not lock. The HST PFR was brought into the cabin following the EVA and evaluated and behaved normally after some initial cycling. The HST PFR was not used for the remaining EVA, but it was taken into the payload bay for stowing during EVA 3.

Also, the EV4 crewmember reported a carbon dioxide (CO_2) high message on his display control module (DCM) about 4 ½ hours into the EVA 2. The EMU CO_2 sensor was reading 30 millimeters of mercury, which corresponds to a full-scale high value. For this case, crewmembers are reminded to perform a self-evaluation of potential high CO_2 symptoms throughout the remainder of EVA.

During EVA 3 preparation, the EV2 EMU 2 DCM showed a failed built-in test equipment (BITE) indication and the crewmember received a caution and warning tone when the EMU was switched to battery power (Flight Problem STS-103-X-01). The power source switch was cycled, and the anomaly did not clear. EMU 2 was considered non-operational and replaced with EMU 3. Resizing of the suit was completed using previously developed procedures.

Crew egress for the third EVA to perform the final servicing of the HST occurred at 358:19:54 G.m.t. (04:19:04 MET). The EVA crewmembers were Steve Smith (EV1)

and John Grunsfeld (EV2). EVA 3 was successfully completed at 359:03:24 G.m.t. (05:02:34 MET) for an official EVA time of 8 hours and 8 1/2 minutes. Activities that the crew completed included the changeout of the telescope's S-Band Single Access Transmitter and Solid State Recorder as well as replacement of the worn multilayer insulation on bays 9 and 10 of the HST. Because of time limitations, replacement of the insulation on bays 5, 6, 7, and 8 was not attempted.

Prior to airlock repressurization at the end of EVA 3, the Airlock Power Supply (ALPS) would not power EMU 3 with the servicing and cooling umbilical (SCU) connected. A repeat operation of the airlock wall switch produced the same results. The repressurization was performed with EMU 3 on battery power. An inspection of the DCM and SCU electrical connectors following repressurization identified two bent pins on the DCM side connector (Flight Problem STS-103-X-02). The location description from the crew along with downlinked photos were used to determine that the pin numbers were 12 and 13, which are SENSE + and SUIT POWER. An interruption in either contact would cause the ALPS to shut down power. Ground personnel identified a procedure to attempt straightening the bent pins using an on-board connector pin tool should EMU 3 be required for a contingency EVA.

The HST was unberthed from the flight support system (FSS) in the payload bay at 359:21:18:41 G.m.t. (05:20:28:41 MET). The HST was released by the RMS at 359:23:03:01 G.m.t. (05:22:13:01 MET). The RMS performance was satisfactory during the HST release.

Following the release of the HST, two RCS separation maneuvers were performed. The first was initiated at 359:23:03:45 G.m.t. (05:22:13:45 MET) with a total firing duration of 5 seconds. A total of 1.2 ft/sec was imparted to the vehicle. The second separation maneuver was initiated at 359:23:38:54 G.m.t. (05:22:48:54 MET) with a total firing duration of 5 seconds. A total of 1.2 ft/sec was imparted to the vehicle.

Four minor video camera problems were noted during the mission.

a. At 354:02:00 G.m.t. (00:01:12 MET), the downlinked video from camera D exhibited two smudges on the lens. The two smudges were oval in shape and easily observed. This condition did not impact mission operations.

b. At 359:03:22 G.m.t. (05:02:32 MET), the downlinked video from camera A exhibited a pink and blue image during a pass through the South Atlantic Anomaly. Ground controllers performed a power cycle of the camera and a normal image returned. The problem did not repeat.

c. At 359:13:49 G.m.t. (05:13:09 MET), ground controllers reported that the iris on the camera C lens went to a fixed full-open position. A short power cycle did not clear the problem. An extended camera power down of about one hour was performed, and after power up the iris function returned to normal.

d. At 360:12:05 G.m.t. (06:11:15 MET), video from camera D showed that the camera A pan/tilt cable was catching on the camera pan/tilt hardware at certain pan/tilt angles. As a result of the interference, camera A's full tilt capability was lost at pan angles approximately ±20 degrees from the aft direction.

The flight control system (FCS) checkout was performed using auxiliary power unit (APU) 1 at 360:18:52:01.740 G.m.t. (06:18:02:01.740 MET). The data showed FCS and APU performance was nominal. The checkout run lasted for 4 minutes 13 seconds and 13 lb of fuel were consumed. Because of the short run-time of the APU, water spray boiler (WSB) 1 cooling was not required as the APU 1 lubrication oil temperature only reached 200 °F.

The RCS hot-fire began at 360:19:44 G.m.t. (06:16:54 MET) and was completed by 360:19:53 G.m.t. (06:17:03 MET). All primary thrusters were fired without incident.

A RCS orbit adjust maneuver was performed at 360:21:08:30.1 G.m.t. (06:20:18:30.1 MET). Two –X primary RCS thrusters were fired for 94.7 seconds and 24.1 ft/sec were imparted to the vehicle. The perigee of the orbit was lowered 15 nmi., and the orbit was 301 by 329 nmi.

The payload bay doors were closed and latched for landing at 361:18:28:01 G.m.t. (07:17:38:01 MET). The dual-engine deorbit maneuver for the first landing opportunity at the Kennedy Space Center (KSC) Shuttle Landing Facility (SLF) was waved because of excessive crosswinds and observed turbulence in the pitch axis. The deorbit maneuver for the second KSC landing opportunity was performed on orbit 119 at 361:22:48:26.2 G.m.t. (07:21:58:26.2 MET). The maneuver was 289.0 seconds in duration with a ΔV of 513.8 ft/sec.

Entry interface occurred at 361:23:29:41 G.m.t. (07:22:39:41 MET), and entry was completed satisfactorily. At 361:23:52:16 G.m.t. (07:23:02:16 MET) when the air data probes were deployed, the left air data probe did not complete deployment until about 1 minute later. A data review was made and the initial indications were that a switch tease may have occurred.

At 361:23:58:15 G.m.t. (07:23:08:15 MET), which was approximately 2 minutes 33 seconds prior to landing, the right nose landing gear tire pressure measurement began toggling off-scale low. This condition caused a tire pressure message to be annunciated several times.

Main landing gear touchdown occurred on SLF concrete runway 33 at 362:00:00:47 G.m.t. (07:23:10:47 MET) on December 27, 1999. The drag chute was deployed at 362:00:00:49.9 G.m.t. The nose gear touchdown occurred at 362:00:00:58 G.m.t. The drag chute was jettisoned at 362:00:01:17.7 G.m.t. with wheels stop occurring at 362:00:01:35 G.m.t. The rollout was normal in all respects. The flight duration was 7 days 23 hours 10 minutes 47 seconds. The APUs were shut down 18 minutes 4 seconds after landing.

During the postflight inspections of the vehicle, a black tile was found missing from the right inboard elevon, -Y side edge, and infrared data revealed no objects falling from the Orbiter during final approach and landing (Flight Problem STS-103-V-02). STS-103 was the sixth flight of this tile since it was installed. The forward piece of strain isolation pad (SIP) was completely missing with only remnants of SIP fibers showing in the bonding adhesive. Room temperature vulcanizing (RTV) material was dark red in color and appeared to be bubbled. The perimeter of the SIP areas had dark outgassing deposits. The aft SIP was mostly intact. A few areas existed where the tile dense layer was still adhered to the SIP. A large area of the SIP appears to be intact with some of

the membrane still in place. Damage to the aft fuselage sidewall tile was in line with the missing tile and was most likely caused by the tile when it came off. The structure will be ultrasound tested and conductivity tested to ensure that no delamination of the honeycomb to facesheet occurred. This condition was made a constraint to the launch of STS-99.

The left-hand radial carbon carbon (RCC) was found damaged during the postflight inspections (Flight Problem STS-103-V-03). The damage is located two inches below the apex on the leading edge of the panel. Substrate is visible. The damaged panel was removed and shipped to the vendor. There was no damage in the area behind the outer mold-line damage, and coin tap inspection revealed no internal damage in this area. A detailed inspection of the panel interior revealed that the lower inboard lug that had been previously repaired four times was cracked again. This condition was made a constraint to the launch of STS-99.

PAYLOADS

HUBBLE SPACE TELESCOPE

Summary

STS-103 was the third servicing mission to the Hubble Space Telescope (HST), which was launched on STS-31 on April 25, 1990,. The Science Community was pleased with the satisfactory functional testing of the components replaced during the extravehicular activities (EVAs). All of the HST listed primary objectives for the third servicing mission were fully accomplished.

a. Installation of three rate sensor units (RSUs), containing six gyroscopes;

b. Installation of six voltage/temperature improvement kits (VIKs);

c. Installation of a 486 computer; and

d. Installation of fine guidance sensor (FGS) 2, including connecting of the FGS to the optical control electronics enhancement kit (OCE-EK).

In addition to the primary objectives, the following listed secondary objectives were also successfully accomplished.

a. Exchange of S-band single-axis transmitter 2 (SSAT2);

b. Replacement of the Engineering/Science Tape Recorder (ESTR) with a solid–state recorder; and

c. Installation of new outer blanket layers (NOBL) on bays 9 and 10.

All of these units passed their functional tests and were operating satisfactorily when this report was written. The HST was redeployed on December 25, and normal science operations were resumed after completion of the checkout period.

Mission Operations

All HST cargo elements were unpowered, as planned, for launch. The HST aperture door was automatically closed in November when the fourth gyroscope failed. The high gain antenna was retracted prior to rendezvous. On flight day 2, the HST space support equipment (SSE) activation and checkout was performed as well as a survey of the SSE and the payload bay with the remote manipulator system (RMS).

After completion of the satisfactory rendezvous, the HST was grappled with the RMS at 356:00:34:01 G.m.t. (01:23:44:01 MET). The HST was berthed in the flight support system (FSS) in the payload bay at 356:01:42 G.m.t. (02:00:52 MET). Following the connection of the HST umbilical and power being supplied by the Orbiter, a detailed photographic survey was made of the HST. The initial results of the survey showed the

HST to be in good condition with no apparent changes from the last servicing mission (STS-82),

During the three EVAs, the crew performed all the planned tasks. In addition, the crew also opened two near infrared camera and multi-object spectrometer (NICMOS) coolant valves during the first EVA. Opening these valves allowed any residual coolant in those lines to be vented into space in preparation for servicing activities on the next HST mission. A total of 24 hours 32 minutes was spent on EVA operations to service the HST.

The crew successfully redeployed the HST on time into a 330 by 316 nmi. orbit on flight day 7 (Christmas day). No reboost of the HST was planned or performed during this mission. With the successful completion of the post-deployment checkout operations, the HST resumed normal scientific operations on January 8, 2000.

VEHICLE PERFORMANCE

SOLID ROCKET BOOSTERS

All Solid Rocket Booster (SRB) systems performed nominally, with the exception of the left-hand C-band transponder, which is discussed in a following paragraph. The SRB prelaunch countdown was normal, and no SRB Launch Commit Criteria (LCC) or Operational Maintenance Requirements and Specifications Document (OMRSD) violated occurred. Likewise, no in-flight anomalies have been identified in the data analysis and review.

This was the fourth flight for the External Tank (ET) thermal protection system (TPS) observation cameras, one of which was flown on each SRB. The cameras functioned as designed and provided continuous visual coverage of the ET thrust panel area from liftoff to SRB separation.

Two data acquisition system (DAS) units, one flown on each SRB, failed to record any data. An investigation has shown that through an oversight, neither unit was initialized prior to flight. The DAS procedure has been reviewed and modified to prevent a recurrence of this condition.

Evaluation of the thrust vector controller (TVC) data indicated that the TVC subsystem responded as expected to the SSME trim modifications that were flown on the previous eight flights as well as STS-103. These trim changes decreased the angle between the SSME and the SRB thrust vectors during first stage, after which the SRB thrust vectors were trimmed to maintain moment balance. The trimming of the SRB thrust vectors resulted in the TVC actuator positions being outside of their experience base during certain specific time frames. The overall actuator position experience base was not exceeded, only certain areas of the time-specific experience base were expanded.

Both SRBs were successfully separated from the ET 124.8 seconds after liftoff, and reports from the recovery area indicate that all deceleration subsystems performed nominally with the exception of two sea-water activated release links on one of the main parachutes. The SRBs were retrieved and towed to port and transferred to KSC where the SRBs were disassembled and refurbishment was initiated.

REUSABLE SOLID ROCKET MOTORS

Data indicate that all Reusable Solid Rocket Motor (RSRM) subsystems performance was well within the allowable envelopes and was typical of the performance observed on previous flights. No LCC or OMRSD violations occurred during the countdown, nor were any in-flight anomalies noted during the data review and analysis. Delivered burn rates were a nominal 0.3670 and 0.3674 inch per second for the left and right RSRMs, respectively.

Power-up and operation of all igniter and field joint heaters were accomplished routinely. All RSRM temperatures were maintained within acceptable limits throughout the countdown. The heated, ground-supplied, aft skirt purges maintained the case/nozzle joint and flex bearing temperatures within the required LCC ranges.

The motor performance parameters for this flight were within the contractor end item (CEI) specification limits. Reconstructed propulsion performance is summarized in the following table. The calculated RSRM propellant mean bulk temperature (PMBT) was 70 °F at liftoff. The maximum trace-shape variation of pressure versus time was calculated to be 0.43 percent at 62 seconds (left motor) and 1.16 percent at 79 seconds (right motor). Both values were well within the 3.2 percent allowable limits.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 70 °F		Right motor, 70 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10^6 lbf-sec	64.97	65.05	64.90	64.71
I-60, 10^6 lbf-sec	174.17	174.58	174.03	173.26
I-AT, 10^6 lbf-sec	297.15	297.77	297.13	296.08
Vacuum Isp, lbf-sec/lbm	268.5	269.1	268.5	267.6
Burn rate, in/sec @ 60 °F at 625 psia	0.3674	0.3670	0.3672	0.3674
Event times, seconds[a]				
Ignition interval	0.232	N/A	0.232	N/A
Web time[b]	109.9	110.3	110.0	110.1
50 psia cue time	120.0	119.8	120.1	120.2
Action time[b]	122.2	122.3	122.4	122.6
Separation command	124.5	124.7	124.5	124.7
PMBT, °F	70	70	70	70
Maximum ignition rise rate, psia/10 ms	90.4	N/A	90.4	N/A
Decay time, seconds (59.4 psia to 85 K)	3.1	3.5	3.1	3.4
Tailoff Imbalance Impulse differential, Klbf-sec	Predicted		Actual	
	N/A		310.9	

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

[a]All times are referenced to ignition command time except where noted by a [b]

[b]Referenced to liftoff time (ignition interval).

The field joint heaters operated for 12 hours 26 minutes during the launch countdown. Power was applied to the heating elements 26-percent (average) of the time during the LCC time frame. The field joint heaters on this flight heated unevenly. As a result, as well as the expected cold temperatures, the heater set point was lowered from 98 °F to 90 °F. This action avoided any field joint temperature violations and maintained the temperatures in family.

The igniter joint heaters operated 12 hours 17 minutes during the final countdown. Power was applied to the heaters 61-percent of the time and the igniter joints were maintained in their normal operating range.

The aft skirt purge was activated three times during the LCC time frame of the final countdown for a total of 5 hours 51 minutes to maintain the nozzle/case joint

temperatures above the minimum LCC temperature. The final flex bearing mean bulk temperature was 81 °F.

EXTERNAL TANK

All objectives and requirements associated with the ET propellant loading and flight operations were met. No significant oxygen or hydrogen leakage concentrations were detected in the intertank. All ET electrical equipment and instrumentation operated satisfactorily. The ET purge and heater operations were monitored and all performed properly. No LCC or OMRSD violations were identified.

No unexpected ice/frost formations were observed on the ET during the countdown. Likewise, there was no ice or frost observed on the acreage areas of the ET. Less than normal quantities of ice or frost were present on the liquid oxygen (LO_2) and liquid hydrogen (LH_2) feedlines, the pressurization line brackets, and along the LH_2 protuberance air load (PAL) ramps. Two typical cracks in the TPS, the largest of which was approximately 10 inches long and 1/8 inch wide. All observations were acceptable per NSTS 08303.

Propellant loading was nominal. All LO_2 and LH_2 tank ullage pressures were within acceptable limits throughout loading and prepressurization. Hydrogen ullage pressure transducer 2 exhibited dropouts during replenish, but performed normally during ascent. Hydrogen ullage pressure sensor 3 exhibited the "stuck wiper" behavior at low tank pressures but performed normally during ascent. This condition is common to the transducers installed in these applications.

The ET pressurization system functioned properly throughout engine start and flight. The minimum LO_2 ullage pressure could not be measured as the telemetry sensor did not operate most of the time when there was no change in the tank pressure.

ET separation occurred as planned, with entry and breakup of the ET occurring approximately 93 nmi. uprange of the preflight predicted point and well within the predicted footprint for impact.

SPACE SHUTTLE MAIN ENGINES

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

Flight data indicate that the SSME performance during main-stage, throttling, shutdown and propellant dump operations was normal, and no in-flight anomalies were identified during the data analysis. The high-pressure oxidizer turbopump (HPOTP) and high-pressure fuel turbopump (HPFTP) temperatures were well within specifications throughout engine operation. Space Shuttle main engine cutoff (MECO) occurred 505.4 seconds after lift-off, and this was 0.5 second later than predicted preflight. The specific impulse (I_{sp}) was 452.9 seconds, which was 0.8 second higher than predicted based on engine acceptance tests. There were no failures and significant SSME problems during the flight.

SSME 2045 was originally scheduled to fly on the STS-103 mission. However, during the review process the decision was made to remove the engine and retrieve a drill bit that had broken off inside the main injector between the primary and secondary face plates. The engine change was accomplished in the Vehicle Assembly Building prior to the vehicle being rolled out to the launch pad.

During the normal postflight inspection of SSME 2043 and HPFTP 6014, a second stage turbine tip seal segment was found to have an area were the nickel was debonded. The STS-99 vehicle was cleared for launch for this issue as the investigation of this problem is continuing.

SHUTTLE RANGE SAFETY SYSTEM

The Shuttle range safety system (SRSS) performed as designed. The SRSS closed-loop testing was completed as scheduled during the launch countdown. All SRSS safe and arm (S&A) devices were armed and system inhibits turned off at the appropriate times. As planned, the SRB S&A devices were safed, and SRB power was turned off at the appropriate times. All SRSS measurements indicated that the system operated as expected throughout the flight. The SRSS was deleted from the ET.

ORBITER SUBSYSTEMS PERFORMANCE

Main Propulsion System

The overall performance of the main propulsion system (MPS) was nominal, with no LCC or OMRSD violations noted during the prelaunch operations nor any in-flight anomalies noted during ascent.

During the first ET loading, the LH_2 liquid level sensor failed to respond within the 9-second limit. The liquid-level sensor checkout was repeated with nominal results and no further action was required.

The hydrogen Orbiter inlet temperature sensor data became suspect at approximately minus 2 hours in the countdown, because of a sudden data shift of + 4 degrees. This sensor provides backup data to confirm the tail service mast (TSM) drain during the countdown. A work-around was implemented to use the television image of the TSM to observe the drain valve position, if necessary. The work-around was not implemented because the TSM drain was normal.

The LO_2 and LH_2 loading were completed satisfactorily with no stop-flows or reverts. Throughout the period of the preflight operations, no significant hazardous gas concentrations were detected. The maximum hydrogen concentration level in the Orbiter aft compartment was approximately 78 ppm, which compares favorably with previous data for this vehicle.

Ascent performance was normal, and data indicate that the LO_2 and LH_2 pressurization subsystems performed as planned. Likewise, all net positive suction pressure (NPSP) requirements were met throughout the flight. Performance analyses of the propulsion systems during start, mainstage, and shutdown operations indicated that the performance was nominal and all requirements were satisfied. Tabulations of

prelaunch, MECO, post-MECO and entry/landing events revealed no anomalous valve movements. All timings were within the required specification and within current historical data.

The gaseous hydrogen (GH_2) system in-flight performance was nominal. The gaseous oxygen (GO_2) fixed orifice pressurization system performed as predicted. Reconstructed data from engine and MPS parameters closely matches the actual ET ullage-pressure measurements. All three flow control valves operated nominally. Helium system performance for the SSME and pneumatic helium systems was nominal. Entry helium usage was 58.5 lbm which is within the requirements.

Reaction Control Subsystem

The reaction control subsystem (RCS) performed satisfactorily throughout the mission. No LCC or OMRSD violations were noted prior to launch, and no failures of problems were noted during the mission.

A total of 4269.6 lbm propellants (2586.6 - oxidizer, 1683 - fuel) were used during the rendezvous mission with the HST. The primary RCS thrusters had 3552 firings and a total firing time of approximately 1139.97 seconds. The vernier RCS thrusters had 12662 firings and a total firing time of 10956.72 seconds. No aft interconnect operations occurred with the orbital maneuvering subsystem (OMS). No in-flight anomalies were noted during the data review and analysis.

On-orbit, a total of twelve RCS translational maneuvers were performed. These included two phasing maneuvers for rendezvous, five rendezvous maneuvers, two separation maneuvers, two post-OMS maneuver corrections and one orbital adjustment maneuver, which used the forward RCS. The RCS maneuvers are shown in the table on the following page.

The flight day 2 flight plan was revised to reprioritize three of the thrusters (F2R, F2D, and L2U) from first priority to last priority to protect against a single jet driver failure causing the loss of manifold 2 thrusters. This reprioritization was performed on every flight that used the OI-26B flight software because the I-loaded thruster priorities have all the F2 and L2 thrusters in first priority.

The RCS hot-fire began at 360:19:44 G.m.t. (06:16:54 MET) and was completed by 360:19:53 G.m.t. (06:17:03 MET). All primary thrusters were fired without incident.

A RCS orbit adjust maneuver was performed at 360:21:08:30.1 G.m.t. (06:20:18:30.1 MET). The perigee of the orbit was lowered 15 nmi. to an orbit of 301 by 329 nmi.

During entry at 361:23:11:41 G.m.t. (07:22:27:41 MET), a four-thruster 18-second forward RCS propellant dump was made. The thrusters used were F1L, F3L, F2R, and F4R and all performed nominally. After landing, the postflight redundant circuit verification test was performed with satisfactory results. All applicable valves and switches were exercised.

RENDEZVOUS, SEPARATION, AND ORBIT ADJUST MANEUVERS

Maneuver[a]	Time, G.m.t./MET	System	ΔV, ft/sec	Duration, sec
NC-1 Trim	355:04:32:23 01:03:42:23	RCS Primary	0.06	0.44
NC-2	355:05:26:49 01:04:36:49	RCS Primary	7.4	31
NSR Trim	355:18:26:55.1 01:17:36:55.1	RCS Primary	0.2	0.24
NCC	355:21:28:00 01:20:38:00	RCS Primary	0.3	1.0
TI	355:22:28:06 01:21:38:06	RCS Primary	4.1	8.7
MC-1	355:22:48:06 01:21:58:06	RCS Primary	0.3	0.5
MC-2	355:23:22:58 01:22:32:58	RCS Primary	0.9	2.9
MC-3	355:23:39:58 01:22:49:58	RCS Primary	0.4	1.0
MC-4	355:23:49:58 01:22:59:58	RCS Vernier	1.8	7.2
SEP 1	359:23:03:45 05:22:13:45	RCS Primary	1.2	4.8
SEP 2	359:23:38:54 05:22:48:54	RCS Primary	1.2	4.8
-X ORBIT ADJUST	360:21:08:30.1 06:20:18:30.1	FRCS Primary	24.1	94.7

[a] Two maneuvers, NPC and NC-3, were cancelled.

Orbital Maneuvering Subsystem

The OMS performed satisfactorily in every aspect of the subsystem throughout the mission. Pertinent data concerning the OMS maneuvers is shown in the following table.

Maneuver	Time, G.m.t./MET	ΔV, ft/sec	Duration, sec
OMS 2	354:01:34:08.5 00:00:44:38.5	246.8	152.9
OMS 3	354:06:15:30.4 00:05:25:30.4	151.4	91.5
OMS 4	355:04:31:20.3 01:03:41:20.3	79.2	47.6
OMS 5 (right engine)	355:18:26:22.0 01:17:36:22.0	16.1	19.8
OMS-6 (left engine)	355:19:14:33.6 01:18:24:33.6	13.9	16.8
Deorbit	361:22:48:26.2 06:21:58:26.2	513.8	289.0

No deviations from the OMRSD or LCC requirements occurred during prelaunch operations. No in-flight anomalies were identified from the data review and analysis. The six OMS maneuvers consumed 22,967 lbm of propellants during the mission.

Approximately 1.5 hours prior to launch, the left OMS engine arm/pressurization switch indicated arm/pressurization after being set to the arm/pressurization position. The OMS gaseous nitrogen accumulator pressure indicated that the isolation valve had actuated properly. After approximately 3 seconds, the switch contact showed the switch to be in the off position. The crew reported that the switch appeared to be in the arm/pressurization position; however, when compared with the right arm/pressurization switch, the left switch was slightly offset. The crew took the switch to off and the switch contact showed momentarily showed the switch to be in the arm/pressurization position prior to showing off, thus indicating that the switch had been close to the arm/pressurization position. The switch was taken again to the arm/pressurization position and operated normally for the remainder of the countdown and the flight.

Power Reactant Storage and Distribution Subsystem

The performance of the power reactant storage and distribution (PRSD) subsystem was nominal during the STS-103 mission. No in-flight anomalies were identified from the data analysis and review. The PRSD subsystem supplied a total of 2041 lbm of oxygen and 257 lbm of hydrogen to the fuel cells for electrical energy production. In addition, the PRSD supplied 123 lbm of oxygen to the environmental control and life support system (ECLSS) for life support. One set of the oxygen/hydrogen manifold isolation valves were cycled each day to support the crew sleep periods and satisfy the OMRSD in-flight checkout requirement. A 122-hour mission-extension capability existed at landing based on the oxygen (limiting reactant) remaining at an average power level of 15.6 kW. However, at an extension-day power-level of 13.2 kW, a 144-hour mission-extension capability existed.

One item of interest was noted during the cabin depressurization while oxygen tank 4 was controlling the manifold pressure. The pressure decayed to below 811 psia, causing the oxygen tank 1 heaters to activate. The high flow to the cabin during this process, 9.9 lbm of oxygen, caused the manifold pressure to decay faster than oxygen tank 4 could manage. The pressure stabilized and increased nominally when the tank 1 heaters came on. This situation has been noted in previous-mission cabin depressurizations.

Fuel Cell Powerplant Subsystem

Performance of the fuel cell powerplant (FCP) subsystem was nominal throughout the STS-103 mission. The average electrical power level and load was 15.6 kW and 507 amperes. During the 191.2-hour flight, the fuel cells produced 2,298 lbm of water and 2,982 kWh of electrical energy from 2,041 lbm of oxygen and 257 lbm of hydrogen. Three purges of the fuel cells were performed during the flight, and both the automatic and manual modes were demonstrated. The actual fuel cell voltages at the end of the mission were 0.25 V above the predicted value for fuel cells 1 and 3, and 0.3 V above the predicted value for fuel cell 2.

The overall thermal performance of the fuel cell water relief, water line, and reactant purge systems was nominal. All heaters operated properly.

The fuel cell monitoring system provided data on individual cell voltages during the prelaunch, on-orbit, and postlanding time periods. All cell performance monitor values remained stable throughout the mission. The fuel cell 3 alternate water line temperature was erratic for the entire mission. The check valve in this line has a history of internal leakage that allows a small amount to warm fuel cell water to leak into the alternate water line. This condition does not impact normal fuel cell operation in any manner.

Auxiliary Power Unit Subsystem

The auxiliary power unit (APU) subsystem performed nominally throughout the STS-103 mission. No APU in-flight anomalies were recorded. The run times and fuel consumption for the APUs are summarized in the following table.

APU RUN TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (a) (b) (S/N 310)		APU 2 (a) (S/N 204)		APU 3 (a) (S/N 404)	
	Time, Min:sec	Fuel consumption, lb	Time, min:sec	Fuel Consumption, Lb	Time, min:sec	Fuel consumption, lb
Ascent	20.37	53	20:42	58	20:46	55
FCS checkout	4:13	13				
Entry[a]	61:36	122	95:10	198	61:53	139
Total	86:26	188	115:52	256	82:39	194

[a] APUs were shut down 18 minutes 02 seconds after landing.

The APU 1 exhaust gas temperature 1 (EGT 1) measurement was erratic for about one minute after start-up before liftoff, went open for about 2 minutes after FCS checkout shutdown, and then was erratic twice for a total period of more than three minutes during entry. This sensor will be replaced prior to the next flight of this APU.

Hydraulics/Water Spray Boiler Subsystems

The overall hydraulics and water spray boiler (WSB) subsystem performance was nominal. There were no WSB over-cooling or under-cooling conditions noted during ascent or entry. Likewise, no in-flight anomalies were identified from the data. All three WSBs operated nominally throughout the flight. No leakage was noted in the system.

The WSB 2 relief valve cracking pressure was slightly higher during ascent. This same condition occurred on the previous flight of this vehicle. The actual cracking pressure was 0.13 psig above the maximum of 33.5 psig. The fact that the valve cracked and then reseated nominally indicates that no major concern exists. The most likely cause is minor stiction in the relief valve knife-edge poppet seal or spring seat assembly. Checkout of this valve will be performed during the turnaround flow operations.

Flight control system (FCS) checkout was performed with system 1, and APU 1 ran for 4 minutes 13 seconds. Because of the short operating time of the APU, no WSB cooling was noted. The lubrication oil return temperature reached approximately 200 °F at APU shutdown.

Hydraulic performance was nominal during entry. Hydraulic heat exchanger mode was achieved on all three systems. Systems 1 and 2 achieved heat exchanger mode during entry and system 3 postlanding.

Electrical Power Distribution and Control Subsystem

The data review and analysis of all available electrical power distribution and control (EPDC) subsystem parameters revealed nominal values throughout the flight. No in-flight anomalies were identified, and all file IX requirements were fulfilled.

Atmospheric Revitalization Pressure Control Subsystem

The atmospheric revitalization pressure control subsystem (ARPCS) performed normally throughout the flight. The redundant component check of the pressure control system was performed normally, and the alternate system performed nominally. The active system monitor parameters indicated normal outputs throughout the duration of the flight.

Cabin depressurization to 10.2 psia in preparation for the planned extravehicular activities (EVAs) was begun at 354:17:08 G.m.t. (00:18:18 MET) and completed at 043:04:36 G.m.t. (00:19:41 MET). During the depressurization, the activity was stopped at 10.5 psia to install a modified depressurization valve cap. The depressurization was then resumed to 9.5 psia to verify the valve cap flow rate before its intended use during the three EVAs. The depressurization rate was at the expected value and the cabin pressure was raised to 10.2 psia.

Following the completion of the third EVA, the cabin repressurization to 14.7 psia was initiated at 360:00:11:00 G.m.t. (05:23:41:00 MET) and was completed satisfactorily.

Atmospheric Revitalization Subsystem

All atmospheric revitalization subsystems (ARS) performed nominally during the mission.

On the previous two missions of this vehicle, the avionics bay IIIA differential pressure (ΔP) approached the OMRSD and LCC upper limit of 4.3 inches of water. During STS-103, the fan ΔP peaked at 4.1 inches of water. This was due in part to the removal of the Space-to-Space Orbiter Radio (SSOR) avionics box but the SSOR orifice remained installed.

For the STS-103 mission, the water separator was replaced with a newly refurbished unit. No water carry-over was noted during the flight, and the refurbished separator operated nominally.

During the 10.2 psia cabin pressure operations, the cabin temperature climbed above the 80 °F limit. These conditions occurred during the rendezvous/grapple of the HST, during the third EVA, and during the deployment of the HST. The first excursion of the temperature was above the 80 °F limit for 5 hours and 15 minutes, and peaked to 82.4 °F for a duration of 1 hour 22 minutes. Prior to the second excursion, the crew was requested to power on cathode ray tube (CRT) 4. Approximately two hours later, the cabin temperature sensor indicated 78 °F and measured temperatures at other positions in the cabin were in the lower 70 's. Postflight tests of the cabin temperature sensor will be made to verify it operation. About 4 ½ days into the mission, the cabin temperature controller was configured to the secondary controller, which operated nominally for the remainder of the mission.

Active Thermal Control Subsystem

The active thermal control subsystem (ATCS) operation was satisfactory throughout the mission.

Radiator flow was initiated at 354:02:09 G.m.t. (00:01:19 MET), and the payload bay doors were opened 22 minutes later. The radiators were not deployed during this mission. Both Freon loop flow proportioning valves remained in the interchanger position for the entire mission to provide cooling support for the cabin during the 10.2 psia operations. The flash evaporator system (FES) was turned off to warm up the liquid cooling garment (LCG) lines in preparation for the first EVA. The original plan was to leave the FES off for 26 minutes; however, the FES was off for over an hour and that caused the cabin temperature to rise. The FES was not turned off for the remainder of the EVAs, and the external airlock water line heater string C was used to condition the water lines for the EVAs.

The payload bay doors were closed at 361:18:24 G.m.t. (07:17:34 MET), and the radiator cold soak was satisfactory in providing cooling throughout entry. The radiators were turned to the high setpoint four minutes after landing, and the ammonia boiler system (ABS) B was activated less than two minutes later. The ABS B system provided cooling for 41 minutes after which system A was turned on. Ground cooling was initiated about nine minutes later and the FES outlet temperature began responding to the ground cooling.

Supply and Waste Water Subsystem

The supply and waste water subsystems performed nominally throughout the mission, and all file IX requirements were satisfied prior to landing. No in-flight anomalies were identified from the data analysis and review.

Prior to launch, water tank A was depressurized to 15.0 psia with the tank quantity at 54 percent and the galley isolation valve open. The isolation valve is normally closed in this condition to prevent the ingestion of air into the tank. The crew was informed that air may possibly be in the initial water dispenses. The crew did not report any air problems during the mission or during postflight debriefings.

Supply water was managed through the use of the flash evaporator system (FES) and the overboard dump system. Three supply water dumps were performed at an average

rate of 1.6 percent/minute (2.7 lb/min). The supply water dumps were simultaneous with the waste water. The supply water dump line temperature was maintained between 59.7 and 95.8 °F with the operation of the line heater.

Waste water was gathered at about the predicted rate. Three waste water dumps were performed at an average rate of 1.8 percent/minute (3.0 lb/min). The waste water dump line temperature was maintained between 57.2 and 85.8 °F through the use of a line heater. The vacuum vent line temperature was maintained between 58.5 and 83.3 °F.

Waste Collection Subsystem

The waste collection subsystem performed normally throughout the mission with no in-flight anomalies or problems identified.

Airlock Support System

The airlock support system performed satisfactorily in the support of three EVAs. The active system monitor parameters indicated normal outputs throughout the remainder of the flight.

As a result of the procedures followed on the STS-82 mission (second HST repair mission), new procedures were developed for depressurizing the cabin and to prevent damage to the solar arrays on the HST. The new procedure allowed a flow rate of less than 100 lb/hr, and the procedure was satisfactory in that little of no movement of the HST solar cells was noted during the three depressurizations.

Prior to airlock repressurization at the end of EVA 3, the Airlock Power Supply (ALPS) would not power EMU 3 with the servicing and cooling umbilical (SCU) connected. A repeat operation of the airlock wall switch produced the same results. The repressurization was performed with EMU 3 on battery power. An inspection of the DCM and SCU electrical connectors following repressurization identified two bent pins on the DCM side connector. The location description from the crew along with downlinked photos were used to determine that the pin numbers were 12 and 13, which are SENSE + and SUIT POWER. An interruption in either contact would cause the ALPS to shut down power. Ground personnel identified a procedure to attempt straightening the bent pins using an on-board connector pin tool should EMU 3 be required for a contingency EVA.

Smoke Detection and Fire Suppression Subsystem

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

Flight Data System

The flight data systems performed satisfactorily throughout the STS-103 mission. No in-flight anomalies were identified during the review and analysis of the data.

Flight Software

The flight software performed flawlessly throughout the mission. No in-flight anomalies or problems were identified in the data review and analysis.

Flight Control Subsystem

Flight control system (FCS) performance was satisfactory throughout the duration of the mission.

The inertial measurement unit (IMU) performance was nominal during prelaunch operations and during the mission.

Descent navigation performed nominally with no hardware failures of deselections by the redundancy management (RM).

An evaluation of the –Y and –Z star tracker performance showed nominal operations.

The backup flight system (BFS) navigation data exhibited similar characteristics to the primary flight system. Postflight error analysis has shown good comparison between the primary flight system state vectors and the BFS state vectors.

Displays and Controls Subsystem

The displays and controls subsystem performed nominally throughout the mission.

Communications and Tracking Subsystems

The communications and tracking subsystems performed nominally. No in-flight anomalies were identified. Minor problems were noted, but none had any impact on the successful completion of the mission.

Four minor video camera problems were noted during the mission.

a. At 354:02:00 G.m.t. (00:01:12 MET), the downlinked video from camera D exhibited two smudges on the lens. The two smudges were oval in shape and easily observed. This condition did not impact mission operations.

b. At 359:03:22 G.m.t. (05:02:32 MET), the downlinked video from camera A exhibited a pink and blue image during a pass through the South Atlantic Anomaly. Ground controllers performed a power cycle of the camera and a normal image returned. The problem did not repeat.

c. At 359:13:49 G.m.t. (05:13:09 MET), ground controllers reported that the iris on camera C iris went to a fixed full-open position. A short power cycle did not clear the problem. An extended camera power down of about one hour was performed, and after power up the iris function returned to normal.

d. At 360:12:05 G.m.t. (06:11:15 MET), video from camera D showed that the camera A pan/tilt cable was catching on the camera pan/tilt hardware at certain

pan/tilt angles. As a result of the interference, camera A's full tilt capability was lost at pan angles approximately ±20 degrees from the aft direction.

Operational Instrumentation/Modular Auxiliary Data System

The operational instrumentation (OI) subsystem and modular auxiliary data system (MADS) performed nominally.

At 361:23:58:15 G.m.t. (07:23:08:15 MET), which was approximately 2 minutes 33 seconds prior to landing, the right nose landing gear tire pressure measurement began toggling off-scale low. This condition caused a tire pressure message to be annunciated several times. An evaluation will be performed to determine the cause of this condition.

Structures and Mechanical Subsystems

The structures and mechanical subsystems performed satisfactorily throughout the mission. Landing data are presented 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	2925.9	185.0	-1.74	N/A
Nose gear touchdown	5998.2	138.2	N/A	-4.59

Brake initiation speed	108.0 knots
Brake-on time	29.94 seconds
Rollout distance	6,975.2 feet
Rollout time	48.15 seconds
Runway	33 (Concrete) KSC
Orbiter weight at landing	212,311 lb

Brake sensor location	Peak pressure, psia	Brake assembly	Gross energy, million ft-lb
Left-hand inboard 1	863.2	Left-hand inboard	17.69
Left-hand inboard 3	863.2		
Left-hand outboard 2	821.6	Left-hand outboard	16.83
Left-hand outboard 4	821.6		
Right-hand inboard 1	927.1	Right-hand inboard	16.13
Right-hand inboard 3	927.1		
Right-hand outboard 2	831.2	Right-hand outboard	15.21
Right-hand outboard 4	831.2		

During airlock ingress following the second EVA, the crew noted that one of the PIP pins on the starboard hinge was out of place. The pin was re-inserted and the hatch closure was nominal. Discussions with the crew revealed that the pin could have been

bumped. The crew checked the pins while egressing for EVA 3 and reported that the pins were properly installed and secure.

At 361:23:52:16 G.m.t. (07:23:02:16 MET) when the air data probes were deployed, the left air data probe did not complete deployment until about 1 minute later. Data evaluation indicated that the switch was initially moved from the stowed to the deploy position at the time shown and came partially out of the deployed position 0.7 second later. The switch was repositioned to the deploy position 48 seconds later and the probe deployed nominally in dual motor time. Postflight discussions with the crew revealed that a clear switch position feedback was not present on the left probe switch. They believe that the imperfect initial positioning of the left probe switch was the cause of the non-deployment.

The Orbiter tires were in good condition for a landing at KSC with a 5 to 8 knot crosswind.

The ET/Orbiter (EO) separation devices (EO-1, EO-2 and EO-3) functioned normally. No ordnance fragments were found on the runway beneath the umbilicals. The EO-2 and EO-3 fitting retainer springs appeared to be in the nominal configuration. No umbilical closeout foam or white room temperature vulcanizing (RTV) dam material adhered to the umbilical plate near the LH_2 recirculation-line disconnect.

All components of the drag chute were recovered and appeared to have functioned normally. Both reefing line cutter pyrotechnics were expended. A postflight inspection of the drag chute door frame lug revealed that the upper shear pin lower lug had a gouged damage place on the upper face. Also, the lower lug shear pin was displaced. An evaluation of the cause of this condition is continuing.

Integrated Aerodynamics, Heating and Thermal Interfaces

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

The entry aerodynamic heating to the SSME nozzles was nominal.

Thermal Control Subsystem

The performance of the thermal control subsystem (TCS) was satisfactory throughout the mission. The mission was benign from a thermal standpoint. All Orbiter subsystem temperatures were maintained within acceptable limits, and heater operation was nominal.

The upper and lower heater control set points for the hydraulic circulation pump were lowered between 25 and 30 °F to provide data on cryogenic consumption for future power-critical missions. No circulation pump runs occurred during the mission; however, few were expected because of the warm attitude profile. The lowest temperature observed on the hydraulic circulation pumps was an acceptable –14 °F.

Aerothermodynamics

At the time of this writing, the MADS data has not been reduced so that an evaluation of the aerothermodynamics can be made.

Thermal Protection Subsystem and Windows

The TPS performed satisfactorily. Entry heating was significantly higher than expected based on lower-surface structural temperature response data. Boundary layer transition from laminar flow to turbulent flow cannot be determined as the MADS data from entry, which could be used to confirm the transition, has at this writing not been released for evaluation. The bondline temperature data indicate a higher-than-usual temperature rise, which may indicate the occurrence of early transition.

A black tile from the right inboard elevon, -Y side edge, was missing, and infrared data revealed no objects falling from the Orbiter during final approach and landing (Flight Problem STS-103-V-02). The missing tile was the right-hand inboard elevon drain hole tile, and it was installed on June 8, 1996. STS-103 was the sixth flight of this tile since it was installed. This tile contained a two-piece strain isolation pad (SIP) to accommodate the drain hole and drain path. The forward piece of SIP was completely missing with only remnants of SIP fibers showing in the bonding adhesive. Room temperature vulcanizing (RTV) material was dark red in color and appeared to be bubbled. The perimeter of the SIP areas had dark outgassing deposits. The aft SIP was mostly intact. A few areas existed where the tile dense layer was still adhered to the SIP. A large area of the SIP appeared to be intact with some of the membrane still in place. Membrane and the surface of the SIP where membrane was missing was charred. The remainder of SIP (mostly along bottom and aft edges) was charred and eroded. Filler bar around the perimeter of the tile cavity had category II/III charring. The flexible reusable surface insulation (FRSI) edge member along the top surface was degraded and bubbled. The gap filler along the forward edge of the cavity was in place with only minor damage. The gap filler on the bottom edge (adjacent to lower surface tiles) was missing though residue gap filler material was noted on the filler bar in several locations along the bondline. Gap filler along the aft edge of cavity (adjacent to corner tile) was missing. Gap filler between the corner tile and the upper surface trailing edge tile was missing with no sign of charring at the inner mold line. The elevon trailing edge honeycomb section was under the aft piece of SIP and therefore somewhat protected. There were two damage sites to the tiles aft of the missing tile. One tile had a small damage site on one corner and the second had a small damage site on the forward edge, and the silica in the damaged areas was not glazed. However, the lower forward corner of one of the two tiles had a slumped area with molten gap filler material evident on the surface. The interior of the drain hole exhibited only minor outgassing deposits. Damage to the aft fuselage sidewall tile was in line with the missing tile and was most likely caused by the tile when it came off.

The structure will be ultrasound tested and conductivity tested to ensure that no delamination of the honeycomb to facesheet occurred. This condition was made a constraint to the launch of STS-99.

The left-hand radial carbon carbon (RCC) was found damaged during the postflight inspections (Flight Problem STS-103-V-03). The damage was located two inches below the apex on the leading edge of the panel. Substrate was visible. The damaged

panel was removed and shipped to the vendor. There was no damage in the area behind the outer mold-line damage, and a coin tap inspection revealed no internal damage in this area. A detailed inspection of the panel interior revealed that the lower inboard lug that had been previously repaired four times was cracked again. This condition has been made a constraint to the launch of STS-99. Postflight non-destructive tests and an inspection of a cross-section of the damaged area confirmed that the damage was caused by an impact. The damage had trademark impact signatures, which included coating impact failure surfaces and coating debris in the cavity. The final analysis was unable to identify the source of the pink and yellow discoloration.

The postlanding inspection of the Orbiter TPS identified a total of 153 impacts of which 18 had a major dimension of 1-inch or larger. The distribution of these impacts on the vehicle is shown in the following table. This total does not include the numerous damage sites on base heat shield that are attributed to the flame arrestment sparkler system, SSME vibration/acoustics and exhaust plume recirculation.

TPS DAMAGE SITES

Orbiter Surfaces	Hits > 1 Inch	Total Hits
Lower Surface	13	84
Upper Surface	1	9
Window Area	9	43
Right Side	1	5
Left Side	0	2
Right OMS Pod	0	4
Left OMS Pod	0	6
Total	24	153

A comparison of the number of damage sites with statistics from previous missions indicates that both the total number of hits as well as the number of hits 1-inch or larger compared well with the cumulative fleet average when compared with previous missions.

The total number of lower surface impact sites was 84, of which 13 were greater than 1-inch in diameter. Approximately half of the damage sites were concentrated in the area from the nose gear to the main landing gear wheel wells on both the left and right chines. The location/damage pattern was similar to that observed on the previous nine flights. In general, the lower surface tile damage on STS-103 is considered to be at the lower end of the damage spectrum when compared with the symmetrical damage pattern on the forward part of the Orbiter that first began being measured on STS-86. Preliminary indications are that venting the ET intertank TPS has had a positive effect on reducing the number and size of Orbiter lower surface tile damage sites forward of the main landing gear.

The largest lower surface tile damage site, located near the LH_2 ET/Orbiter umbilical, measured 5 inches long by 2.5 inches wide by 0.25 inch deep. The damage sites around the LH_2 and LO_2 ET/Orbiter umbilicals were greater in number and size than usual. This damage was caused by contact with shredded pieces of umbilical purge

barrier material flapping in the airstream. This condition is very visible in the launch films.

COMPARISON OF DAMAGE SITE DATA FROM LAST NINE FLIGHTS

Parameter	STS -86	STS -87	STS -89	STS -90	STS -91	STS -95	STS -88	STS -96	STS -93	STS -103
Lower surface total hits	100	244	95	76	145	139	80	160	161	84
Lower surface hits > 1 in.	27	109	38	11	45	42	21	66	42	13
Longest damage site, in.	7	15	2.8	3.0	3.0	4.0	4.5	4.0	6.0	1.5
Deepest damage site, in.	0.4	1.5	0.2	0.25	0.5	0.4	0.5	0.5	0.5	0.25

Typical amounts of tile damage were noted on the base heat shield. All SSME dome-mounted heat shield (DMHS) closeout blankets were in good condition although the material was torn/frayed at the 12:00 o'clock position on SSME 1 and the 9:00 to 12:00 o'clock position on SSME 3.

Tiles on the vertical stabilizer and "stinger" were intact and mostly undamaged. One small damage site was attributed to a launch debris impact rather than contact from the drag chute risers. No significant damage was noted on the OMS pods.

Damage sites on the window perimeter tiles were greater than usual in both quantity and size. There were 43 hits with 9 larger than 1-inch in the vicinity of the windows. The damage may be attributed to impacts from the forward RCS thruster paper covers and RTV adhesive. Hazing and streaking of forward-facing Orbiter windows was moderate.

GAS SAMPLE BOTTLE RESULTS

The gas sample bottle system operated nominally and provided the program with six excellent gas samples on this twenty-eighth flight of the redesigned system. All six bottle pressures were in the range expected. The hydrogen concentration was within the data base for all Space Shuttle vehicles. The oxygen data was within the bands of error as determined by the argon measurement, and the amount detected is attributed to air.

STS-103 was the third flight for these bottles, which had been subjected to the same cleaning procedures and vacuuming processing cycle as when the bottles were new.

EXTRAVEHICULAR ACTIVITY OPERATIONS

Three scheduled extravehicular activities (EVAs) were performed during the third Hubble Space Telescope (HST) reservicing mission. All of the STS-103 EVA major mission objectives were successfully completed. A total of 24 hours 32 minutes of official EVA time are credited to the OV-103 crew members and total man-hours EVA are 49 hours 04 minutes.

EVA 1

Crew egress on flight day 4 for the first EVA to service the HST occurred at 356:19:01 G.m.t. (02:18:11 MET). The EVA crewmembers were Steve Smith (EV1) and John Grunsfeld (EV2). As a result of the new airlock depressurization procedure, no significant Hubble Space Telescope (HST) solar-array disturbance was observed during egress from the airlock. EVA 1 was successfully completed at 357:03:09:46 G.m.t. (03:02:19:46 MET) for an official EVA time of 8 hours and 15 minutes.

Upon exiting the airlock, the crew began configuring the remote manipulator system (RMS) for the EVA. After completion of the RMS setup activities, the manipulator foot restraint (MFR) –based crewmember was maneuvered to the HST doors which covered the three rate sensor units (RSUs). During the changeout of the RSUs, the arm was used to move the crew between the RSU work-site locations and the orbital replacement unit (ORU) carrier that was fixed in the payload bay. The replacement RSUs were stowed in the contingency ORU protective enclosure (COPE) portion of the ORU carrier. The COPE also served as the storage location for the removed SRUs.

After successfully completing the RSU changeout, the arm was used to move the crew to the location for reconfiguration of the Near Infrared Camera and Multi-Object Spectrometer (NICMOS) valves. The valves were opened in preparation for the upcoming installation of the NICMOS cooling system (NCS) during the next HST servicing mission that is scheduled for 2001. With the completion of the valve-opening procedure, the doors were closed and secured.

The final major EVA task of the first EVA was the installation of the six Voltage Improvement Kits (VIKs). These were installed on the batteries in bays 3 and 2 to prevent overheating when recharging the batteries. The HST project reported that the checkout of all RSU assemblies indicated proper functioning. Functional testing of the VIK was completed during flight day 5 with satisfactory results.

During EVA 1 operations, the Power Ratchet Tool (PRT) failed to function properly and this resulted in using the Pistol Grip Tool (PGT) as a backup tool. Additionally, the roll joint jammed on one of the STS Portable Foot Restraints (PFRs) making it unusable for the remaining EVAs. However, the STS PFR from the forward bulkhead was available. Following the EVA, the crew reported that one side of extravehicular mobility unit (EMU) middeck battery charger (serial no. 1002) was not functioning properly. The spare charger (serial no. 1001) was used and a nominal recharge was performed. The crew also reported that the EV1 crewmember Communications Carrier Assembly (CCA) lost audio on one side during airlock repressurization. As a result, the EV1 crewmember used the EV4 crewmember's CCA during EVA 3.

EVA 2

Crew egress for the second EVA to continue servicing the HST occurred at 357:19:11 G.m.t. (03:18:21 MET). The EVA crewmembers were Michael Foale (EV3) and Claude Nicollier (EV4). EVA 2 was successfully completed at 358:03:16 G.m.t. (04:02:26 MET) for an official EVA time of 8 hours and 10 minutes.

During EVA 2 operations, the HST PFR boot plate pitch joint would not lock. The HST PFR was brought into the cabin following the EVA and evaluated and behaved normally after some initial cycling. The HST PFR was not used for the remaining EVA, but it was taken into the payload bay for stowing during EVA 3.

After exiting the airlock, one crewmember ingressed the MFR and the crew was moved to the bay 1 doors of the HST to change out the computer. After removing the old DF-224 computer, it was moved to the larger ORU protective enclosure (LOPE) where it was exchanged for the new 486 computer. The arm moved the crewmember and computer back bay 1 where the computer was installed and the doors closed. Following the door closure, a new outer blanked layer (NOBL) was installed on the door.

After exchanging crewmembers on the RMS, and the HST was rotated to provide access to the +V3 fine guidance sensor (FGS) work-site, the arm moved the crewmember to the work-site to begin the exchange of the FGS. After opening the FGS-2 doors, the FGS connectors were demated, a handhold was attached to the FGS and the FGS latches were released. The arm assisted the crewmembers in extracting the FGS from the HST and moving the FGS to the ORU carrier aft fixture where it was temporarily stowed. The crewman was then moved to the FGS Scientific Instrument Protective Enclosure (GSIPE) where the replacement FGS was removed and transported to the +V3 work-site location for installation in the HST. After inserting the new FGS into the HST, the latches were re-engaged and the connectors were mated. The crew then took video photographs of the installation and closed the doors. The removed FGS was then placed in the FSIPE for final storage.

Following this activity, the crew returned to the airlock and the EVA was completed satisfactorily.

The EV4 crewmember reported a carbon dioxide (CO_2) high message on his display control module (DCM) about 4 ½ hours into the EVA 2. The EMU CO_2 sensor was reading 30 millimeters of mercury, which corresponds to a full-scale high value. For this case, crewmembers were reminded to perform a self-evaluation of potential high CO_2 symptoms throughout the remainder of EVA 2.

EVA 3

During EVA 3 preparation, the crew reported that when EMU 2 power was switched to battery, the DCM displayed a "No Power Restart" message and a BITE light. Also, a caution and warning tone was sounded. The crew placed the EMU 2 power switch to SCU and all signatures repeated and the message could not be cleared. The crew was asked to take the airlock power mode switch and bus select switch for EMU 2 to off. The crew repeated the EMU 2 DCM power switch throws with the same results. The crew then powered down the airlock power mode and bus select switches,

disconnected and reattached the SCU, repeated the EMU 2 DCM switch throws with the same results. The crew was instructed to use EMU 3 in place of EMU 2.

Crew egress for the third EVA to perform the final servicing of the HST occurred at 358:19:54 G.m.t. (04:19:04 MET). The EVA crewmembers were Steve Smith (EV1) and John Grunsfeld (EV2). EVA 3 was successfully completed at 359:03:24 G.m.t. (05:02:34 MET) for an official EVA time of 8 hours and 8 1/2 minutes.

The first major task of the third EVA was for the arm to move the crewmembers to HST bay 3 where the doors were opened. The additional Optical Control Electronics Enhancement Kit (OCE-EK) cable connectors were mated to the FGS. Subsequently, the doors were again closed, after which the crewmembers were moved to bay 5.

The bay 5 doors were opened, and the old S-band Single Access Transmitter (SSAT) was removed and replaced with the SSAT-2R unit. The unit had been exchanged and retrieved by the crewmember who was not on the RMS arm. After completion of this task, the old reel-to-reel style data tape recorder (ESTR-3) was removed and replaced with a new digital solid state recorder (SSR-3). With the SSR-3 installed, a closeout video of the bay 5 work-sites was made and the bay doors were closed and fastened.

The next task involved moving to bay 9 and10 of the HST to install NOBL, which was completed satisfactorily. Because of time limitations, replacement of the insulation on bays 5, 6, 7, and 8 was not attempted.

Prior to airlock repressurization at the end of EVA 3, the Airlock Power Supply (ALPS) would not power EMU 3 with the servicing and cooling umbilical (SCU) connected. A repeat operation of the airlock wall switch produced the same results. The repressurization was performed with EMU 3 on battery power. An inspection of the DCM and SCU electrical connectors following repressurization identified two bent pins on the DCM side connector. The location description from the crew along with downlinked photos were used to determine that the pin numbers were 12 and 13, which are SENSE + and SUIT POWER. An interruption in either contact would cause the ALPS to shut down power. Ground personnel identified a procedure to attempt straightening the bent pins using an on-board connector pin tool should EMU 3 be required for a contingency EVA.

REMOTE MANIPULATOR SYSTEM

The remote manipulator system (RMS) performed in an excellent manner throughout the mission. All RMS tasks during the capture, servicing and release of the Hubble Space Telescope (HST) were satisfactorily performed. STS-103 was the fifty-fourth flight of RMS during the Space Shuttle Program and the eighteenth flight of this particular arm. The primary tasks of the arm were to retrieve and berth the HST and then provide support for the three extravehicular activities (EVAs) during which maintenance, repairs and installation of upgraded components were performed.

During RMS checkout on flight day 2, the end effector (EE) grapple fixture snares failed to fully open during the backup release test. During the test at 354:20:27:43 G.m.t. (00:19:37:43 MET), power was applied to the RMS for 20 seconds. Downlink video showed that the snares opened for approximately 5 seconds and then appeared to stop. There was no motion for approximately 7 seconds, followed by the snares beginning to open intermittently until the mechanism stopped completely 8 seconds later. The crew also reported that power was applied for an additional 5 seconds with no motion of the snares. When power was removed, the snares did not appear to have opened enough to allow a grapple pin to be released from the EE. The backup release is only required to release a payload if the automatic and manual modes of operation should fail.

At the end of the checkout, the crew repeated the test and release occurred in approximately 15 seconds. The manual and auto EE release modes worked properly and there was no mission impact. On flight day 7, following the release of the Hubble Space Telescope (HST), the backup release test was rerun 5 times. Each of the releases appeared nominal and the times were 17, 16, 16, 16 and 15 seconds.

The RMS checkout was completed, and the RMS performance was nominal. Following the checkout, the RMS was used to conduct a video survey of the HST space support equipment, which concluded the RMS flight day 2 activities.

The HST rendezvous and capture was successfully conducted with the grapple completed at 356:00:34:01 G.m.t (01:23:44:01 MET). The RMS performance was nominal and berthing was accomplished at 356:01:26 G.m.t. (02:00:36:00 MET).

The RMS was used during each EVA in the performance of the servicing tasks and performed satisfactorily with no RMS problems noted.

The HST was unberthed from the flight support system (FSS) in the payload bay at 359:21:18:41 G.m.t. (05:20:28:41 MET). The HST was released by the RMS at 359:23:03:45 G.m.t. (05:22:13:45 MET). The remote manipulator system (RMS) performance was satisfactory during the HST release.

GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

The Government furnished equipment/flight crew equipment (GFE/FCE) performed nominally throughout the mission.

It was noted at 354:23:53 G.m.t. (00:23:03 MET) that the HST turnaround plugs were not stowed for flight. These plugs are used to provide a backup method for the HST telemetry to bypass the payload signal processor (PSP) and go directly from the payload interrogator to the payload data interleaver (PDI) and downlinked to the ground. An in-flight maintenance procedure (IFM) was successfully performed to regain this backup method. A review of the documentation determined that the turnaround plugs were called out for use during the mission, but were not called out in the Orbiter stowage drawings, and consequently, were not stowed.

During the post EVA 1 activities, the EV1 crewmember reported during airlock repressurization that half of his Communications Carrier Assembly (CCA) had failed. EV1 used EV4's CCA for EVA 3. A communications check was performed during EVA 3 preparations and the full communication capability was restored. The failure could not be reproduced in the laboratory during postflight testing. This problem is believed to be a known condition in which perspiration from the crewmember clogs the earpiece. This condition has been noted previously and has been corrected by allowing the cap to dry while on orbit. The particular unit was checked prior to EVA 3 and was found to be in good working order, which is indicative of the past history of this condition.

Additionally, the roll joint was jammed in the B.5 position on one of the STS Portable Foot Restraints (PFRs) making it unusable for the remaining EVAs. The two roll control buttons would neither fully depress or fully pop-out. Near the end of the first EVA, the roll joint was moved to position A, but required a lot of effort. However, the STS PFR from the forward bulkhead was available.

Following the EVA, the crew reported that one side of extravehicular mobility unit (EMU) middeck battery charger (serial no. 1002) was not functioning properly. The spare charger (serial no. 1001) was used and a nominal recharge was performed.

During EVA 2 operations, the HST PFR boot-plate roll joint would not lock. The HST PFR was brought into the cabin following the EVA and evaluated and behaved normally after some initial cycling. The HST PFR was not used for the remaining EVA, but it was taken into the payload bay for stowing during EVA 3.

During EVA 1 operations, the Power Ratchet Tool (PRT) failed to function properly and this resulted in using the Pistol Grip Tool (PGT) as a backup tool.

Also, the EV4 crewmember reported a carbon dioxide (CO_2) high message on his display control module (DCM) about 4 ½ hours into the EVA 2. The EMU CO_2 sensor was reading 30 millimeters of mercury, which corresponds to a full-scale high value. For this case, crewmembers are reminded to perform a self-evaluation of potential high CO_2 symptoms throughout the remainder of EVA.

During EVA 3 preparation, the crew reported that when EMU 2 power was switched to battery, the DCM displayed a "No Power Restart" message and a BITE light. Also, a

caution and warning tone was sounded (Flight Problem STS-103-X-01). The crew placed the EMU 2 power switch to SCU and all signatures repeated and the message could not be cleared. The crew was asked to take the airlock power mode switch and bus select switch for EMU 2 to off. The crew repeated the EMU 2 DCM power switch throws with the same results. The crew then powered down the airlock power mode and bus select switches, disconnected and reattached the SCU, repeated the EMU 2 DCM switch throws with the same results. The crew was instructed to use EMU 3 in place of EMU 2.

During EVA preparation, the EV2 EMU 2 DCM showed a failed built-in test equipment (BITE) indication and the crewmember received a caution and warning tone when the EMU was switched to battery power. The power source switch was cycled, and the anomaly did not clear. An inspection of the DCM and SCU electrical connectors following repressurization identified two bent pins on the DCM side connector (Flight Problem STS-103-X-02). The location description from the crew along with downlinked photos were used to determine that the pin numbers were 12 and 13, which are SENSE + and SUIT POWER. An interruption in either contact would cause the ALPS to shut down power. Ground personnel identified a procedure to attempt straightening the bent pins using an on-board connector pin tool should EMU 3 be required for a contingency EVA. EMU 2 was considered non-operational and replaced with EMU 3. Resizing was completed using previously developed procedures.

The crew reported that the color printer was printing ¾ of a message on one sheet of paper and the remaining ¼ on a second sheet of paper. The color printer intermittently did not work correctly throughout the mission.

Four minor video camera problems were noted during the mission.

a. At 354:02:00 G.m.t. (00:01:12 MET), the downlinked video from camera D exhibited two smudges on the lens. The two smudges were oval in shape and easily observed. This condition did not impact mission operations.

b. At 359:03:22 G.m.t. (05:02:32 MET), the downlinked video from camera A exhibited a pink and blue image during a pass through the South Atlantic Anomaly. Ground controllers performed a power cycle of the camera and a normal image returned. The problem did not repeat.

c. At 359:13:49 G.m.t. (05:13:09 MET), ground controllers reported that the iris on camera C iris went to a fixed full-open position. A short power cycle did not clear the problem. An extended camera power down of about one hour was performed, and after power up the iris function returned to normal.

d. At 360:12:05 G.m.t. (06:11:15 MET), video from camera D showed that the camera A pan/tilt cable was catching on the camera pan/tilt hardware at certain pan/tilt angles. As a result of the interference, camera A's full tilt capability was lost at pan angles approximately ±20 degrees from the aft direction.

CARGO INTEGRATION

Integration hardware performance was nominal throughout the mission.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DEVELOPMENT TEST OBJECTIVES

DTO 700-14 - Single String Global Positioning System (Payload Ground Support Computer Option) Miniature Air-To-Ground Receiver - The miniature air-to-ground receiver (MAGR) was powered on about five hours prior to launch, with data recording to the MAGR payload ground support computer (PGSC) beginning approximately one hour prior to launch. The performance of the MAGR during ascent and entry was nominal and other than some anomalous behavior early in the flight, the MAGR performance during the entire mission was nominal. The Global Positioning System (GPS) antenna coverage tests produced very valuable data, which will be used in the certification of the MAGR for three-string operation with the goal being to eventually replace the Tactical Air Navigation (TACAN) equipment.

At 355:03:02:36 G.m.t. (01:02:12:36 MET), the Miniature Airborne Global Positioning System (GPS) Receiver (MAGR) [Development Test Objective (DTO) 700-14] performed an autonomous reset (tilt) following an extended period of degraded tracking during the single antenna tracking test. Prior to the upper-antenna-only test, which began at 35416:18 G.m.t. (00:15:28 MET), the MAGR performance appeared nominal, with the exception of erroneous antenna-in-view indications from prior to launch until 355:03:02:26 G.m.t (01:02:12:36 MET). Nominal MAGR behavior resumed following the tilt.

DTO 700-15 - Space Integrated Global Positioning System/Inertial Navigation System – Configuration B - The Space Integrated Global Positioning System (GPS)/Inertial Navigation System (SIGI) and the SIGI PGSC were powered about 18 hours prior to launch. The PGSC began recording data automatically prior to issuing prelaunch commands to the SIGI. An objective of this mission was to test the MAGR-S and SIGI performance while powering on and off the GPS antenna preamplifiers according to a predefined schedule. SIGI did not operate well in this test environment. Early in the mission [355:02:42 G.m.t. (01:01:52 MET), the SIGI first encountered problems. Eventually the SIGI recovered from loss of service that was caused by the antenna preamplifier being powered off, but fail bits set during this incident were never successfully reset. As a result of the fail bit, no GPS measurements could then be incorporated into the GPS/INS blended navigation state vector. The crew attempted hardware recovery procedures, but the SIGI did not respond. The PGSC continued to record data from the SIGI throughout the mission and the data were downlinked via the Orbiter Communications Adapter (OCA) four or five times for analysis. On landing day, the PGSC was stowed and the DTO was configured for entry data collection.

During the initial set-up for this DTO, the data connection between the SIGI and the PGSC could not be established. The crew initially reported that the communication cable set-up was correct and no communications could be established. Later the crew reported that the data cable between the SIGI and PGSC was installed incorrectly. The crew reinstalled the data cable and normal communications were established. Evaluation showed that the cable had been installed incorrectly during the preflight routing.

DETAILED SUPPLEMENTARY OBJECTIVES

DSO 496 - Individual Susceptibility to Post-Spaceflight Orthostatic Intolerance - This DSO involved preflight and postflight data gathering which was performed. The results of this DSO will be published in a separate publication.

DSO 498 - Space Flight and Immune Function - This DSO involved preflight and postflight data gathering which was performed. The results of this DSO will be published in a separate publication.

PHOTOGRAPHY AND TELEVISION ANALYSIS

LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS

On launch day, 24 of 24 expected launch videos were reviewed, and no anomalous conditions were noted. Following launch day activities 20 additional films were screened. Twenty-two additional films were received for contingency support and anomaly resolution, but were not screened, as there were no major launch/ascent issues. No anomalies were seen in the launch imagery.

ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS

No unplanned on-orbit analysis was performed. Pre-planned real-time analysis support was provided to the Hubble Space Telescope capture, repair and deployment.

LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSIS

Ten videos and seven films of landing were received and screened. No major anomalies were noted in the approach, landing, and roll-out video and film views screened. All observations were nominal.

TABLE I.- STS-103 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	354:00:45:11.245 354:00:45:12.699 354:00:45:13.952
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	354:00:49:32.12 354:00:49:32.28 354:00:49.32.44 354:00:49 32.60
Main Propulsion System Start[a]	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	354:00:49:53.455 354:00:49:53.571 354:00:49:53.701
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	354:00:49:59.986
Throttle up to 104.5 Percent Thrust[a]	ME-3 Command accepted ME-2 Command accepted ME-1 Command accepted	354:00:50:03.914 354:00:50:03.931 354:00:50:03.942
Throttle down to 67 Percent Thrust[a]	ME-3 Command accepted ME-2 Command accepted ME-1 Command accepted	354:00:50:31.755 354:00:50:31.771 354:00:50:31.783
Maximum Dynamic Pressure (q)	Derived ascent dynamic pressure	354:00:50:51
Throttle up to 104.5 Percent[a]	ME-3 Command accepted ME-2 Command accepted ME-1 Command accepted	354:00:50:58.316 354:00:50:58.332 354:00:50:58.343
Both RSRM's Chamber Pressure at 50 psia[a]	LH SRM chamber pressure mid-range select RH SRM chamber pressure mid-range select	354:00:51:59.656 354:00:52:00.256
End RSRM [a] Action[a] Time	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	354:00:52:02.52 354:00:52:02.84
SRB Physical Separation[a]	LH rate APU turbine speed - LOS	354:00:52:04.66
SRB Separation Command	SRB separation command flag	354:00:52:05
Throttle Down for 3g Acceleration[a]	ME-3 command accepted ME-2 command accepted ME-1 command accepted	354:00:57:23.603 354:00:57:23.620 354:00:57:23.629
3g Acceleration	Total load factor	354:00:57:56.1
Throttle Down to 67 Percent Thrust[a]	ME-3 command accepted ME-2 command accepted ME-1 command accepted	354:00:58:18.964 354:00:58:18.981 354:00:58:19.021
SSME Shutdown[a]	ME-3 command accepted ME-2 command accepted ME-1 command accepted	354:00:58:25.405 354:00:58:25.421 354:00:58:25.430
MECO	MECO command flag MECO confirm flag	354:00:58:26 354:00:58:27
ET Separation	ET separation command flag	354:00:58:45

[a]MSFC supplied data

TABLE I.- STS-103 SEQUENCE OF EVENTS
(Continued)

Event	Description	Actual time, G.m.t.
APU Deactivation	APU-2 GG chamber pressure APU 1 GG chamber pressure APU 3 GG chamber pressure	354:01:05:44.113 354:01:05:51.309 354:01:05:53.499
OMS-1 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Not performed - direct insertion trajectory flown
OMS-1 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	
OMS-2 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	354:01:34:08.5 354:01:39:08.5
OMS-2 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	354:01:36:41.5 354:01:36:41.5
Payload Bay Doors (PLBDs) Open	PLBD right open 1 PLBD left open 1	354:02:29:40 354:02:30:58
OMS-3 Ignition	Right engine bi-prop valve position Left engine bi-prop valve position	354:06:15:30.4 354:06:15:30.5
OMS-3 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	354:06:17:02.0 354:06:17:02.1
Cabin Depressurization to 10.2 psia	Cabin pressure	354:20:08:06
OMS-4 Ignition	Right engine bi-prop valve position Left engine bi-prop valve position	355:04:31:20.3 355:04:31:20.4
OMS-4 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	355:04:32:08.2 355:04:32:08.3
OMS-5 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Right engine only 355:18:26:22.0
OMS-5 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	Right engine only 355:18:26:41.8
OMS-6 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	355:19:14:33.6 Left engine only
OMS-6 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	355:19:14:50.6 Left engine only
Hubble Space Telescope Grapple	Payload captured	356:00:34:01
Hubble Space Telescope Berth	Payload latch 1A latched indication	356:01:42:00
Airlock Depressurization 1 (End)	Airlock differential pressure no. 1	356:18:41:37
Airlock Repressurization 1 (Start)	Airlock differential pressure no. 1	357:03:09:28
Airlock Depressurization 2 (End)	Airlock differential pressure no. 1	357:18:52:33
Airlock Repressurization 2 (Start)	Airlock differential pressure no. 1	358:03:16:19
Airlock Depressurization 3 (End)	Airlock differential pressure no. 1	358:19:09:51

TABLE I.- STS-103 SEQUENCE OF EVENTS
(Continued)

Event	Description	Actual time, G.m.t.
Airlock Repressurization 3 (Start)	Airlock differential pressure no. 1	359:03:25:48
Hubble Space Telescope Grapple	Payload captured	359:20:00:30
Hubble Space Telescope Unberth	Payload latch 1A released indication	359:21:18:41
Hubble Space Telescope Release	Payload captured	359:23:03:01
Cabin Repressurization to 14.7 psia	Cabin pressure	360:00:12:02
Flight Control System Checkout		
APU Start	APU 3 GG chamber pressure	360:18:52:01.740
APU Stop	APU 3 GG chamber pressure	360:18:56:12.704
Payload Bay Doors Close	PLBD left close 1	361:18:23:56
	PLBD right close 1	361:18:27:02
APU Activation for Entry	APU-2 GG chamber pressure	361:22:43:32.147
	APU-1 GG chamber pressure	361:23:16:54.343
	APU-3 GG chamber pressure	361:23:16:57.460
Deorbit Burn Ignition	Left engine bi-prop valve position	361:22:48:26.2
	Right engine bi-prop valve position	361:22:48:26.3
Deorbit Burn Cutoff	Left engine bi-prop valve position	361:22:53:15.4
	Right engine bi-prop valve position	361:22:53:15:5
Entry Interface (400K feet)	Current orbital altitude above	361:23:29:41
Blackout end	Data locked (high sample rate)	No blackout
Terminal Area Energy Management	Major mode change (305)	361:23:54:19
Main Landing Gear Contact	LH main landing gear tire pressure 1	362:00:00:47
	RH main landing gear tire pressure 2	362:00:00:47
Main Landing Gear Weight on Wheels	LH MLG weight on wheels	362:00:00:47
	RH MLG weight on wheels	362:00:00:47
Drag Chute Deployment	Drag chute deploy 1 CP volts	362:00:00:49.9
Nose Landing Gear Contact	NLG LH tire pressure 1	362:00:00:58
Nose Landing Gear Weight On Wheels	NLG weight on wheels 1	362:00:00:58
Drag Chute Jettison	Drag chute jettison 1 CP Volts	362:00:01:17.7
Wheel Stop	Velocity with respect to runway	362:00:01:35
APU Deactivation	APU-1 GG chamber pressure	362:00:18:28.272
	APU-2 GG chamber pressure	362:00:18:39.728
	APU-3 GG chamber pressure	362:00:18:48.989

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

No.	Title	Reference	Comments
STS-103-V-01	Remote Manipulator System End Effector Backup Release Initial Failure to Fully Open	354:20:36 G.m.t. 00:19:46 MET IPR 92V-0006 CAR DN 16310	During the remote manipulator system (RMS) checkout, the end effector (EE) grapple fixture snares failed to full open during the backup release test. During the test, power was applied for 19 seconds and downlink video showed that there were two periods of 3 to 4 seconds each where the snares tried to open. When power was removed, the snares did not appear to have opened enough to allow a grapple pin to be released from the EE. The crew repeated the test and release occurred in approximately 15 seconds. The manual and automatic EE release modes worked properly and there was no mission impact. Following the release of the Hubble Space Telescope (HST), the backup release test was rerun five times. Each of the releases appeared nominal and the times were 17, 16, 16, 16, and 15 seconds. KSC: Troubleshooting is in work.
STS-103-V-02	Missing Right-Hand Inboard Elevon Tile	Postlanding Inspection Postlanding CAR 103RF02 PR RWNG-3-28-5671	The tile missing is the right-hand inboard elevon drain hole tile and it was installed on June 8, 1996. STS-103 was the sixth flight of this tile since it was installed. This tile contains a two-piece strain isolation pad (SIP) to accommodate the drain hole and drain path. The forward piece of SIP is completely missing with only remnants of SIP fibers showing in the bonding adhesive. Room temperature vulcanizing (RTV) material is dark red in color and appears to have bubbled. The perimeter of the SIP areas had dark outgassing deposits. The aft SIP is mostly intact. A few areas exist where the tile dense layer is still adhered to the SIP. A large area of the SIP appears to be intact with some of the membrane still in place. Membrane and surface of SIP where membrane is missing is charred. Remainder of SIP (mostly along bottom and aft edges) is charred and eroded. Filler bar around perimeter of tile cavity exhibits category II/III charring. The flexible reusable surface insulation (FRSI) edge member along top surface is degraded and bubbled. The gap filler along the forward edge of cavity is in place with only minor damage. Gap filler on bottom edge (adjacent to lower surface tiles) is missing though residue gap filler material exists on filler bar in several locations along the bondline. Gap filler along aft edge of cavity(adjacent to corner tile) is missing. Gap filler between the corner tile and upper surface trailing edge tile is missing with no signs of charring at the inner mold line. The elevon trailing edge honeycomb section is under the aft piece of SIP and thereby somewhat protected. There are two damage sites to the tiles aft of the missing tile. One tile has a small damage site on one corner and the second has a small damage site on the forward

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

No.	Title	Reference	Comments
STS-103-V-02	Missing Right Hand Inboard Elevon Tile	Postlanding Inspection Postlanding CAR 103RF02 PR RWNG-3-28-5671	edge, and the silica in the damaged areas is not glazed. However, the lower forward corner of one of the two tiles has a slumped area with molten gap filler material evident on the surface. The interior of the drain hole exhibits only minor outgassing deposits. Damage to the aft fuselage sidewall tile is inline with the missing tile and was most likely caused by the tile when it came off. KSC: The structure will be ultrasound tested and conductivity tested to ensure that no delamination of the honeycomb to facesheet occurred. KSC will inspect and repair. This condition has been made a constraint to the launch of STS-99 with presentations required to the PRCB on the cause and corrective actions to prevent a recurrence of the missing tile.
STS-103-V-03	Damaged to Left-hand Radial Carbon Carbon Panel 8	Postlanding Inspection Postlanding CAR 103RF03 PR TES-3-28-0622	The left-hand radial carbon carbon (RCC) was found damaged during the postflight inspections. The damage is located two inches below the apex on the leading edge of the panel. Substrate is visible. The damaged panel was removed and shipped to the vendor. There was no damage in the area behind the outer mold-line damage, and coin tap inspection revealed no internal damage in this area. A detailed inspection of the panel interior revealed that the lower inboard lug that had been previously repaired four times was cracked again. The defect will be examined by the vendor. KSC: KSC will inspect and repair. This condition has been made a constraint to the launch of STS-99 with presentations required to the PRCB on the cause and corrective actions to prevent a recurrence of the missing tile.

TABLE III.- STS-103 EVA IN-FLIGHT ANOMALY LIST

No.	Title	Time	Comments
STS-103-X-01	EMU 2 Failure During Power-up.	358:16:09 G.m.t. 04:15:19 MET	During EVA 3 preparation, the crew reported that when EMU 2 power was switched to battery, the DCM displayed a "No Power Restart" message and a BITE light. Also, a caution and warning tone was sounded. The crew placed the EMU 2 power switch to SCU and all signatures repeated and the message could not be cleared. The crew was asked to take the airlock power mode switch and bus select switch for EMU 2 to off. The crew repeated the EMU 2 DCM power switch throws with the same results. The crew then powered down the airlock power mode and bus select switches, disconnected and reattached the SCU, repeated the EMU 2 DCM switch throws with the same results. The crew was instructed to use EMU 3 in place of EMU 2. KSC: No action required.
STS-103-X-02	EMU 3 DCM Bent Pin	359:03:11 G.m.t. 005:02:21 MET	Prior to airlock repressurization at the end of EVA 3, the airlock power supply (ALPS) would not power EMU 3 with the SCU connected. A repeat of the airlock wall switch throws produced the same results. As a result, the repressurization with EMU 3 was performed on battery power. Inspections of the DCM and SCU electrical connectors after the repressurization was complete revealed two bent pins on the DCM side connector. The location description from the crew along with downlinked photographs helped to determine that the pin numbers were 12 and 13, which are the SENSE + and SUIT POWER. KSC: No action required.

DOCUMENT SOURCES

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

1. Flight Requirements Document
2. Public Affairs Press Kit
3. Customer Support Room (CSR) Daily Science Reports, and Final CSR Report
4. MER Daily Reports
5. MER Mission Summary Report
6. MER Problem Tracking List
7. MER Event Times
8. Subsystem Manager Reports/Inputs
9. MOD Systems Anomaly List
10. MSFC Flash Report
11. MSFC Event Times
12. MSFC Interim Report
13. Crew Debriefing comments
14. Shuttle Operational Data Book
15. STS-103 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
ALPS	airlock power supply
APU	auxiliary power unit
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
ATCS	active thermal control system
BFS	backup flight system
BITE	built in test equipment
CCA	communications carrier assembly
CEI	contractor end item (specification)
CO_2	carbon dioxide
CRT	cathode ray tube
DAS	data acquisition system
DCM	display control module
DMHS	dome-mounted heat shield
ΔP	differential pressure
deg/sec	degree per second
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
ΔV	differential velocity
ECLSS	environmental control and life support system
EE	end effector
EGT	exhaust gas temperature
EMU	extravehicular mobility unit
EO or E/O	External Tank/Orbiter
EPDC	electrical power distribution and control
e.s.t.	eastern standard time
ESTR	Engineering/Science Tape Recorder
ET	External Tank
EVA	extravehicular activity
EV 1 - EV 4	extravehicular crewmember identification
FCE	flight crew equipment
FCP	fuel cell powerplant
FCS	flight control system
FES	flash evaporator system
FGS	Fine Guidance Sensor
FSS	flight support system
ft-lb	foot-pound
ft/sec	feet per second
GFE	Government furnished equipment
GH_2	gaseous hydrogen
G.m.t.	Greenwich mean time
GO_2	gaseous oxygen

GPC	general purpose computer
GPS	Global Positioning System
HPFTP	high pressure fuel turbopump
HPOTP	high pressure oxidizer turbopump
HST	Hubble Space Telescope
IFM	in-flight maintenance
IMU	inertial measurement unit
I_{sp}	specific impulse
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt/hour
lbm	pound mass
lb/min	pound per minute
lb/hr	pound per hour
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 air-to-ground receiver
MC	midcourse correction (maneuvers)
MECO	main engine cutoff
MET	mission elapsed time
MPS	main propulsion system
NASA	National Aeronautics and Space Administration
NAV	navigation
NC1 - 2	rendezvous maneuvers (two)
NCC	corrective combination maneuver
NICMOS	Near Infrared Camera and Multi-Object Spectrometer
nmi.	nautical mile
NOBL	new outer blanket layers
NPC	rendezvous maneuver
NPSP	net positive suction pressure
NSR	rendezvous maneuver
NSTS	National Space Transportation System (i.e., Space Shuttle Program)
OCA	Orbiter Communications Adapter
OCE-EK	Optical Control Electronics Enhancement Kit
OI	operational instrumentation
OML	outer mold line
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OV	Orbiter vehicle
PAL	protuberance air load
PDI	payload data interleaver
PFR	portable foot restraint
PGSC	payload general support computer
PGT	pistol grip tool
PMBT	propellant mean bulk temperature

ppm	parts per million
PRSD	power reactant storage and distribution
PRT	power ratchet tool
psia	pound per square inch absolute
psig	pound per square inch gravity
PSP	payload signal processor
RCC	radial carbon carbon
RCS	reaction control subsystem
RM	redundancy management
RMS	Remote Manipulator System
RSU	Rate Sensor Unit
RTV	room temperature vulcanizing (material)
RSRM	Reusable Solid Rocket Motor
S&A	safe and arm
SCU	service and cooling umbilical
SIGI	Space Integrated Global Positioning System (GPS) Inertial Navigation System
SIP	strain isolation pad
SLF	Shuttle Landing Facility
SLWT	super lightweight tank
S/N	serial number
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSAT2	S-band single-axis transmitter
SSE	space support equipment
SSOR	space-to-space Orbiter radio
SSME	Space Shuttle main engine
STS	Space Transportation System
TACAN	Tactical Air Navigation
TCS	thermal control subsystem/trajectory control sensor
TI	terminal phase initiation maneuver
TPS	thermal protection system/subsystem
TSM	tail service mast
TVC	thrust vector controller
V	Volt
VIK	Voltage Improvement Kit
WSB	water spray boiler