

STS-95 SPACE SHUTTLE MISSION REPORT

January 1999



**National Aeronautics and
Space Administration**

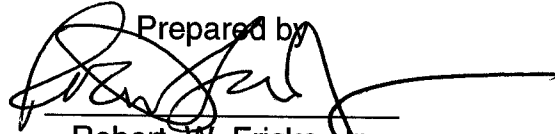
**Lyndon B. Johnson Space Center
Houston, Texas**

STS-95

SPACE SHUTTLE

MISSION REPORT

Prepared by

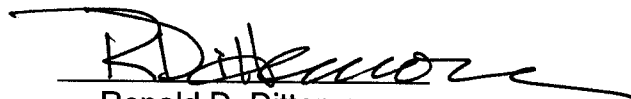


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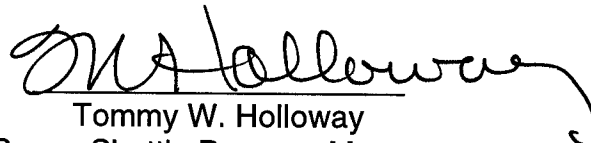
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INTRODUCTION

The STS-95 Space Shuttle Program Mission Report presents a discussion of the Orbiter subsystem operation and the in-flight anomaly that was identified during mission. The report also summarizes the mission activities and presents a summary of the External Tank (ET), Solid Rocket Booster (SRB), Reusable Solid Rocket Motor (RSRM), and Space Shuttle main engine (SSME) performance during this ninety-second mission of the Space Shuttle Program. STS-95 was the sixty-seventh flight since the return to flight, and the twenty-fifth flight of the (Discovery) Orbiter vehicle.

The flight vehicle consisted of the OV-103 Orbiter; an ET that was designated ET-98, which was the second super lightweight tank (SLWT); three Block IIA SSMEs that were designated as serial numbers (S/N) 2048, 2043, and 2045 in positions 1, 2, and 3, respectively; and two SRBs that were designated BI-096. The two RSRMs were designated RSRM 068 with one installed in each SRB. The individual RSRMs were designated 360W068A for the left SRB, and 360W068B for the right SRB.

The STS-95 Space Shuttle Program Mission Report fulfills the Space Shuttle Program requirements as documented in NSTS 07700, Volume VII, Appendix E. The requirement is that each organizational element supporting the Program will report the results of their hardware and software evaluation and mission performance plus identify all related in-flight anomalies.

The primary objectives of the STS-95 flight were to perform operations of Research Payloads in a single Spacehab module, the Hubble Orbital Systems Test (HOST) Platform, International Extreme Ultraviolet Hitchhiker (IEH-03), SPARTAN 201, Cryogenic Thermal Storage Unit (CRYOTSU), and two Get-Away Special (GAS) Carrier Payloads. The secondary objectives of this flight were to perform the operations of the Protein Crystal Growth - Single Locker Thermal Enclosure System (PCG-STES), Shuttle Amateur Radio Experiment - II (SAREX-II), and Biological Research in Canisters (BRIC).

The STS-95 mission was a planned 9-day plus 2-contingency-day mission during which 83 individual experiments would be performed. The two contingency days were available for bad weather avoidance for landing, or other Orbiter contingency operations. The STS-95 sequence of events is shown in Table I, the Space Shuttle Vehicle Engineering Office (SSVEO) In-Flight Anomaly List is shown in Table II, and the Marshall Space Flight Center (MSFC) Problem Tracking List is shown in Table III. Appendix A lists the sources of data, both informal and formal, that were used in the preparation of this report. Appendix B provides the definitions of all acronyms and abbreviations used in this report. All times are given in Greenwich mean time (G.m.t.) and mission elapsed time (MET).

The seven crewmembers of the STS-95 mission consisted of Curtis L. Brown, Jr., Lt. Col., U. S. Air Force, Commander; Steven W. Lindsey, Lt. Col. U. S. Air Force, Pilot; Stephen K. Robinson, Ph. D., Civilian, Payload Commander and Mission Specialist 1; Scott E. Parazynski, M. D and Ph. D., Civilian, Mission Specialist 2; Pedro Duque, Civilian, Mission Specialist 3; Chiaki Mukai, M. D., Ph. D., Payload Specialist 1; and

John H. Glenn, Jr. Col., U. S. Marine Corps Retired, Payload Specialist 2. STS-95 was the fourth Space Shuttle flight for the Commander, the third Space Shuttle flight for Mission Specialist 1, the second Space Shuttle flight for the Pilot and Mission Specialist 2, and the first Space Shuttle flight for the Mission Specialist 3, and Payload Specialists 1 and 2. However, Payload Specialist 2 flew once during Project Mercury on the Mercury-Atlas 6 (Friendship 7) spacecraft in February 1962. On that flight, he logged more than 4 hours in space.

MISSION SUMMARY

The STS-95 vehicle was launched on an inclination of 28.45 degrees at 302:19:19:33.984 G.m.t. (2:19:19 p.m. e.s.t. on October 29, 1998) following two holds during the final countdown. The first hold occurred at T-9 minutes and lasted for 9 minutes 36 seconds during which the cause of three master alarms was resolved. The first alarm occurred during the 2-psid cabin repressurization check. Cabin pressure passed through 15.35 psi, the level at which the alarm is set, and a nominal master alarm occurred. The second master alarm occurred when the cabin pressure was stabilized at 16.72 psia and the cabin repressurization probe was removed. The momentary pressure drop rate exceeded -0.08 psi/minute and caused a nominal differential pressure/differential time ($\Delta p/\Delta t$) master alarm. The third master alarm was also a $\Delta p/\Delta t$ alarm and it occurred when the cabin vent and vent isolation valves were opened to depressurize the cabin to ambient pressure. The pressure drop rate again exceeded the -0.08 psi/minute and the third nominal master alarm occurred.

The second hold occurred at T-5 minutes and lasted for 9 minutes 59 seconds during which unidentified aircraft were cleared from the launch area.

During the Space Shuttle main engine (SSME) ignition sequence at 302:19:19:30.693 G.m.t., ground-based photography showed the drag parachute panel falling away from the vehicle (Flight Problem STS-95-V-01). An investigation team evaluated the potential for ascent damage, on-orbit operations impact, entry effects, contingency situations, and post-landing safety. The film and video review showed that the door detached three seconds before liftoff and struck the bell of SSME 1 as it fell. The drag parachute was visible in the cavity until about T+25 seconds, and no debris was seen falling from the vehicle through Solid Rocket Booster (SRB) separation plus 45 seconds. The remains of the door were found in the launch pad area; no other vehicle hardware was found. Thermal models predicted ascent heating of the surface of the drag parachute compartment above the melting point of the contained materials.

The team postulated that for entry, one of three conditions would exist: the parachute was intact and retained; the parachute had fallen out; or the parachute was intact, but in an unknown, possibly melted, condition. For the normally retained case, no action was recommended. This recommendation was based on the premises that the parachute would be retained by the retention straps; no pyrotechnic wiring damage concerns exist; and the pyrotechnic temperature would only rise 10 °F above its initial temperature during entry. An available temperature sensor on the mortar canister provided for the monitoring of the temperature. Parachute deployment was available to the crew in case of an emergency condition such as a flat tire or to prevent runway departure. For the missing parachute case, there were no additional concerns.

If the parachute was present, but melted in some way, it would most likely remain in-place during entry as the entry loads are less severe than the 3g ascent loads. Entry loads push the parachute into the cavity with an average force of 0.2g. The possibility of a spontaneous deployment during entry is considered remote. Nevertheless, analysis and simulations have been performed to identify the cues that would alert the crew if the parachute spontaneously deploys. Below 30,000 feet, strong vehicle cues exist as well as visual verification by the Shuttle training aircraft (STA) or ground cameras. For some

altitudes with full inflation of the parachute, it will break away on its own. However, for other deployed conditions, the crew will notice the cues and can arm, deploy, and jettison the parachute. The response to these cues is not time critical at higher altitudes, but becomes more important at lower altitudes. If no cues are present, no action was recommended. The postflight video review of the vehicle showed the drag parachute to be intact in its compartment with little evidence of discoloration. The investigation team will continue in its efforts to determine the cause and corrective action for this anomaly.

All SSME and RSRM start sequences occurred as expected and launch phase performance was satisfactory in all respects. First stage ascent performance was as expected. SRB separation, entry, deceleration, and water impact occurred as anticipated. Both SRBs were recovered. Performance of the SSMEs, ET, and main propulsion system (MPS) was normal. A determination of vehicle performance was made using vehicle acceleration and preflight propulsion prediction data. From these data, the average flight-derived engine I_{sp} for the time period between SRB separation and start of 3g throttling was 453.1 seconds, which compares favorably with the MPS tag value of 452.26 seconds.

The orbital maneuvering subsystem (OMS) 2 maneuver was performed at 302:20:01:31.5 G.m.t. [00:00:41:56.5 Mission Elapsed Time (MET)]. The maneuver was 305.8 seconds in duration with a differential velocity (ΔV) of 464.1 ft/sec. The resultant orbit was 295.4 by 303.2 nmi.

The payload bay doors operated nominally within dual motor times. The starboard payload bay door was opened at 302:20:43:20 G.m.t. (00:01:23:45 MET), and the port payload bay door was opened at 302:20:44:39 G.m.t. (00:01:25:04 MET). Both the port and starboard radiator panels were also deployed.

At 303:04:24 G.m.t. (00:09:04 MET), the crew reported that a portion of a thermal protection system (TPS) blanket on the left OMS pod was protruding approximately 45 degrees from its normal position (Flight Problem STS-95-V-04). This was later confirmed by video from the stowed remote manipulator system (RMS) cameras. During the subsequent payload bay survey with the RMS camera, a closer inspection was made. It was identified as a small piece of TPS blanket at the aft of the left OMS pod above the stinger. No impact to the mission was identified. The postflight inspection video also showed that the small portion of the protruding TPS had burned off. This condition did not affect the vehicle operation during entry.

At 302:23:57 G.m.t. (00:04:38 MET) during the low iodine removal system (LIRS) installation, the crew reported a water leak from the flexible hose that connects the cartridge to the water supply from the bulkhead. The leak was at the cartridge end of the hose, and there was no leak at the joint or fitting. The crew described the leak as large and spraying. The LIRS installation was terminated, and the galley iodine removal assembly (GIRA) was installed. Subsequently, an in-flight maintenance (IFM) procedure was performed on flight day 2 using a hose from the IFM kit. Following the IFM, the GIRA was removed and the LIRS was reinstalled, and nominal operations followed. The hose leak was duplicated on the ground using the STS-88 unit at the same location. The leak was approximately the same size based on the crew description of the on-orbit leak.

At 304:02:31 G.m.t. (01:07:12 MET), the crew reported that the galley water from the LIRS had a bad taste, and this condition was confirmed with a ground-based unit. Procedures were developed to purge the galley and remove the LIRS and reinstall the GIRA should the water quality fail to improve. During the next crew day, the crew purged the galley and replaced the LIRS with the GIRA. Subsequently, the crew reported that the water taste was nominal.

While setting up the Space Integrated Global Position System (GPS)/Inertial Navigation System (SIGI) hardware for on-orbit data collection, communications between the payload data interleaver demultiplexer payload and ground support computer (PGSC) and the SIGI PGSC could not be established via the RS232 data cable (Flight Problem STS-95-V-05). The cable was replaced with a backup cable, and the system performed nominally for the remainder of the mission.

The crew performed the checkout of payload bay color television cameras A and B in support of Development Test Objective (DTO) 700-11, the Orbiter space vision system (OSVS), which was operated during the berthing of the SPARTAN payload on flight day 7. The OSVS photogrammetry technology uses camera views of various targets on the payload and the payload bay hardware to provide precise relative position, attitude, and rate data for berthing a payload using the RMS. This DTO evaluated the performance of the operational vision unit in conjunction with the Orbiter closed circuit television (CCTV) system. The OSVS is planned for use early in the International Space Station (ISS) assembly sequence and will be the primary source of precision data for the RMS operator when performing ISS assembly operations.

The RMS was powered at 305:17:04 G.m.t. (02:21:45 MET), and the arm was placed in the pre-cradle position 11 minutes later. The SPARTAN was grappled at 305:17:27:14 G.m.t. (02:22:07:40 MET). The SPARTAN was unberthed and moved to the release position and released at 305:19:00:12 G.m.t. (02:23:40:48 MET). The deployment was nominal in all respects. The RMS arm was cradled at 305:19:55 G.m.t. (03:00:50 MET). All RMS operations were performed satisfactorily.

Two reaction control subsystem (RCS) separation maneuvers were performed following the SPARTAN release. The first maneuver was performed at 305:19:06:40 G.m.t. (02:23:47:06 MET), and the ΔV was 1.0 ft/sec. The second separation maneuver was performed at 305:19:36:26 G.m.t. (03:00:17:14 MET), and the ΔV was 1.1 ft/sec. Also, three nominal correction (NC) maneuvers (phasing maneuvers) were performed. The first maneuver (NC-1) was made at 305:20:58:34 G.m.t. (03:01:39:00 MET) and had a ΔV of 2.1 ft/sec and a duration of 0.9 second. The second phasing maneuver (NC-1A) was initiated at 306:00:56:34 G.m.t. (03:05:37:00 MET), had a duration of 0.2 second and imparted a ΔV of 0.5 ft/sec to the vehicle. The third phasing maneuver, NC-3, was initiated at 307:02:17:34 G.m.t. (04:06:58:00 MET), had a duration of 6.0 seconds and a ΔV of 1.4 ft/sec was imparted to the vehicle. The NC2 and NC-2A maneuvers were not required. The RCS performed satisfactorily during these separation and phasing maneuvers.

The following RCS and OMS firings were performed to complete the rendezvous with the SPARTAN spacecraft. A 32-second nominal correction (NC-4) maneuver with the RCS was initiated at 307:14:11 G.m.t. (04:18:52 MET) and a ΔV of 7.3 ft/sec was

imparted to the vehicle. The nominal height adjust (NH) maneuver was not required. A RCS pre-terminal phase initiation (TI) maneuver was initiated at 307:16:21 G.m.t. (04:21:02 MET), followed by an 11.6-second OMS-3 TI maneuver at 307:17:21 G.m.t. (04:22:02 MET) using the right engine. The differential velocity for the OMS-3 maneuver was 10.2 ft/sec. Midcourse correction maneuvers MC1, MC2, MC3, and MC4 were performed during the rendezvous time-frame of 307:17:35 G.m.t. to 307:19:00 G.m.t. (04:22:16 MET to 04:23:41 MET). All RCS thrusters and the OMS engine performed satisfactorily during the maneuvers.

The RMS was powered at 307:16:53 G.m.t. (04:21:34 MET), and the arm was placed in the pre-cradle position 3 minutes later. The SPARTAN was captured at 307:20:48 G.m.t. (05:01:29 MET) and 11 minutes later, the RMS was maneuvered for SPARTAN berthing. The SPARTAN was un-grappled at 307:21:11 G.m.t. (05:01:52 MET) and the RMS was cradled and powered off 15 minutes later. The grapple and berthing operations were nominal, and all RMS operations were performed satisfactorily.

The RMS was powered and uncradled at 308:14:20 G.m.t. (05:19:01 MET). The SPARTAN was grappled at 308:14:39 G.m.t. (05:19:20 MET), and the SPARTAN was unberthed in support of OSVS operations. The SPARTAN was then maneuvered in and out of the berthing V-guides for the OSVS tests at 308:16:00 G.m.t. (05:20:41 MET). At 308:16:30 G.m.t. (05:22:11 MET), the RMS maneuvered the SPARTAN around the cargo bay in support of video guidance sensor (VGS) tests. At 308:17:00 G.m.t. (05:21:41 MET), the arm maneuvered SPARTAN for another OSVS test after which the SPARTAN was berthed and the arm was cradled and powered off. All OSVS/VGS planned procedures were successfully accomplished, and all RMS operations were nominal. RMS operations were completed for STS-95 with the successful conclusion of the OSVS/VGS tests.

On flight day 7, image optimization testing using varying illumination levels was performed for the OSVS DTO. The checkout of payload bay camera B, as well as a sunset test, night operation, and a sunrise test were completed successfully to conclude this DTO for STS-95.

On flight day 8, the Space-to-Space Communications System (SSCS) flight demonstration (DTO 700-18) was completed successfully. The SSCS enabled direct communications between orbiting spacecraft in close proximity, and will provide the Orbiter, the ISS, and extravehicular activity (EVA) astronauts the capability to use the same communications system for voice and data independent of ground support. The SSCS augments the S-band system and will replace the current EVA communication bands. An extravehicular mobility unit (EMU) was powered up, checked and its operation with the Space-to-Space Orbiter Radio (SSOR) was verified. The test lasted about 30 minutes and all functions were nominal.

The flight control system (FCS) checkout was performed using auxiliary power unit (APU) 2. APU 2 was started at 310:13:11 G.m.t. (07:17:52 MET) and ran for approximately 5 minutes and 30 seconds with a fuel consumption of 15 pounds. APU 2 and hydraulic system 2 performed nominally during the checkout.

The RCS hot fire was performed following FCS checkout. The single-pulse hot-fire was performed at 310:14:01 G.m.t. (07:18:42 MET), and all thrusters performed nominally with the exception of L3L. Thruster L3L failed off, then failed leak (Flight Problem STS-95-V-02). The left RCS manifold 3 isolation valve was closed at 310:15:09 G.m.t. (07:19:50 MET) to prevent further leaking of oxidizer. The closing of this manifold isolation valve also disabled thrusters L3D and L3A. This condition results only in a loss of redundancy for entry.

A -X-axis orbit-adjust firing, using the RCS, was performed at 310:20:45:06 G.m.t. (08:01:25:32 MET). The firing was performed over a period of 52.3 seconds and a ΔV of 12.7 ft/sec was imparted to the vehicle.

The Ku-band antenna was stowed in nominal dual motor times at 311:00:17 G.m.t. (08:04:58 MET).

The payload bay doors were closed and latched for landing at 311:13:12:57 G.m.t. (08:17:53:23 MET). APU 2 was started five minutes prior to ignition for the deorbit maneuver. The dual-engine deorbit maneuver for the first landing opportunity at the Kennedy Space Center (KSC) Shuttle Landing Facility (SLF) was performed on orbit 134 at approximately 311:15:52:55 G.m.t. (08:20:33:21 MET). The maneuver was 284 seconds in duration with a ΔV of 470.7 ft/sec. APUs 1 and 3 were started 13 minutes prior to entry interface.

During entry, the forward RCS fuel tank temperature began dropping and reached 8 °F at landing (Flight Problem STS-95-V-03). All other temperatures and pressures in the forward RCS were at the nominally expected values. No evidence of a leak was indicated during the postlanding sniffer checks made after wheels stop. The cause of this temperature decrease is most likely a failure of the temperature instrumentation.

Entry was completed satisfactorily with main landing gear touchdown occurring on SLF concrete runway 33 at 311:17:03:30 G.m.t. (08:21:43:56 MET) on November 7, 1998. The nose gear touchdown occurred at 311:17:03:40 G.m.t. and the Orbiter drag parachute was not deployed because of the drag parachute door anomaly. Wheels stop occurred at 311:17:04:30 G.m.t. The rollout was normal in all respects. The flight duration was 8 days 21 hours 43 minutes 56 seconds. The APUs were shut down 17 minutes 32 seconds after landing.

PAYLOADS AND EXPERIMENTS OPERATIONS

SPACEHAB SYSTEMS

The SPACEHAB module systems were activated successfully 302:22:53 G.m.t. (00:03:34 MET), and module setup was completed at 303:00:42 G.m.t. (00:05:23 MET). All SPACEHAB systems functioned nominally. Minor problems were noted following the Spacehab activation, but all of the problems were corrected.

SPACEHAB PAYLOADS AND EXPERIMENTS

Advanced Organic Separations Experiment

The Advanced Organic Separations (ADSEP) experiment was successfully activated during the flight day 1 initialization activities. All operations were nominal throughout the mission.

Aerogel Experiment

The Aerogel experiment activation was completed on flight day 2. All experiment operations were nominal, and the experiment activities were completed on flight day 5.

Advanced Gradient Heating Facility

Both parts of the Advanced Gradient Heating Facility (AGHF) activation were completed by 303:00:39 G.m.t. (00:05:19 MET). During the first cartridge exchange, the failure light was on and the safe light was blinking. The power was cycled and the cartridge exchange was completed nominally at 303:01:49 G.m.t. (00:06:30 MET). The cause of the blinking light will require postflight evaluation to determine its cause. All samples except GM2 were processed nominally. The AGHF furnace experienced a shut down at 308:00:45 G.m.t. (05:05:26 MET), and the GM2 sample was lost. During the heat-up phase of the GM2 sample, the AGHF furnace was reprogrammed to reach a sample temperature very close to the sample cut-off temperature (1160 °C). Data evaluation led to the conclusion that the sample temperature increase was too drastic, thus resulting in an automatic shut down of the furnace. Additional analysis has shown that the furnace operated in accordance with the design, and the shut down was the result of a ground-command error. Postflight analysis will be required to determine the success of this payload.

Advanced Protein Crystallization Facility

The Advanced Protein Crystallization Facility (APCF) 1 and 2 was activated satisfactorily. Operations were conducted nominally until flight day 6 when it was noted that the temperature light emitting diode (LED) was off. A hand-held temperature probe was used to check air outlets. The Principal Investigator was able to use the Spacehab subsystem monitoring data to verify that the module temperature was within limits. All operations continued nominally. The PI requested that the APCF payload be deactivated on flight day 10 instead of flight day 9 to obtain approximately 30 percent

additional science data. As a result, the APCF was partially deactivated on flight day 9, and power was removed from the facility on flight day 10.

Astroculture Experiment

All operations of the Astroculture (ASC) experiment were completed successfully with the exception of an internal light cycle software problem. The day/night cycle software was reset on flight day 3 and operations continued nominally for the rest of the mission.

BIOBOX Experiment

The BIOBOX completed the first experiment run in accordance with the schedule. However, during a 7-minute period of the second experiment run, the Spacehab systems showed a 4.0-ampere drop in the current on EXCP 4. Erroneous data were also noted at that time. Data showed that the BIOBOX erroneous data coincided with the experiment circuit panel (EXCP) 4 current drop. Analysis confirmed the event to be a drop in the internal peltier furnace element current. Postflight analysis will be required to determine the cause of the current drop.

BioDynamics Bioreactor Experiment

The BioDynamics experiment provided valuable scientific data for the sponsor. The experiment's main and fan circuit breakers were closed initially, which was unexpected. Following the reconfiguration, the activation was completed nominally. The experiment operated nominally until flight day 9, when an inadvertent shut down occurred just prior to the planned deactivation. The crew reported that the temperature limit had been exceeded, and the payload was on battery power. The crew confirmed that the circuit breaker to the panel distribution box was open. The circuit breaker was closed and power was restored to the unit, and the deactivation was completed in accordance with the planned time-line. The initial analysis indicates that the shut down did not impact the science return from this experiment.

Biological Research in Canisters (Spacehab) Experiment

All Biological Research in Canisters (BRIC) Spacehab initialization activities were completed nominally. On flight day 2, the crew noted that the sample that was located on the lid of petri dish B was missing. The crew located the missing petri dish B and lid on flight day 5. The crew confirmed that the petri dish was located on the module ceiling, and the description confirms that the sample probably received the desired light exposure. All other BRIC operations were nominal.

Commercial Generic Bioprocessing Apparatus Experiment

The Commercial Generic Bioprocessing Apparatus (CGBA) experiment operated throughout the mission at a higher temperature than the programmed set point. CGBA-1 was powered down early to preserve the science because of the higher temperature concern. The initial evaluation indicates that valuable science will be gained from this experiment.

Commercial Instrumentation Technology Associates Biomedical Experiment

The experiment activation was completed successfully on flight day 1; however, the 6 °C commercial refrigerator/incubator module (CRIM) was operating at 10 °C. On flight day 2, the CRIM temperature did improve to 9.6 °C, and an IFM was performed to attempt to bring the temperature down to 6 °C. However, the 6 °C CRIM temperature continued to operate at the higher level. The Principal Investigator (PI) confirmed that the higher temperature was not expected to impact the science return. Postflight analysis will be required to determine the amount of science received from the Commercial Instrumentation Technology Associates Biomedical Experiment (CIBX).

A request was made by the CIBX Principal Investigator that the Group B science be activated on flight day 4 or 5. As a result, an ASC data downlink was deleted to provide time for the CIBX operations. The crew attempted the activation of the CIBX Group B samples; however, problems were encountered during the activation of vials A and B of tray 6. The vial A plunger was very hard to push in and sprang back out when released; vial B liquid leaked past the O-ring but did not leak outside of Vial. Tray 6 was placed inside a sealable bag, placed back into the CIBX 20 °C facility, and the procedure was terminated. A second silver-shielded bag was placed around tray 6.

On the next flight day, Group B activities were started for trays 7 and 8. During the operations, the crew noted that the crew procedures did not match the cue cards on the back of the trays. As a result, the Group B operations were halted. New procedures were provided to the crew, and the activity was performed successfully on flight day 9. Group D activities were also successfully completed. Photographs of the hardware were requested to support a postflight investigation of the mixing model procedures.

Commercial Protein Crystal Growth - Vapor Diffusion Apparatus

All Commercial Protein Crystal Growth -Vapor Diffusion Apparatus (CDVA) experiment mission objectives were accomplished, and all planned activities were performed.

The experiment was activated approximately 4 ¼ hours into the mission. All crew operations were nominal. The CDVA CRIM maintained temperature control to 0.5 °C throughout the duration of the flight. No CRIM problems were encountered. The CDVA experiment was deactivated on flight day 9, and all operations were nominal.

Commercial Protein Crystal Growth - Protein Crystallization Facility

All Protein Crystallization Facility (PCF) experiment mission objectives were accomplished and all planned activities were performed. The experiment was activated approximately 15 hours earlier than planned. All crew/mission operations were nominal. The PCF CRIM maintained temperature control to 0.5 °C throughout the duration of the flight and throughout the temperature ramp from 40 °C to 22 °C. No CRIM problems were encountered.

Enhanced Orbiter Refrigerator/Freezer

The Enhanced Orbiter Refrigerator/Freezer (EORF) operated nominally throughout the mission.

Facility for Adsorption and Surface Tension Experiment

The Facility for Adsorption and Surface Tension Experiment (FAST) was activated successfully; however, the experiment began automatically shutting down within a few hours. The experiment power was cycled and the experiment recovered. This cycling of the power was required several times during the mission. Determination of the cause of the anomaly will require postflight hardware inspection and analysis. On flight day 8, the payload automatically powered down during the crew sleep period. The crew performed a power recycle on flight day 9, and this provided a 1.5-hour window to ground-command internal fluid valves closed after which the FAST was deactivated. Although the payload automatically powered down several times through the mission, initial indications are that 60 to 70 percent of the science was obtained.

Microencapsulation Electrostatic Processing System

All Microencapsulation Electrostatic Processing System (MEPS) operations were completed satisfactorily. The experiment operations were initiated on flight day 2. The change out of item 2 for item 1 was performed nominally. The high voltage display was inoperative. The crew noted a bent pin and straightened the pin; however, the display remained non-functional. An IFM procedure was performed that required powering down the payload and validating the high voltage was performed by the crew. The change out of the required items were completed successfully, and the experiment was deactivated nominally.

Microgravity Science Glovebox

The Microgravity Science Glovebox (MGBX) Facility checkout was completed nominally. The checkout of the video was also completed nominally.

Structural Studies of Colloidal Suspensions/Colloidal Disorder-Order Transition

The Structural Studies of Colloidal Suspensions/Colloidal Disorder-Order Transition (CGEL/CDOT) operations were initiated on flight day 2. The homogenization of samples A through G was completed. All operations were nominal except for a large bubble in sample 4. The bubble broke into smaller bubbles when mixed with the magnet but did not impact further operations. During CGEL fluid combination, Samples 23, 24 and 27 showed some wetting of the metal above two O-ring seals. The crew bagged the samples in a sealed bag, which provided the two levels of containment required for toxic level-1 samples.

On flight day 3, the Principal Investigator requested that sample G26 be magnetically stirred. The sample received the magnetic stir and video of the operations was downlinked. In addition, photography of all experiment samples was accomplished including the samples that leaked on flight day 2.

Internal Flows in a Free Drop Experiment

The setup of the Internal Flows in a Free Drop Experiment was completed on flight day 3. All activities scheduled for flight day 3 were successfully completed. The expected results were not observed on this experiment during the second run. The

probe is suspected as being the problem; however, postflight analysis and inspection will be required to determine the cause of the problem.

NHK Camera

In setting up the NHK Camera, the crew noticed white dots (pixel noise) in the view finder. The camera was power cycled and the NHK Camera returned to the nominal configuration. Seven tapes and one battery were used during the mission. The NHK personnel are pleased with the amount of recording accomplished on this mission.

Osteoporosis Experiment in Orbit

The Osteoporosis Experiment in Orbit was completed satisfactorily. Initial indications are that 100 percent of the planned science was obtained.

Protein Turnover Experiment

All in-flight operations were successfully completed with the exception of one saline flush. This was determined to be no impact to operations.

Clinical Trial of Melatonin as Hypnotic for Space Crew Experiment

All in-flight operations were successfully completed with the exception of a minor problem with core temperature data. The data from one recorder was downloaded and the second recorder was reinitialized. These actions resulted in recording of the core temperature data being recovered.

Self-Standing Drawer/Morphological Transition and Model Substances

The success of the Self-Standing Drawer/Morphological Transition and Model Substances (SSD/MOMO) experiment will require postflight evaluation to determine because of a problem that is discussed in the following paragraphs.

On flight day 5, it was determined that random power dropouts resulted in the potential loss of 2 experiment runs. Apparently the first run was not significantly impacted because the experiment was near the end of the run when the power dropout occurred. The impact to the second experiment run was not known. Experiment personnel evaluated the data with reference to the power dropouts; however, the cause of the anomaly could not be determined.

The experiment continued to have power dropouts during the mission and these resulted in the software commanding the experiment to skip a run. The last run of SSD-MOMO revealed that the experiment skipped from step 5 to step 10. Because of this off-nominal condition, contingency shut down procedures were used to deactivate the experiment on flight day 9.

Vestibular Function Experiment Unit

The Vestibular Function Experiment Unit (VFEU) was powered during ascent to obtain data on the fish during that period. No signal was received from Fish Package (FP) 1

because of the position of the fish. Flight day 4 was the first time data were received on both fish as they were oriented in the forward position. The fish package environment was maintained well within limits and both fish continued to transmit data for the remainder of the mission.

HUBBLE SPACE TELESCOPE ORBITAL SYSTEMS TEST PLATFORM

The Hubble Space Telescope Orbital Systems Test (HOST) Platform experiments were highly successful. A total of 100 percent of the planned mission duration at the 28.45-degree inclination and 300-nmi. altitude was accomplished. As expected, the computer experienced no radiation events, while the solid state recorder (SSR) and PHA did record radiation events. The NCS (NICMOS cooling system) successfully cooled down to 78.5 °K, 75.5 °K, and 72.9 °K and showed stability at these temperatures. Additionally, the system cooled down to 72.6°K. A total of four NCS cryogenic cooler cool-down mode operations and three operate-mode operations were completed with extra stability characterizations included. One idle mode and two capillary pump loop (CPL) deprime/restart cycles were also completed. A NCS cryogenic cooler cold restart was also successfully completed. The Fiber Optic Flight Experiment (FOFE) stored a full hard drive of mission data, although the crew did have to restart the cooler several times.

Several HOST components ran near the high temperature limit during the Shuttle Sun-pointing attitudes. These components were also slow to cool during the Shuttle non-Sun-pointing attitudes.

CRYOGENIC THERMAL STORAGE UNIT

The Cryogenic Thermal Storage Unit (CRYOTSU) mission was highly successful. The nominal mission goals for all of the experiments were exceeded and all the data gathered will be instrumental in putting these technologies into future space and ground missions.

CRYOTSU completed approximately 90 hours of operation that included 23 full-melt cycles and 18 partial-melt cycles at various heat loads. The unit performed as expected and correlated very well to tests conducted on the ground. An additional test was conducted at the end of the mission that showed the solid-solid phase change of nitrogen at 35 °K. The cryogenic cooler performance when a good vacuum was present was better than projected. This allowed shorter test cycle times and enabled the 35 °K test to be performed.

The Cryogenic Capillary Pumped Loop (CCPL) completed approximately 54 hours of operation. The CCPL tests included five start-ups, more than 10 power-cycle tests, one low-power test, one long-duration test, a number of condenser sink temperature cycle tests, and a number of reservoir set-point temperature change tests. All of the tests, with the exception of the last one, were conducted with the shroud cold.

The Phase Change Upper End Plate (PCMUEP) has successfully demonstrated three partial melts (two more than the baseline plan). Ground testing indicated that a full melt was nearly impossible to achieve because of much higher-than-expected thermal resistance between the cryogenic coolers and the upper end plate. However, an

interesting effect was noted during some temperature overshoots at the onset of the melt on at least two of the tests. Postflight data reduction will determine if this condition was caused by possible solar heating or by a superheating of the docasene that was not observed on the ground.

At least three attempts were made to measure the "Off" and "On" conductance of the Cryogenic Thermal Switch (CTSW). As expected from the ground testing in the canister, a good off-conductance measurement was not possible due to an under-sizing of the capacity of the hydride bed and a lack of a good cold bias on the hydride pump.

CRYOTSU successfully achieved more than 200 percent of the minimum mission objectives, and over 100 percent of their nominal mission science objectives. The only factor that could have increased the overwhelming success of CRYOTSU was additional operating time. It is estimated that CRYOTSU lost approximately 36 hours of test time due to a degraded vacuum in the canister; however, this condition resulted in an unintentional, yet enlightening, contamination experiment. Also, at least 10 hours was lost because of cryogenic cooler shut-downs necessitated by additional HOST acceleration tests.

INTERNATIONAL EXTREME ULTRAVIOLET HITCHHIKER

The International Extreme Ultraviolet Hitchhiker (IEH-3) payload is the third in a series of five flights dedicated to the investigation of the absolute solar extreme ultraviolet (EUV) and far ultraviolet (FUV) flux emitted by the plasma torus system around Jupiter and stellar objects. The payload also studied the Earth's thermosphere, ionosphere, and mesosphere. The IEH-3 mission was the most successful flight of this payload, as evidenced by the unprecedented achievements of the Ultraviolet Spectrograph Telescope for Astronomical Research (UVSTAR), Solar Extreme Ultraviolet Hitchhiker (SEH) and the Solar Constant Experiment (SOLCON) experiments.

The IEH-3 payload consists of five prime experiments plus two GAS canisters containing educational experiments, which were as follows:

- a. Solar Extreme Ultraviolet Hitchhiker (SEH), managed by University of Southern California;
- b. Ultraviolet Spectrograph Telescope for Astronomical Research (UVSTAR), managed by University of Arizona;
- c. Space Telescope for Astronomical Research (STAR-LITE), managed by the University of Arizona;
- d. Solar Constant Experiment (SOLCON), managed by the Royal Meteorological Institute of Belgium;
- e. Petite Amateur Navy Satellite (PANSAT), managed by the Department of Defense Space Test Program; and
- f. Get-Away Special (GAS) G-238 and G-764 Payloads.

These experiments were supported by the Hitchhiker carrier avionics unit and were mounted on a standard bridge in the payload bay of the Orbiter.

In addition to the scientific objectives of the mounted experiments, the IEH-3 mission included a small non-recoverable PANSAT, developed by the Naval Postgraduate

School (NPS) in Monterey, Calif. PANSAT is both an educational tool for the officer students at NPS and a digital communications satellite that will provide spread spectrum communications for use by the amateur radio community. The picture-perfect deployment of the PANSAT satellite occurred on flight day 2, adding yet another success to the list of IEH mission achievements.

Solar Extreme Ultraviolet Hitchhiker

The Solar Extreme Ultraviolet Hitchhiker (SEH) extreme ultraviolet instrumentation produced excellent full disk absolute solar flux data throughout the mission. All of the primary objectives of this experiment were met or exceeded. The detailed results of this experiment may be obtained from the sponsor of this payload. The observations consisted of 18 solar data sets, including 7 at sunset, eight at sunrise and 2 data sets running from sunrise through sunset. Observing time was approximately 14 hours per instrument. Six instruments were flown giving a total observing time of about 84 hours.

Solar Constant Experiment

The SOLCON dual-channeled radiometer viewed the Sun during 11 dedicated solar periods and during 7 non-dedicated solar periods, acquiring over 17 hours of data.

The preliminary analysis of the SOLCON data indicates successful observations, which were facilitated by the flawless solar pointing (within 0.1 degree of the Sun) throughout the mission by the Orbiter. The instrument provided very consistent results between the left and right channel measurements. These findings indicate that the scientific goals of this SOLCON mission have been successfully met. It will now be possible to utilize the SOLCON data to calibrate and verify the effects of aging on long-term solar-observing radiometers.

International Extreme Ultraviolet Hitchhiker/Space Telescope for Astronomical Research

The objective of the Space Telescope for Astronomical Research (STAR-LITE) project was to build and fly a novel telescope for imaging diffuse sources of ultraviolet (UV) radiation in the wavelength band 1150 to 900 angstroms.

STAR-LITE had two major difficulties during the STS-95 mission that limited the planned program of observations. First, the azimuth drive of the scan platform became stuck at an azimuth of approximately 87 degrees. This restricted the telescope motion to only the elevation axis. With only one degree of freedom, locating suitable targets at different Space Shuttle Orbiter attitudes became a major task during the mission. The second problem was the failure of the star tracker and finder cameras. This left STAR-LITE without fine-pointing information, and with knowledge of the pointing limited to the accuracy of the potentiometers on the scan platform axes that is approximately ± 3 degrees. In spite of these difficulties, the telescope and spectrometer appear to have functioned very much as planned. A number of stars were observed as they passed through or near the field of view of the spectrometer.

The mechanical and electronic failures in the pointing and tracking subsystems had no effect on our ability to make an evaluation of the optical and detector systems.

Throughout the mission, the detector performed very much as expected. This evaluation was a major achievement of this flight.

In all, STAR-LITE slewed to over 80 targets between flight days 2 and 8 of the mission. Nineteen observations have been identified as those containing data of immediate interest and merit further attention. Approximately 4 Gigabytes of data or 12,000 spectra were obtained during the mission. When these data are assembled into chronological order and systematically reduced, it is likely that much more will become evident. In summary, STAR-LITE accomplished about 20 percent of its observational scientific objectives.

International Extreme Ultraviolet Hitchhiker/Ultraviolet Spectrograph Telescope for Astronomical Research

This Ultraviolet Spectrograph Telescope for Astronomical Research (UVSTAR) flight, third of a series of five, was a complete success. All hardware performed as expected, thus enabling all scientific objectives to be met. The UVSTAR obtained a total of 54 series of spectral images: 17 of the Jupiter system, and 37 of celestial targets. In the last set of data are also included several serendipitous spectra which were obtained during the sleep time of the astronauts or during other useful Discovery attitudes.

Changes made in the spectrograph outgassing system and in the pointing/tracking system since the last flight produced the expected improvements in the instrument sensitivity. For one, the spectrograph detectors now operate in a cleaner environment. In addition, the spectrograph detectors now obtain a better spectral resolution (less than 3 arc sec) than in the previous (STS-85) flight.

The minor problems encountered early in the mission were solved during the flight. After an initial failure, the autonomous pointing/tracking system operated very smoothly even during the worst ambient conditions: rapid movements of the Orbiter, water or fuel dumping, etc. Unfortunately, this failure resulted in not acquiring science data of the first scheduled targets: 101, 104, 107 and 112. These are the only data lost during this mission.

SPARTAN 201 AND VIDEO GUIDANCE SENSOR

All SPARTAN and Video Guidance Sensor (VGS) mission objectives were accomplished. SPARTAN downlinked over 500 solar coronal images from the WLC. An additional 600 WLC images and 300 UVCS spectra were stored on the on-board recorders. All telemetry and observations of flight performance indicate nominal SPARTAN spacecraft performance. VGS performance exceeded expectations.

ELECTRONIC NOSE

The Electronic Nose (ENOSE) payload was activated on flight day 2 and daily markers were completed through flight day 7 after which the payload was deactivated and stowed. The crew reported that ENOSE worked very well. All ENOSE operations were nominal and all daily objectives were met. ENOSE has completed a fully successful mission with 100 percent of the objectives met.

VAPOR DIFFUSION APPARATUS/SINGLE LOCKER THERMAL ENCLOSURE SYSTEM

The vapor diffusion apparatus (VDA) was activated satisfactorily approximately eight hours after liftoff. The VDA experiment was deactivated on flight day 9, and the hardware operated nominally throughout the mission with no anomalies noted. One of the objectives of the experiment, reflected in a flight rule, which was to provide power to this experiment for thermal control to the experiment samples if power became available, was not accomplished. Although energy became available, the payload was not powered because crew time was not available to perform the procedure. Loss of science was expected as a result of the unexpected high cabin temperatures. However, postflight analysis of the crystals indicates that nine of the ten cells in the VDA contain crystals of sufficient quality to be used in the next step of the experiment.

All activities with the exception of powering up the experiment early in the mission were accomplished.

BIOLOGICAL RESEARCH IN CANISTERS

The Biological Research in Canisters (BRIC) payload performed satisfactorily. The only crew activity required was a transfer of the canister on flight day 5. Preliminary indications are that the canister transfer as well as hardware operations were nominal.

GET-AWAY SPECIALS

The GAS canisters performed nominally on this flight. The amount of data received as well as the results of these experiments cannot be determined until the flight hardware has been returned to the experiment sponsors facility. A minimum of two months will be required before this activity is completed.

RISK MITIGATION EXPERIMENT

RME 1334 - Wireless Network Connectivity Experiment - The wireless local area network (LAN) was 100-percent successful for STS-95. It was setup, and an radio frequency (RF) connection to the Orbiter communications adapter (OCA) payload and ground support computer (PGSC) was verified. Due to timeline constraints, the crew was unable to obtain the highly desirable RF signal-strength data in various configurations throughout the Orbiter and Spacehab.

HUMAN EXPLORATION AND DEVELOPMENT OF SPACE TECHNOLOGY DEMONSTRATION

HTD 1402 - The prelaunch integrated vehicle health monitoring (IVHM) data takes for the Human Exploration and Development of Space Technology Demonstration (HTD) indicated nominal readings except for two gaseous hydrogen (GH₂) sensors which displayed unexpected hydrogen concentration readings. These readings were compared to on-orbit readings to verify operation and no problems were noted. Nominal power down by the crew approximately 5 ½ hours into the mission occurred in accordance with the timeline.

On-orbit, the timeline directed the crew to activate the IVHM hardware once each day for a one-hour data take during pre-sleep activities. These data were not downlinked during the mission; consequently, the data will be accessed and analyzed during the postflight period.

VEHICLE PERFORMANCE

SOLID ROCKET BOOSTERS

All Solid Rocket Booster (SRB) systems performed satisfactorily. The SRB prelaunch countdown was normal, and no SRB Launch Commit Criteria (LCC) or Operational Maintenance Requirements and Specification Document (OMRSD) violations occurred. No SRB in-flight anomalies were identified from the data of this mission.

An External Tank (ET) thermal protection system (TPS) observation camera was mounted on the left SRB to provide video of the TPS on the ET thrust panel area. The camera was located in a housing mounted in the unused range safety cross-over cut-out of the left SRB forward skirt. The camera functioned as designed and provided continuous visual coverage of the desired thrust panel from lift-off through SRB separation.

Aft skirt doubler brackets were installed for the first time on this flight. These aluminum brackets were designed to increase the factor of safety of the hold-down post weld from 1.28 to 1.4. Strain gages mounted on the aft skirts verified that the brackets functioned as designed and increased the factor of safety to greater than 1.4.

This was the first flight on which all main parachutes were equipped with sea water activated release (SWAR) links (eight to each parachute). All SWARs except one functioned as designed. One link failed to release and the cause of the failure is being investigated.

Evaluation of the thrust vector controller (TVC) data showed that the TVC subsystem responded as expected on this fifth flight of the SSME trim modifications, which decreased the angle between the SSME and SRB thrust vectors during first stage operations. The SRB thrust vectors were trimmed to maintain thrust balance. The trimming of the SRB thrust vectors resulted in the TVC actuator positions being outside of the experience base during specific time frames. This condition did not impact the operations of the SRBs.

Both SRBs were successfully separated from the External Tank at approximately T+123 seconds. Reports from the recovery area indicated that the decelerations subsystems performed as designed, and recovery operations were completed satisfactorily. The SRBs were towed to shore and transported to Kennedy Space Center (KSC) for disassembly and refurbishment.

The SRBs were inspected for debris damage and debris sources following their return to Cape Canaveral. The inspection revealed that both frustums were in excellent condition. Likewise, the forward skirts exhibited no debonded areas or missing TPS. The field joint protection system (FJPS) closeouts were generally in good condition. The damage noted resulted from the severance of the nozzle extension. Separation of the aft ET/SRB struts appeared normal, and the damage to the fairings was attributed to water impact. Overall, the external conditions of the SRBs was excellent.

REUSABLE SOLID ROCKET MOTORS

All Reusable Solid Rocket Motor (RSRM) systems performed satisfactorily. The RSRM prelaunch countdown was normal, and no RSRM LCC or OMRSD violations occurred. No in-flight anomalies were noted in the review and analysis of the data.

Power up and operation of all igniter-joint and field-joint heaters was accomplished routinely. All RSRM temperatures were maintained within acceptable limits throughout the countdown. For this flight, the heated ground purge in the SRB aft skirts that is used to maintain the case/nozzle joint temperatures within the required LCC ranges was on the high range throughout the countdown.

The motor performance parameters for this flight were within the contract end item specification limits. The propulsion performance is shown in the following table.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 79 °F		Right motor, 79 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10 ⁶ lbf-sec	66.35	66.33	66.09	66.26
I-60, 10 ⁶ lbf-sec	176.55	176.84	176.00	176.99
I-AT, 10 ⁶ lbf-sec	296.94	296.88	297.05	297.62
Vacuum Isp, lbf-sec/lbm	268.6	268.6	268.6	269.1
Burn rate, in/sec @ 60 °F at 625 psia	0.3688	0.3694	0.3678	0.3687
Event times, seconds ^a				
Ignition interval	0.232	N/A	0.232	N/A
Web time ^b	108.6	108.3	109.0	107.8
50 psia cue time	118.3	118.0	118.7	118.0
Action time ^b	120.3	120.1	120.8	120.5
Separation command	123.6	-----	123.6	-----
PMBT, °F	79	79	79	79
Maximum ignition rise rate, psia/10 ms	90.4	N/A	90.4	N/A
Decay time, seconds (59.4 psia to 85 K)	2.8	2.9	2.8	3.4
Tailoff Imbalance Impulse differential, Klbf-sec	Predicted		Actual	
	N/A		372.7	

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

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

^bReferenced to liftoff time (ignition interval).

The calculated propellant mean bulk temperature (PMBT) was 79 °F at the time of launch. The maximum trace shape variation of pressure versus time during the 62 to 80 second was well below the 3.2 percent allowable limits.

The aft skirt purge operated for 14 hours 30 minutes during the launch countdown. It was activated to maintain the nozzle/case joint temperatures above the minimum LCC temperature. During the LCC time frame, the nozzle/case joint temperatures ranged from 83 °F to 90 °F and 82 °F to 88 °F on the left and right motors, respectively. The calculated flex bearing mean bulk temperature (FBMBT) was a nominal 82 °F.

The RSRM hardware performed as expected during the flight. The RSRM assessment indicated that the hardware was in good condition and nominal erosion was noted on each nozzle.

EXTERNAL TANK

This second flight of the super lightweight tank (SLWT) was satisfactory with all systems operating nominally. All flight objectives were satisfied, and no in-flight anomalies were noted during the review and evaluation of the data.

All objectives and requirements established for the External Tank (ET) propellant loading and flight operations were successfully met. All ET electrical equipment and instrumentation operated satisfactorily. The ET purge and heater operations were monitored and all performed properly. No violations of the LCC or the OMRSD were noted during the test.

No unacceptable ice/frost formations were observed on the ET during the countdown. All observed icing conditions were within the historical conditions as referenced in the NSTS 08303 document. The Ice/Frost Inspection Team reported the normal recurring crack where the foam bridges between the vertical strut cable tray and fitting fairing that is caused by joint rotation.

The ET pressurization performed nominally. No significant hazardous gas concentrations were noted during the countdown with the maximum concentration level reaching a very favorable level of 92 ppm, which compares well with previous data for this vehicle.

ET separation occurred as planned with ET entry and breakup within the predicted footprint. The postflight predicted ET intact impact point was approximately 77 nmi. uprange of the preflight prediction.

Postflight evaluation of the photographs and video of the ET that were taken with hand-held cameras showed the ET to be in good condition with relatively few discernible divots. A more detailed evaluation of the photography is contained in the Photography and Television Analysis section of this report.

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. No OMRSD violations occurred. Engine ready was achieved at the proper time; all LCC were met; and engine start and thrust buildup were normal. No in-flight anomalies were noted in the data analysis.

During the SSME ignition sequence at 302:19:19:30.693 G.m.t., ground-based photography showed the drag parachute panel falling away from the vehicle. The film and video review showed that the door detached three seconds before liftoff and struck the bell of SSME 1 as it fell (Flight Problem STS-95-V-01). Postflight inspections revealed no damage to the engine. A discussion of this anomaly may be found in the Drag Parachute Door Anomaly section of this report.

The SSME performance during mainstage, throttling, shutdown, and propellant dump operations was nominal. The high pressure oxidizer turbopump (HPOTP) and the high pressure fuel turbopump (HFOTP) temperatures were well within specification throughout the SSME operation. The specific impulse (Isp) was rated as 453.1 seconds, which compares well with the preflight predictions. Controller and software performance was also nominal. SSME cutoff (MECO) occurred at liftoff plus 501.2 seconds.

Evaluation of the TVC data showed that the TVC subsystem responded as expected on this fifth flight of the SSME trim modifications, which decreased the angle between the SSME and SRB thrust vectors during first stage operations. The SRB thrust vectors were trimmed to maintain thrust balance. The trimming of the SRB thrust vectors resulted in the TVC actuator positions being outside of the experience base during specific time frames. The overall actuator position experience base was not exceeded, but only certain areas of the time specific experience base required expanding.

SHUTTLE RANGE SAFETY SYSTEM

The Shuttle range safety system (SRSS) closed-loop testing was completed as scheduled during the launch countdown. All SRSS safe and arm (S&A) devices were armed and system inhibits turned off at the appropriate times. All SRSS measurements indicated that the system operated as expected throughout the countdown. As planned, the SRB S&A devices were safed, and the SRB system power was turned off prior to SRB separation. No in-flight anomalies were noted in the data analysis.

The ET SRSS has been, as planned, non-operational for a number of previous flights as well as STS-95. Present planning does not include the reactivation of the ET SRSS subsystem.

ORBITER SUBSYSTEMS PERFORMANCE

Main Propulsion System

The overall performance of the main propulsion system (MPS) was nominal throughout the mission, and all in-flight requirements were satisfied. Liquid oxygen (LO₂) and liquid hydrogen (LH₂) loading was performed with no stop-flows or reverts, and there were no OMRSD or LCC violations during the prelaunch period. One ground measurement, LH₂ high-point bleed temperature, was 0.5 °R above the historical high, however, the temperature did not exceed the specified launch commit criteria. No in-flight anomalies were identified from the data analysis.

Throughout the period of preflight operations, no significant hazardous gas concentrations were detected. The maximum hydrogen concentration level in the

Orbiter aft compartment was approximately 92 ppm, which compares well with previous data for this vehicle. This condition occurred shortly after the start of fast-fill, which is when the peak concentration level normally is recorded.

STS-95 was the first flight of the Integrated Vehicle Health Monitoring (IVHM) system. Special data for vacuum jacket pressure, helium solenoid leakage, umbilical plate gap differential pressure (ΔP), skin temperatures and hydrogen and oxygen detection were available during loading through to liftoff. The data from this initial flight indicates that the technology performed well; however, minor modifications to the software and hardware are being pursued prior to the next flight of the system.

Approximately 3 seconds prior to liftoff, the drag parachute door dislodged and fell toward the flame trench. The door struck the SSME 1 nozzle coolant manifold; however, this occurrence had no impact on flight operations. The postflight inspection revealed no damage to the SSME 1 coolant manifold. A discussion of this anomaly may be found in the Drag Parachute Door Anomaly section of this report.

Ascent MPS performance was completely nominal. Data indicate that the LO_2 and LH_2 pressurization systems performed as planned, and show that all net positive suction pressure (NPSP) requirements were met throughout the flight. The ET pressurization system functioned properly throughout the engine operations. The minimum LO_2 ullage pressure experienced during the period of the ullage pressure slump was 14.2 psid.

The overall in-flight performance of the gaseous hydrogen (GH_2) was nominal. All three flow control valves (FCVs) performed nominally with only 14 cycles of the FCVs during the flight. Likewise, the gaseous oxygen (GO_2) fixed orifice pressurization system performed as predicted. Reconstruction of the engine and MPS data parameters closely matched the actual ullage pressure measurements.

Helium system performance for the SSME and pneumatic helium systems performance were nominal. Entry helium usage was 61.5 lbm which is well within requirements.

Reaction Control Subsystem

The overall performance of the reaction control subsystem (RCS) was nominal, and no LCC or OMRSD violations occurred. Two in-flight anomalies were identified from the data. Thruster L3L failed off when first fired for the flight control system (FCS) checkout, and the forward RCS fuel tank began an erroneous slow quantity decay to near full-scale low. These anomalies are discussed in later paragraphs of this section. Neither of these conditions impacted the successful completion of the mission.

Of the total propellants consumed by the RCS (4892 lbm), 99.2 lbm were provided by the orbital maneuvering subsystem (OMS) during left-pod interconnect operations. The primary RCS had a total of 3524 firings, and a total firing time of 1072.55 seconds. The vernier RCS had a total of 21,855 firings, and a total firing time of 20,714.9 seconds.

During ascent, the left OMS pod aft outboard Y-web door carrier panel advanced flexible reusable surface insulation (AFRSI) blanket peeled back approximately eight inches into the air stream. The major concern with this condition was the temperature limits on propellant lines below the blanket. Analysis showed that some thruster performance

degradation does occur with higher temperatures; however, these higher temperatures were not expected to occur. This condition did not impact on-orbit or entry operations.

The following RCS thruster firings were performed to complete the rendezvous with the SPARTAN spacecraft. All RCS thrusters performed satisfactorily during the maneuvers.

RCS RENDEZVOUS MANEUVERS

RCS maneuver	Ignition, G.m.t./MET	ΔV , ft/sec	Firing time, sec
SPARTAN separation - 1	305:19:06:40 G.m.t. 02:23:47:06 MET	1.0	3.2
SPARTAN separation - 2	305:19:36:26 G.m.t. 03:00:17:14 MET	1.1	4.8
NC-1 phasing	305:20:58:34 G.m.t. 03:01:39:00 MET	2.1	0.9
NC-1A phasing	306:00:56:34 G.m.t. 03:05:37:00 MET	0.5	0.2
NC-2 and NC-2A phasing	Canceled	N/A	N/A
NC-3 phasing	307:02:17:34 G.m.t. 04:06:58:34 MET	1.4	6.0
NC-4 phasing	307:14:11 G.m.t. 04:18:52 MET	7.3	32.0
Height adjust	Canceled	N/A	N/A
Pre-OMS terminal phase initiation	307:16:21 G.m.t. 04:21:02 MET	3.2	11.7
Midcourse correction 1	307:17:41:10 G.m.t. 04:22:21:36 MET	0.4	1.5
Midcourse correction 2	307:18:14 G.m.t. 04:22:55 MET	0.8	3.1
Midcourse correction 3	307:18:31 G.m.t. 04:23:12 MET	0.5	1.9
Midcourse correction 4	307:18:54 G.m.t. 04:23:35 MET	1.5	6.4

The RCS hot-fire was performed following FCS checkout. The single-pulse hot-fire was initiated at 310:14:02 G.m.t. (07:18:43 MET), and all thrusters performed nominally with the exception of L3L. A failed-off thruster onboard fault message was annunciated at 310:14:08:27 G.m.t. (07:18:43:53 MET) when the thruster was commanded to fire for 320 msec. The chamber pressure only reached 0.8 psia, which is the vapor pressure of the fuel. After 240 msec, the RCS redundancy management (RM) deselected the thruster (Flight Problem STS-95-V-02). The final chamber pressure reading before termination of the attempted firing was 1.6 psia. This signature indicates that the oxidizer valve stage did not open because the chamber pressure did not rise above the fuel vapor pressure. The slight rise in the chamber pressure near the end of the attempted firing indicates that the oxidizer valve pilot stage may have opened slightly. At 310:14:09:11 G.m.t. (07:18:49:37 MET), the onboard fault summary message time tag indicated a fail-leak condition as determined from the oxidizer injector temperature going below 30 °F. The left RCS manifold 3 isolation valve was closed at 310:17:53 G.m.t. (07:22:34 MET) to prevent further leaking of oxidizer. The closing of

this manifold isolation valve also disabled thrusters L3D and L3A. The loss of this manifold did not impact entry operations.

A -X-axis orbit-adjust firing, using the RCS, was performed at 310:20:45:06 G.m.t. (08:01:25:32 MET). The firing was performed over a period of 52.3 seconds and a ΔV of 12.7 ft/sec was imparted to the vehicle.

At entry interface, the forward RCS fuel tank temperature began an erroneous slow decay to near full-scale low (approximately 5 °F) at 311:16:30:00 G.m.t. (08:57:11 MET), approximately 2 ½ minutes prior to entry interface (Flight Problem STS-95-V-03). Because the data were indicative of a propellant leak, the forward RCS isolation valves were secured approximately one minute after landing. After 30 minutes, the forward RCS manifold pressures reached a range of 570 to 670 psia, and sniff checks as well as system parameters did not indicate any propellant leakage. As a result of the pressures and data indications, the four forward RCS manifolds were opened and still no indication of a leak was present. Based on all of the indications and data, it is apparent that an erroneous temperature measurement was present.

Orbital Maneuvering Subsystem

The OMS performed satisfactorily throughout the flight, and no LCC or OMRSD violations occurred during the prelaunch operations. No in-flight anomalies were recorded. The inlet pressures, chamber pressure and regeneration jacket temperature for both engines were at expected levels. The OMS firing times and propellant consumption were consistent with predictions, thereby verifying nominal performance. A total of 22,859 lbm of OMS propellants were consumed during the mission, and of this total 99.2 lbm were consumed by the RCS during the left OMS pod interconnect operations.

The OMS maneuvers performed during the flight are shown in the following table. The OMS-2 maneuver was the longest firing of the engines in the history of the Space Shuttle Program.

OMS MANEUVERS

Maneuver	System configuration	Ignition time, G.m.t./MET	Firing time, seconds	ΔV , ft/sec
OMS-2	Both engines	302:20:01:31.6 G.m.t. 00:00:41:57.6 MET	305.4	464.2
OMS-3 (TI)	Right engine	307:17:21:22.6 G.m.t. 04:22:01:48.6 MET	12.4	9.9
Deorbit	Both engines	311:15:52:54.0 G.m.t. 08:20:33:20.0 MET	287	470.7

Following the OMS-2 firing, the gaseous nitrogen (GN₂) regulators for both engines locked up at approximately 322 psia. About 46 hours later, the vehicle attitude resulted in both engine compartments getting colder. This temperature decrease resulted in the left OMS GN₂ accumulator pressure lowering to 310 psia. To prevent a possible alarm during the following crew sleep period, the left OMS GN₂ accumulator was repressurized to approximately 330 psia.

The dual-engine deorbit maneuver for the first landing opportunity at the Kennedy Space Center (KSC) Shuttle Landing Facility (SLF) was performed on orbit 134.

Power Reactant Storage and Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem performed nominally throughout the mission with no in-flight anomalies identified. There were no LCC violations noted during the prelaunch operations. A one-time waiver for STS-95 was required because the hydrogen (H₂) tank 5 quantity measurement self-test value exceeded the upper limit (102.5 percent) stated in the OMRSD. Previous ground test data indicated a consisted 100.5 percent, thus indicating that the measurement had shifted upward 2.3 percent. The zero point also shifted upward by the same amount. This bias remained consistent throughout the mission and caused no impact to system operation.

The subsystem provided the fuel cells with 2652 lbm of oxygen and 334 lbm of hydrogen for the production of electricity. In addition, the environmental control and life support system (ECLSS) was supplied 87 lbm of oxygen. A 68-hour mission-extension capability existed at touchdown at the average mission power level of 17.9 kW, and at an extension-day power level of 13.2 kW, a 94-hour mission extension was available.

Fuel Cell Powerplant Subsystem

Performance of the fuel cell powerplant subsystem was nominal throughout the STS-95 mission with no in-flight anomalies identified from the data. The average electrical power level and load for the mission was 17.9 kW and 589 amperes. The fuel cells produced 3818 kWh of electrical energy and 2986 lbm of by-product potable water while using 2652 lbm of oxygen and 334 lbm of hydrogen.

Five purges of the fuel cells using both the automatic and manual systems were performed satisfactorily during the mission. The third fuel cell purge was performed earlier than planned to ensure that a purge would not be required during the SPARTAN rendezvous activities. The actual fuel cell voltages at the end of the mission were 0.15 Vdc above predicted for fuel cell 1, 0.20 Vdc above predicted for fuel cell 2, and 0.15 Vdc above predicted for fuel cell 3. The fuel cell operating times for the mission were 240:31 hours for fuel cell 1, 240:01 hours for fuel cell 2, and 239:24 hours for fuel cell 3.

The fuel cell monitoring system (FCMS) was flown for the second time and the system provided data for use in the prelaunch and postflight evaluation of fuel cell operation. The FCMS was not required to operate during the flight as none of the cell performance monitor (CPM) value changes exceeded the flight rule covering the operation of the FCMS.

Auxiliary Power Unit Subsystem

The auxiliary power unit (APU) subsystem performed nominally with no in-flight anomalies noted in the data. The table on the following page provides data concerning the run times and fuel consumption of the APUs during the mission.

APU 2 was started five minutes prior to ignition for the deorbit maneuver. APUs 1 and 3 were started 13 minutes prior to entry interface. No hydraulic load test was required after landing because all of the APUs had fewer than five flights since refurbishment.

APU RUN TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (S/N 310)		APU 2 (S/N 403)		APU 3 (S/N 404)	
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	19:44	50	19:46	56	19:49	54
FCS checkout			05:30	15		
Entry ^a	61:13	122	92:55	179	61:25	137
Total	80:57	172	118:11	250	81:14	191

^a APUs were shut down 17 minutes 28 seconds after landing.

^b APU 2 was used for the FCS checkout.

Hydraulics/Water Spray Boiler Subsystem

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

During the previous mission of this vehicle (STS-91), WSB system 2 experienced over-cooling three times during entry. On the STS-95 mission, WSB system 2 experienced over-cooling six times during entry. The WSB 2 over-cooling temperatures varied from the nominal steady-state value of 253 °F to as low as 195 °F. The over-cooling condition did not affect hydraulic operations during entry. WSB 2 as well as WSB 1 and WSB 3 operated nominally with no over-cooling or under-cooling during ascent.

APU 2 and hydraulic system 2 were used for FCS checkout because of the erratic behavior observed on SSME 2 TVC pitch actuator position transducer during the STS-91 postflight turnaround activities. Using APU 2 enabled a determination of whether SSME 2 violated the 2-degree step constraint, which it did not violate during the FCS checkout. Because of the short APU run time (approximately 5 ½ minutes), the WSB 2 did not spray.

Electrical Power Distribution and Control Subsystem

The electrical power distribution and control (EPDC) subsystem performed satisfactorily throughout the flight, and no in-flight anomalies were noted in the data. All File IX in-flight checkout requirements were also met.

Atmospheric Revitalization Pressure Control Subsystem

The primary and alternate atmospheric revitalization pressure control subsystems (ARPCS) operated satisfactorily throughout the flight. However, during prelaunch

operations, three master alarm fault messages were recorded during the 2-psid cabin leak check, and the resolution of these alarms resulted in a hold of 9 minutes 36 seconds. The first alarm occurred when the cabin pressure passed through 15.35 psi, the level at which the alarm is set, and a nominal master alarm occurred. The second master alarm occurred when the cabin pressure was stabilized at 16.72 psia and the cabin repressurization probe was removed. The momentary pressure-drop rate exceeded -0.08 psi/minute and caused a nominal differential pressure/differential time ($\Delta p/\Delta t$) master alarm. The third master alarm was also a $\Delta p/\Delta t$ alarm and it occurred when the cabin vent and vent isolation valves were opened to depressurize the cabin to ambient pressure. The pressure-drop rate again exceeded the -0.08 psi/minute and the third nominal master alarm occurred. All of these alarms are expected under the conditions which they occurred.

Atmospheric Revitalization System

The atmospheric revitalization system (ARS) performed nominally throughout the STS-95 mission with no in-flight anomalies identified in the data.

The cabin temperatures, cabin heat exchanger outlet temperatures, and cabin humidity were all maintained within satisfactory limits throughout the mission. The avionics bays temperature parameters also remained within satisfactory limits.

The partial pressure carbon dioxide (PPCO₂) peaked at a satisfactory level of 5.5 mmHg on flight day 4. PPCO₂ concentrations averaged 2.31 mmHg for the duration of the flight.

Active Thermal Control System

The active thermal control subsystem (ATCS) operations were satisfactory throughout the mission. Ascent performance was nominal with radiator flow initiated about 8 minutes before the payload bay doors were fully open. The radiators were deployed approximately 3 hours after liftoff to ensure adequate cooling for the Orbiter and the Spacehab module. It was necessary to inhibit the flash evaporator system several times during the mission to enable payload and experiment operations to be performed.

The radiator coldsoak prior to payload bay door closure provided cooling during entry. The radiators started to lose control one minute prior to landing, and temperatures continued to climb until two minutes after landing when the radiators were taken to high set-point and the ammonia boiler system (ABS) B was activated. The possibility of a leaking thruster delayed the attachment of ground cooling; consequently the ABS A was activated for the last six minutes prior to ground cooling being attached.

Supply and Waste Water Subsystem

The supply water and waste management subsystem performed satisfactorily throughout the mission, and all in-flight requirements were satisfied. No in-flight anomalies were identified in the data analysis.

Supply water was managed using the flash evaporator system (FES) and the water dump system. Seven supply water dumps were performed at an average dump rate of

1.65 percent/minute (2.73 lb/min). The supply water dump line temperature was maintained in a satisfactory range of 67.5 °F to 97.3 °F throughout the mission with the operation of the line heater. Following the sixth water dump, the line heater began controlling to a range of 5 to 10 °F instead of the nominal 20 °F for a duration of approximately 8.5 hours. The supply dump procedure requires a purge of the dump line with cabin air to prevent freezing of the dump valve, and this results in a mixture of air and water in the dump line after the dump is complete. The most probable cause of the thermostat's tighter control band was an air bubble migrating over the temperature sensor.

Waste water was gathered at the predicted rate. Four waste water dumps were performed at an average dump rate of 1.89 percent/minute (3.13 lb/min). The waste water dump line temperature was maintained in a satisfactory range between 58.5 °F and 85 °F throughout the mission.

The vacuum vent line temperature was maintained in a satisfactory range between 59.3 °F and 82.8 °F throughout the mission.

Waste Collection Subsystem

The waste collection subsystem performed normally throughout the mission with no reports of problems during the mission.

Airlock Support System

The active airlock support system monitor parameters indicated normal operation throughout the flight. As there was no extravehicular activity performed, the airlock support system was not exercised to its normal operating conditions.

Smoke Detection and Fire Suppression Subsystem

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

Flight Data System

The flight data system performed satisfactorily throughout the mission. No in-flight anomalies were noted in the data review and analysis.

The inertial measurement units (IMUs) performed nominally throughout the mission. On-orbit, only one adjustment of the IMU accelerometer compensations was performed for all three units. No drift compensations were required during the mission.

Flight Software

The flight software performed satisfactorily throughout the mission. No in-flight anomalies were noted during the data review.

Flight Control Subsystem

The flight control system (FCS) performed satisfactorily throughout the mission.

After the Orbiter was in the vertical position, the SSME 2 pitch actuator position transducer operation became erratic. The data were showing position offsets of -1.7 to -2.1 degrees. This level was within the LCC of five of six SSME TVC actuator position transducers operating properly. An OMRSD waiver was processed for the mission. During ascent, the measurement showed offsets exceeding -6 degrees. During entry, the measurement intermittently was off-scale, which represents an offset of at least -11.3 degrees. On the prior flight of this vehicle (STS-91), the right outboard elevon actuator displayed a ringing tendency during the flight. This condition was not observed on the STS-95 mission.

During the on-orbit FCS checkout, the TVC isolation valve was opened after the APU was started in the low-pressure mode. The pre-planned procedure was used for verifying that the step magnitude was within the flight rule limit of two degrees. Following the verification, the APU normal-pressure mode was selected prior to closing the isolation valve to restow the actuator. APU 2 was selected for the checkout so that the pitch and yaw actuators on SSME 2 and 3 were restowed. The erratic measurement would also preclude the normal post-landing repositioning of the engines to the rain-drain position. Consequently, a pre-planned and verified alternate procedure was used to complete the engine positioning.

The FCS checkout was performed using APU 2. APU 2 was started at 310:13:11 G.m.t. (07:17:52 MET) and ran for approximately 5 minutes and 30 seconds with a fuel consumption of 15 pounds. APU 2 and hydraulic system 2 performed nominally during the checkout.

Displays and Controls Subsystem

The displays and controls subsystem performed satisfactorily throughout the mission. No in-flight anomalies were noted in the data evaluation.

Communications and Tracking Subsystems

The communications and tracking subsystems performed nominally throughout the mission with no in-flight anomalies noted in the review of the data.

Operational Instrumentation/Modular Auxiliary Data System

The operational instrumentation (OI) and modular auxiliary data system (MADS) performed nominally with no in-flight anomalies noted in the data.

Structures and Mechanical Subsystems

The structures and mechanical subsystems performed satisfactorily throughout the mission. The discussion of the drag parachute door anomaly is provided in a separate

section of this report. The landing and braking parameters for this flight are shown in the following table.

LANDING AND BRAKING PARAMETERS

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	3333.3	194.8	-1.7	N/A
Nose gear touchdown	6263.0	162.2	N/A	-5.62
Brake initiation speed		154.4 knots		
Brake-on time		49.1 seconds		
Rollout distance		9511 feet		
Rollout time		59.7 seconds		
Runway		33 (Concrete) KSC		
Orbiter weight at landing		228639.2 lb		
Brake sensor location	Peak pressure, psia	Brake assembly	Gross energy, million ft-lb	
Left-hand inboard 1	1173	Left-hand inboard	31.51	
Left-hand inboard 3	1173			
Left-hand outboard 2	1157	Left-hand outboard	30.10	
Left-hand outboard 4	1157			
Right-hand inboard 1	1549	Right-hand inboard	47.27	
Right-hand inboard 3	1549			
Right-hand outboard 2	1441	Right-hand outboard	44.56	
Right-hand outboard 4	1441			

All four main landing gear tires, which exhibited some ply undercutting and rubber tread erosion, were found to be in reasonably good condition for a landing on the KSC concrete runway in a strong cross wind.

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 umbilical cavities. The EO-3 fitting retainer springs were in nominal configuration while the spherical washer and retainer springs in the EO-2 fitting were displaced. Two clips were missing from the EO-3 "salad bowl". Virtually no umbilical closeout foam or white room temperature vulcanizing (RTV) dam material adhered to the umbilical plate near the LH₂ recirculation line disconnect.

Integrated Aerodynamics, Heating and Thermal Interfaces

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

The local and acreage heating on the vehicle was also normal. The protruding OMS pod carrier panel blanket came through the entry as expected with the protruding portion shredded, the exposed structure charred, and the downstream AFRSI blanket damaged.

Thermal Control Subsystem

The thermal control systems performed nominally during the mission. The thermal conditioning plan for the main landing gear tires was altered slightly from the preflight plan to increase the bottom sun from 7 to 10 hours. The deorbit attitudes were changed from tail sun to nose-sun pitch-up 25 degrees to provide the drag parachute with a lower initial temperature for entry.

Aerothermodynamics

Data indicate that a normal symmetrical transition occurred. Aileron data, wing skin temperature and yaw thruster firings were all normal. Skin temperature rise indicates a turbulent to laminar transition time of 1252 seconds. No protruding AMES gap fillers were reported.

Thermal Protection Subsystem and Windows

The thermal protection subsystem (TPS) and windows performed nominally with no in-flight anomalies identified. Entry heating was normal based on structural temperature rise data. MADS data showed transition from turbulent to laminar flow occurred at 1252 seconds after entry interface and was symmetric. Entry heating was normal based on structural temperature rise data. MADS data showed transition from turbulent to laminar flow occurred at 1252 seconds after entry interface and was symmetric.

At 303:04:24 G.m.t. (00:09:04 MET), the crew reported that a portion of the TPS blanket on the left OMS pod was protruding approximately 8-in. and at a 45-degree angle from its normal position (Flight Problem STS-95-V-04). This was later confirmed by video from the stowed RMS cameras. During the subsequent payload bay survey with the RMS camera, a closer inspection was made of the TPS protrusion on the left OMS pod. It was identified as a small piece of TPS blanket at the aft of the left OMS pod above the stinger. No impact to the mission was identified. The postflight inspection video also showed that the small portion of the protruding TPS, had burned off. This condition did not affect the vehicle operation during entry.

The Orbiter TPS sustained a total of 187 damage sites (hits) during the mission. Of this total, 45 had a major dimension of 1-inch or larger. The total does not include the numerous damage sites on the base heat shield that are attributed to SSME vibration/acoustics and exhaust plume recirculation. A comparison of these numbers to 71 missions of similar configuration indicates both the total number of sites as well as the number of sites greater than 1-inch was greater than the cumulative mission average. The table on the following page provides the data for the total number of damage sites on the STS-95 Orbiter.

TPS DAMAGE SITES

Orbiter Surfaces	Hits > 1 Inch	Total Hits
Lower Surface	42	139
Upper Surface	1	6
Right Side	0	0
Left Side	0	4
Right OMS Pod	0	1
Left OMS Pod	0	4
Window Area	2	33
Total	45	187

The lower surface damage sites, shown in the preceding table, were concentrated in an areas aft of the nose landing gear doors and up to the main landing gear wheel wells on both the left and right chines. There was virtually no damage on the Orbiter centerline. Seven small damage sites that were located immediately aft of the nose landing gear doors were attributed to small pieces of rubber from the nose landing gear tires that were released from the tires during the landing and initial spin-up of the tires. It is interesting to note that the outboard damage sites on the chines followed the same location/damage pattern that was documented on the previous four Space Shuttle missions. STS-95 was the second flight of the super lightweight ET, and the number and size of damage sites were very similar to the STS-91 results (first flight of super lightweight tank). A comparison of the lower surface damage-site data from the previous five flights is shown in the following table.

COMPARISON OF DAMAGE SITE DATA FROM LAST FIVE FLIGHTS

	STS-87	STS-89	STS-90	STS-91	STS-95	Fleet Average
Lower surface total hits	244	95	76	145	139	83.2
Lower surface hits > 1 in.	109	38	11	45	42	13.3
Longest damage site, in.	15	2.8	3.0	3.0	4.0	N/A
Deepest damage site, in.	1.5	0.2	0.25	0.5	0.4	N/A

Tile damage sites around and aft of the LH₂ and LO₂ ET/Orbiter umbilicals were much less than usual. This damage is usually caused by impacts from umbilical ice or shredded pieces of umbilical purge barrier material flapping in the airstream. Also, less than the usual amounts of tile damage occurred on the base heat shield. All SSME dome-mounted heat shield (DMHS) closeout blankets were in excellent condition though there was some fraying on the SSME 1 blanket at the 5:00 to 6:00 o'clock position. Likewise, less than the usual amount of tile damage occurred on the leading edges of the OMS pods. However, a carrier panel and associated flexible insulation blanket (FIB) on the left OMS pod near the aft RCS thrusters was severely damaged during entry. This was the same item that was noted to be partially detached during the flight. The carrier panel/blanket immediately aft of this location was also damaged by repeated contact with the discrepant panel flaying in the airstream.

Hazing and streaking of the forward-facing windows was moderate to heavy. Damage sites on the window perimeter tiles was less than usual in quantity and size. Some of

the damage sites were attributed to old repair material falling out and these were not included in the assessment.

REMOTE MANIPULATOR SYSTEM

The remote manipulator system (RMS) performed satisfactorily throughout the mission, and all planned RMS activities were successfully completed. No in-flight anomalies or significant problems were noted during the system operation.

The crew reported that a portion of a thermal protection system (TPS) blanket on the left OMS pod was protruding approximately 45 degrees from its normal position. This was later confirmed by video from the stowed remote manipulator system (RMS) wrist camera. During the subsequent payload bay survey with the RMS wrist camera, a closer inspection was made of the TPS protrusion on the left OMS pod. In addition, the RMS wrist camera was used to inspect the area of the drag parachute door as well as SSME 1, which had been struck by the door as it was falling away.

A checkout of payload bay color television cameras A and B was made in support of Development Test Objective (DTO) 700-11, the Orbiter space vision system (OSVS), which was operated during the berthing of the SPARTAN payload on flight day 7. The OSVS photogrammetry technology uses camera views of various targets on the payload and the payload bay hardware to provide precise relative position, attitude, and rate data for berthing and unberthing a payload using the RMS. The OSVS is planned for use early in the International Space Station (ISS) assembly sequence and will be the primary source of precision data for the RMS operator when performing ISS assembly operations.

The RMS was repowered at 305:17:05 G.m.t. (02:21:45 MET), and the arm was placed in the pre-cradle position 10 minutes later. The SPARTAN was grappled at 305:17:27:14 G.m.t. (02:22:07:40 MET). The SPARTAN was unberthed and moved to the release position and released at 305:19:00:12 G.m.t. (02:23:40:48 MET). The deployment was nominal in all respects. The RMS arm was cradled at 305:19:55 G.m.t. (03:00:50 MET) and subsequently deselected.

The RMS was repowered at 307:16:54 G.m.t. (04:21:35 MET), and the arm was placed in the pre-cradle position 2 minutes later. The SPARTAN was captured at 307:20:48 G.m.t. (05:01:29 MET) and 11 minutes later, the RMS was maneuvered for SPARTAN berthing. The SPARTAN was berthed at 307:21:06 G.m.t. (05:01:47 MET), un-grappled at 307:21:11 G.m.t. (05:01:52 MET) and the RMS was cradled and powered off 16 minutes later.

The RMS was repowered and uncradled at 308:14:20 G.m.t. (05:19:01 MET). The SPARTAN was grappled at 308:14:39 G.m.t. (05:19:20 MET), and the SPARTAN was unberthed in support of OSVS operations. The SPARTAN was then maneuvered in and out of the berthing V-guides for the OSVS tests at 308:16:03 G.m.t. (05:20:42 MET). From 308:16:18 G.m.t. (05:21:59 MET) to 308:16:35 G.m.t. (05:22:16 MET), the RMS maneuvered the SPARTAN around the cargo bay in support of video guidance sensor (VGS) tests. At 308:16:53 G.m.t. (05:21:34 MET), the arm maneuvered SPARTAN for another OSVS test after which the SPARTAN was berthed and the arm was cradled and powered off at 308:18:13 G.m.t. (05:22:54 MET). All OSVS/VGS planned procedures were successfully accomplished, and all RMS operations were nominal. RMS

operations were completed for STS-95 with the successful conclusion of the OSVS/VGS tests.

The digital servo power amplifiers (SPAs) flown on this mission had a known software servo initialization error that could occur when transitioning the brakes from on to off. Under worst case conditions, this error could result in a brief tip of the arm point of reference (POR) transient with a maximum movement of 4 inches. The probability of this transient occurring on each brake transition was calculated to be approximately 2 percent. The low probability was evaluated and it was deemed satisfactory to fly the arm with this existing condition. A detailed analysis of the flight data showed 42 brake on-off transitions with no evidence that the software transient occurred.

RENDEZVOUS OPERATIONS

SPARTAN UNBERTHING, RELEASE AND SEPARATION

The SPARTAN 201-5 was a free-flying payload that was deployed using the remote manipulator system (RMS). The SPARTAN payload was grappled by the RMS on flight day 4 at 305:17:27:14 G.m.t. (02:22:07:40 MET) and unberthed at 305:18:03:17 G.m.t. (02:22:43:43 MET). The SPARTAN was released at 305:19:00:12 G.m.t. (02:23:40:48 MET). Two reaction control subsystem (RCS) separation maneuvers were performed following the SPARTAN release. The first maneuver was performed at 305:19:06:40 G.m.t. (02:23:47:06 MET), and the ΔV was 1.0 ft/sec. The second separation maneuver was performed at 305:19:36:26 G.m.t. (03:00:16:52 MET), and the ΔV was 1.1 ft/sec.

SPARTAN RENDEZVOUS, CAPTURE AND BERTHING

Three nominal correction (NC) maneuvers (phasing maneuvers) were performed. The first maneuver (NC-1) was made at 305:20:58:34 G.m.t. (03:01:39:00 MET) and had a ΔV of 2.1 ft/sec and a duration of 0.9 second. The second phasing maneuver (NC-1A) was initiated at 306:00:56:34 G.m.t. (03:05:37:00 MET), had a duration of 0.2 second and imparted a ΔV of 0.5 ft/sec to the vehicle. The third phasing maneuver, NC-3, was initiated at 307:02:17:34 G.m.t. (04:06:58:00 MET), had a duration of 6.0 seconds and a ΔV of 1.4 ft/sec was imparted to the vehicle. The NC2 and NC-2A maneuvers were not required.

The following RCS and OMS firings were performed to complete the rendezvous with the SPARTAN spacecraft. A 32-second nominal correction (NC-4) maneuver with the RCS was initiated at 307:14:11 G.m.t. (04:18:52 MET) and a ΔV of 7.3 ft/sec was imparted to the vehicle. The nominal height adjust (NH) maneuver was not required. A RCS pre-terminal phase initiation (TI) maneuver was initiated at 307:16:21 G.m.t. (04:21:02 MET), followed by an 11.6-second OMS-3 TI maneuver at 307:17:21 G.m.t. (04:22:02 MET) using the right engine. The ΔV for the OMS-3 maneuver was 10.2 ft/sec. Midcourse correction maneuvers MC1, MC2, MC3, and MC4 were performed during the rendezvous time-frame of 307:17:35 G.m.t. to 307:19:00 G.m.t. (04:22:16 MET to 04:23:41 MET).

The SPARTAN was captured at 307:20:48 G.m.t. (05:01:29 MET) and 11 minutes later, the RMS was maneuvered for SPARTAN berthing. The SPARTAN was berthed and the RMS was un-grappled from the SPARTAN at 307:21:11 G.m.t. (05:01:52 MET). The grapple and berthing operations were nominal.

The SPARTAN was grappled at 308:14:39 G.m.t. (05:19:20 MET), and the SPARTAN was unberthed in support of Orbiter space vision system (OSVS) operations. The SPARTAN was then maneuvered in and out of the berthing V-guides for the OSVS tests at 308:16:00 G.m.t. (05:20:41 MET). At 308:16:30 G.m.t. (05:22:11 MET), the RMS maneuvered the SPARTAN around the cargo bay in support of video guidance sensor (VGS) tests. At 308:17:00 G.m.t. (05:21:41 MET), the arm maneuvered SPARTAN for another OSVS test.

DRAG PARACHUTE ANOMALY INVESTIGATION RESULTS

During the Space Shuttle main engine (SSME) ignition sequence at 302:19:19:30.693 G.m.t., ground-based photography showed the drag parachute panel falling away from the vehicle (Flight Problem STS-95-V-01). An investigation team evaluated the potential for ascent damage, on-orbit operations impact, entry effects, contingency situations, and post-landing safety. The sequence of events that was derived from the analysis of the photography for this anomaly are shown in the following table.

Time, G.m.t. and MET	Event/Condition
320:19:19:30.616 G.m.t.	Faint light-colored vapor seen near drag parachute door just prior to first door motion
320:19:19:30.639 G.m.t.	First motion of door on port side
320:19:19:30.999 G.m.t.	Door detached from starboard hinge
320:19:19:31.091 G.m.t.	Two very small unidentified light-colored pieces of debris seen near drag parachute door detached from starboard hinge. One of the pieces appeared to be falling at the same rate as the door
320:19:19:31.303 G.m.t.	The port -Z corner of the drag parachute door impacted SSME 1 at the nozzle exit plane. The corner of the door was slightly deformed by the impact.
320:19:19:31.127 G.m.t.	Door fell below the main launch platform deck and lost from view. Door was intact until that time
T-0 through 24 seconds MET	Excellent views of aft end of Orbiter and drag parachute compartment. No debris exited the compartment during this time period.
24 seconds MET to 2 minutes 30 seconds (loss of view)	Although debris was seen during ascent (prior to SRB separation), none was seen to originate from the vicinity of the drag parachute compartment.

The velocity of the falling door was measured from the photographic images. The velocity of the mid-point of the door was calculated to be 12 ± 1 ft/sec. This is consistent with the door falling solely due to gravity. The remains of the door were found in the launch pad area; no other vehicle hardware was found. Thermal models predicted ascent heating of the surface of the drag parachute compartment above the melting point of the contained materials.

The postlaunch inspection of Launch Complex 39 Pad B structures and associated area recovered 18 pieces of the drag parachute door. No other flight hardware was recovered.

The team postulated that for entry, one of three conditions would exist: the parachute was intact and retained; the parachute had fallen out; or the parachute was intact, but in an unknown, possibly melted, condition. For the normally retained case, no action was recommended. This recommendation was based on the premises that the parachute would be retained by the retention straps; no pyrotechnic wiring damage concerns exist; and the pyrotechnic temperature would only rise 10 °F above its initial temperature. An

available temperature sensor on the mortar canister provided for the monitoring of the temperature. Parachute deployment was available to the crew in case of an emergency condition such as a flat tire or to prevent runway departure. For the missing parachute case, there were no additional concerns.

If the parachute was present, but melted in some way, it will most likely remain in-place during entry as the entry loads are all less severe than the 3g ascent loads. Entry loads push the parachute into the cavity with an average force of 0.2g. The possibility of a spontaneous deployment during entry is considered remote. Nevertheless, analysis and simulations have been performed to identify the cues that would alert the crew if the parachute spontaneously deploys. Below 30,000 feet, strong vehicle cues exist as well as visual verification by the Shuttle training aircraft (STA) or ground cameras. For some altitudes with full inflation of the parachute, it will break away on its own. However, for other deployed conditions, the crew will notice the cues and can arm, deploy, and jettison the parachute. The response to these cues is not time critical at higher altitudes, but becomes more important at lower altitudes. If no cues are present, no action was recommended.

The drag parachute and associated hardware appeared to be intact with little evidence of discoloration during the postflight video inspection of the vehicle. Further inspection and assessment led to the conclusion that the vehicle was safe for towing to the Orbiter Processing Facility (OPF) without firing the drag parachute pyrotechnic. In addition, SSME 1 appeared to be undamaged by the drag parachute door impact. A white scuff mark was visible on the Inconel "sill" at the nozzle exit plane directly aft of the door hinge location. The metal was not bent or deformed.

The investigation team was continuing as this report was written in its efforts to determine the cause and corrective action for this anomaly. As a result of this unresolved anomaly, the drag parachute deployment was disabled on STS-88.

GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

At 302:23:57 G.m.t. (00:04:38 MET) during the low iodine removal system (LIRS) installation, the crew reported a water leak from the flexible hose that connects the cartridge to the water supply from the bulkhead. The leak was at the cartridge end of the hose, and there was no leak at the joint or fitting. The crew described the leak as large and spraying. The LIRS installation was terminated, and the galley iodine removal assembly (GIRA) was installed. Subsequently, an in-flight maintenance (IFM) procedure was performed on flight day 2 using a hose from the IFM kit. Following the IFM, the GIRA was removed and the LIRS was reinstalled, and nominal operations followed. The hose leak was duplicated on the STS-88 unit at the same location. The leak was approximately the same size based on the crew description of the on-orbit leak.

At 304:02:31 G.m.t. (01:07:12 MET), the crew reported that the galley water from the LIRS had a bad taste, and this condition was confirmed with a ground-based unit. Procedures were developed to purge the galley and remove the LIRS and reinstall the GIRA should the water quality fail to improve. During the next crew day, the crew purged the galley and replaced the LIRS with the GIRA. Subsequently, the crew reported that the water taste was nominal.

While setting up the Space Integrated Global Position System (GPS)/Inertial Navigation System (SIGI) hardware for on-orbit data collection, communications between the payload data interleaver decommutator payload and ground support computer (PGSC) and the SIGI PGSC could not be established via the RS232 data cable (Flight Problem STS-95-V-05). The cable was replaced with a backup cable, and the system performed nominally for the remainder of the mission.

CARGO INTEGRATION

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

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DEVELOPMENT TEST OBJECTIVES

DTO 691 Low Iodine Residual System - The low iodine residual system (LIRS) was installed at the inlet to the galley to reduce iodine content to an acceptable level in the crew drinking water. A water leak at a flexible hose fitting was noted at the completion of the installation. The crew removed the LIRS and installed the activated carbon ion exchange (ACTEX) cartridge, which was flown as a backup to the LIRS. A in-flight maintenance (IFM) procedure was developed to replace the leaking flexible hose and the modified LIRS hardware operated with no leaks after the IFM procedure was performed.

However, about six hours after the IFM was completed, the crew reported poor tasting water coming from the LIRS hardware. Ground testing for this condition implicated the gamma sterilization procedure as the probable source of the LIRS contamination. An IFM procedure was developed to remove the LIRS, purge the galley of contaminated water, and reinstall the ACTEX. The ACTEX was reinstalled about 12 hours later and the water tasted satisfactory. As a result of the ground tests and crew reports, the LIRS was demanifested from the STS-88 mission (next flight), and the ACTEX will serve as the primary iodine removal hardware until the LIRS can be recertified for flight. The final technical analyses of the water samples and resin will be after landing. No data were collected on the ability of the system to remove iodine from the galley water.

DTO 700-11 - Orbiter Space Vision System Testing - STS-95 was the third flight of the Orbiter Space Vision System (OSVS) unit and the first flight to be used in conjunction with RMS operations. This Development Test Objective (DTO) evaluated the performance of the operational vision unit in conjunction with the Orbiter closed circuit television (CCTV) system. The OSVS photogrammetry technology uses camera views of various targets on the payload and the payload bay hardware to provide precise relative position, attitude, and rate data for berthing a payload using the RMS. This was the first flight to evaluate the relative mode of operation, the second flight to use the Camera Control Interface Function (CCIF), and the first flight to evaluate CCIF control of camera iris/gain functionality. The OSVS is planned for use early in the International Space Station (ISS) assembly sequence and will be the primary source of precision data for the RMS operator when performing ISS assembly operations.

The crew performed the checkout of payload bay color television cameras A and B in support of DTO 700-11, the OSVS, which was operated during the berthing of the SPARTAN payload on flight day 7. The crew conducted OSVS operations on three flight days. In addition, Mission Control received downlinked video and processed it with a ground unit during two crew sleep periods. All DTO objectives were met with excellent results.

On flight day 7, the OSVS was powered up, and camera A was setup to support SPARTAN unberthing and berthing operations using the OSVS for positioning cues. Prior to unlatching the SPARTAN, the crew reported the relative positioning error between the SPARTAN and the mission peculiar experiment support structure (MPSS) was as shown in the following table.

Mode	X axis	Y axis	Z axis	Pitch	Yaw	Roll	PSE
Absolute	0.0	0.1	-0.1	0.2	0.1	0.1	.003-5
Relative	-0.1	0.0	0.0	-0.1	0.0	0.0	.003-5

The SPARTAN was unlatched and maneuvered to a position approximately 14 inches above the latched position. The crew configured the OSVS to provide the positioning cues to berth the SPARTAN halfway down the J-guides. They reported that a total of four berthing runs was performed, with both operators performing berthing in both the absolute and relative modes of operation.

After the final SPARTAN berthing, the SPARTAN was again latched to the MPRESS. The crew conducted one final measurement of OSVS positioning performance and stated the post-latching results to be:

Mode	X axis	Y axis	Z axis	Pitch	Yaw	Roll	PSE
Absolute	-0.1	0.0	0.0	0.1	-0.1	0.1	.003-5

On flight day 8, the crew configured camera B in preparation for the image optimization tests. The sunset test began with acquisition of the wire tray targets during the day pass. The operator enabled the image optimization function, and observed the video scene and camera settings as the Orbiter Space Vision Unit (OSVU) generated iris/gain/gamma commands as the Orbiter crossed the terminator and passed into sunset. During the night pass, an illuminator was turned on, and manual changes were made to the iris to observe the subsequent changes in the video as the OSVU responded to the degraded lighting conditions. The final test was to acquire targets and observe the system response as the Orbiter passed through sunrise. The crew reported that all procedures were completed, and that the system response was as expected.

DTO 700-14 - Single String Global Positioning System - The miniature air-to-ground receiver (MAGR) global positioning system (GPS) was an overall success with all objectives being accomplished. Four objectives of this flight were completed; however, two In-flight anomalies were recorded. These were:

Suspected Tilt Conditions. These conditions were a known and expected issue. The anomaly was written to document its occurrence pending further data review to confirm the condition. A fix for this condition is currently in work and will fly on STS-96.

GPS Tilt During Operations (OPS) 2 Preamplifier Test. This test occurred during a non-standard operating configuration (i.e., no satellite signal available to the receiver). A full report will be provided by the unit manufacturer on this condition. Although a data review is proceeding, a preliminary assessment shows the MAGR provided an excellent navigation state vector during all critical mission phases.

DTO 700-15 - Space Integrated Global Positioning System/Inertial Navigation System Tests - While setting up the Space Integrated Global Positioning System (GPS)/Inertial Navigation System (INS) (SIGI) hardware for on-orbit data collection, communications between the payload data interleaver decommutator payload and ground support computer (PGSC) and the Space Integrated Global Positioning System/Inertial Navigation System (SIGI) PGSC could not be established via the RS232 data cable (Flight Problem STS-95_V-05). The cable was replaced with a backup cable, and

the system performed nominally for the remainder of the mission. The SIGI performance was satisfactory. STS-95 marks the first flight of new firmware in the receiver and software in the PGSC that simulates the operational SIGI hardware and general purpose computer (GPC) flight software interface.

Good GPS and blended (GPS/INS) navigation performance was demonstrated during all flight phases. The position and velocity data (GPS solution) was excellent throughout the entire mission. However, the inertial state vector solution began to drift and therefore the blended performance was degraded. The DTO PGSC software was designed to monitor and correct excessive errors in the SIGI via an automated function that commands the receiver to reinitialize its state vector data with the Orbiter state vector. The SIGI did not respond to these initialization commands. On flight day 8, the crew performed a procedure to try and force the SIGI to update its attitude. This initialization was successful. An analysis to determine the cause of the attitude error, and the cause of the failure of the receiver to respond to the automated commands is being performed as this report was being written.

DTO 700-18 - Space-to-Space Communications Flight Demonstration - On flight day 8, the Space-to-Space Communications System (SSCS) flight demonstration was completed successfully. The SSCS enabled direct communications between orbiting spacecraft in close proximity, and will provide the Orbiter, the ISS, and EVA astronauts the ability to use the same communications system for voice and data independent of ground support. The SSCS augments the S-band system and will replace the current EVA communication bands. The crew powered up an EMU and checked its operation with the Space-to-Space Orbiter Radio (SSOR). The test lasted about 30 minutes and all functions were nominal.

DTO 805 - Crosswind Landing Performance - Ground wind measurements show there was a crosswind component during landing and rollout. The review the data by the technical community revealed that the crosswind did not meet the intent of this DTO, and the DTO was not satisfied.

DTO 842 Automatic Targeting and Reflective Alignment Concept Computer Vision System - The purpose of the Automatic Targeting and Reflective Alignment Concept (AutoTRAC) Computer Vision System (ACVS) was to demonstrate a new wireless video system and a vision system using this technology. Tasks were designed to evaluate the use of this system to support element-to-element assembly and berthing operations using the Space Shuttle or ISS RMS. This ACVS system is the DTO version of the Wireless Video System (WVS) that will be implemented as operational hardware on the Space Shuttle and ISS.

The ACVS was operated on flight day 2. All planned activities were successfully performed by the crew within the time allotted, and 100 percent of the ACVS objectives were accomplished. No in-flight failures of any elements were identified.

The camera was exercised to test its controllability and image quality. The system video reception was stable and seamless. This demonstrated that the diversity array antenna-switching concept and its receiver sensitivity can handle the multi-path environment of the Space Shuttle. The camera video and two ACVS targets were used successfully by the crew to control the RMS to maneuver along trajectories that simulate assembly and

berthing tasks. The ACVS PGSC was used to process the RF camera views of the targetings and provided automatic acquisition and tracking of the targets which were displayed and recorded onboard. The lighting conditions encountered went from total darkness to direct Sun behind the camera which forced the crew to adjust the camera (using the wireless command link) to compensate for the extreme conditions.

DTO 1215 - International Space Station/Space Shuttle - Test of Color Printer - The printer has proven to be a 100 percent success and a benefit to the crew. The Color Printer has proven that it can print files remotely. Also, by printing over 300 pages of execute packages and messages, the color printer has proven to be able to handle large-scale print jobs. The color printer was used daily for the majority of the flight having waived most of its specific test objectives.

DETAILED SUPPLEMENTARY OBJECTIVES

DSO 206 - Effects of Space Flight on Bone and Muscle - This Effects of Space Flight on Bone and Muscle Detailed Supplementary Objective (DSO) consisted of preflight and postflight activities only. Data on the results of this experiment may be obtained from the Principal Investigator.

DSO 497 - Effects of Microgravity on Cell Mediated Immunity and Reactivation on Latent Viral Infections - This DSO consisted of preflight and postflight activities only. Data on this experiment may be obtained from the Principal Investigator.

DSO 498 - Space Flight and Immune Function - The Space Flight and Immune Function DSO consists of preflight and postflight activities only. Data on the DSO may be obtained from the Principal Investigator.

DSO 603 - Orthostatic Function During Entry, Landing, and Egress - This DSO observes the impacts of entry on the body. Electrocardiogram, blood pressure and acceleration of g-forces on the body are measured with this device. Voice recordings were also taken during SSME ignition, maximum-gravity, entry interface (EI), and the first time the subject stood erect following entry. The experiment was performed on flight day 9 during deorbit preparations, and the data was analyzed after the flight. There were no reported anomalies during the donning of this hardware.

DSO 605 - Postural Equilibrium Control During Landing/Egress - This Postural Equilibrium Control during Landing/Egress DSO consisted of preflight and postflight activities only. Results of this DSO may be obtained from the Principal Investigator.

DSO 626 - Cardiovascular and Cerebrovascular Responses to Standing Before and After Spaceflight - This Cardiovascular and Cerebrovascular Responses to Standing Before and After Spaceflight DSO consisted of preflight and postflight activities only. Results of this DSO may be obtained from the Principal Investigator.

DSO 627 - Bone Mineral Loss and Recovery - This Bone Mineral Loss and Recovery DSO consisted of preflight and postflight activities only. Results of this DSO may be obtained from the Principal Investigator.

DSO 628 - Magnetic Resonance Imaging After Exposure to Microgravity - The Magnetic Resonance Imaging After Exposure to Microgravity DSO was performed during the postflight period. Results of this DSO may be obtained from the Principal Investigator.

DSO 630 - In-Flight Holter Monitor - The In-Flight Holter Monitor DSO observed how the heart reacts in space, taking a continuous electrocardiogram (ECG). Any irregular heartbeats are detected with this device. This experiment was performed on flight day 6. Results of this experiment may be obtained from the Principal Investigator.

The In-Flight Holter Monitoring hardware experienced an anomaly during donning. The anomaly was resolved and corrected by powering off the hardware and replacing the batteries. The malfunction procedure corrected the problem and procedures to don the monitor were completed. The Holter Monitor was worn for an entire 24-hour data collection period and no other anomalies were reported. Results of this DSO may be obtained from the Principal Investigator.

DSO 802 - Educational Activities - In performing this DTO, good audio contact was established between the Orbiter and John Glenn High School in New Concord, Ohio, and the Newseum in Arlington, Virginia. The event was very successful with the crew answering several questions from each of the sites.

POSTLAUNCH PAD INSPECTION FINDINGS

The postlaunch inspection of Launch Complex 39 Pad B structures and associated area recovered 18 pieces of the drag parachute door. No other flight hardware was recovered. The overall assessment of the pad damage indicated that the damage was minimal.

No stud hang-ups were anticipated to have occurred during the launch. A report of lateral acceleration of 0.13g at Orbiter liftoff was too low to be caused by stud hang-ups. The SRB south hold-down post erosion was less than usual, and the north hold-down post blast covers and T-0 umbilicals exhibited typical exhaust plume damage. The SRB aft skirt gaseous nitrogen (GN₂) purge lines had remained upright after liftoff; however, both purge flexible lines exhibited structural damage and melting of the exterior wire braid.

The tail service masts (TSMs) appeared undamaged, and the bonnets were closed properly. No unusual erosion was noted at the bases of the TSMs where excess grout had been removed. Likewise, the Orbiter access arm (OAA) was undamaged.

The gaseous hydrogen (GH₂) vent line was latched in the fifth of eight teeth of the latching mechanism. The ground umbilical carrier plate (GUCP) 7-inch quick disconnect (QD) surface had no apparent damage. All observations indicated a nominal retraction and latching, although the GH₂ vent line showed some heat effects/damage from the SRB plume. Also, the aluminized thermal blanket was torn and scorched by the plume.

The gaseous oxygen (GO₂) vent arm showed no indications of plume damage.

Debris findings on the fixed service structure (FSS) included loose cable tray covers at the 175-foot and 195-foot levels. Also, approximately a two-foot section of the 1 1/2-inch angle iron was found at the 245-foot level stair, and the elevator door was blown-in at the 255-foot level.

PHOTOGRAPHY AND TELEVISION ANALYSIS

LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS

The 24 launch photography films and the 24 videos were reviewed by KSC, MSFC, and JSC. No anomalous vehicle-related conditions, other than the drag parachute door falling from the vehicle, were noted in any of the photography or videos. An in-depth discussion of the drag parachute door anomaly is contained in the Drag Parachute Anomaly Investigation Results section of this report.

For this mission, a video camera was attached to the left SRB so that the -Y thrust panel on the ET could be observed. This camera provided excellent views of the desired panel with good focus, exposure, and lighting. The first divot was noted at 92 seconds MET. In the period between 92 and 100 seconds, 13 divots were noted with none larger than 1-inch in diameter. During the next 10 seconds, between 60 and 80 divots were noted with 10 to 15 larger than 1-inch in diameter. From 110 to 120 seconds, 80 to 100 divots were noted with approximately 30 larger than 1-inch in diameter; however, none of the divots exceeded 3-inches in diameter. The majority of the divots were seen on the rib heads/top edges, and all of them were shallow with no substrate exposed. The largest concentration of divots was near EB fitting, though some were seen as far outboard as the second stringer beyond the thrust panel. Most of the divots were in the NCFI (insulation material) with only a few visible in the SS-1171 material.

Data analysis of the videos and films from launch was made in support of the drag parachute door anomaly. The films and videos provided extensive data on the loss of the door and the timing of events during the prelaunch time-frame. The analysis could not determine the cause of the door release and loss, but the documentation did provide a detailed time line of the events.

ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS

The 65 photographs that were taken of the ET after separation were well focused and the exposure was also good. The first picture was taken 13 minutes 40 seconds after liftoff using the Nikon 35 mm camera with the 400 mm lens.

The images of the ET were silhouetted by the late afternoon sun and this resulted in large areas of shadow on the ET. Views of the +Y side of the ET and the ET nose were acquired including the +Y thrust panel. No views of the -Y thrust panel or the -Y axis of the ET were obtained. The views of the shadowed areas of the +Y thrust panel were enhanced to bring out more detail. The analysis did not reveal any divots of greater than three inches in diameter, which was the minimum detectable size. The normal SRB separation burn scars and aerodynamic heating marks were identified on the +Y intertank and nose TPS of the ET. Venting that was apparently from the -Y intertank hydrogen vent was visible in four frames. No off-nominal conditions were noted in any of the ET photography.

The tumbling rate of the ET (end-to-end rotation) as well as the rotation around the X-axis was very slow (less than 1 deg/sec) prior to ET venting, and the rate was the lowest observed on any of the past five missions. The distance of the ET from the

Orbiter was calculated to be approximately 1.1 km on the first photographic frame that was acquired. The separation rate from the Orbiter was calculated to be 5.5 ft/sec.

In addition, approximately 7 minutes of hand-held camera video of the ET were acquired by the STS-95 crewmembers. The overall quality of the video was excellent, and the focus was generally good. The exposure was good when the background surrounding the ET was the relatively bright ocean and clouds. No anomalous conditions were noted during the review of the video.

LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSIS

The landing was on runway 33 at the KSC Shuttle Landing Facility, and the 11 videos of landing were reviewed. No in-flight anomalies were noted in the review.

Observations from the review show the touchdown to be normal. A sink rate analysis of the main gear was performed for the main gear touchdown. The sink rate was approximately 1.7 ft/sec. The drag parachute was not deployed as planned after the drag parachute anomaly that occurred approximately 3 seconds prior to liftoff.

TABLE I.- STS-95 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	302:19:14:46.752 302:19:14:48.682 302:19:14:50.970
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	302:19:19:06.104 302:19:19:06.264 302:19:19:06.424 302:19:19:06.584
Main Propulsion System Start ^a	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	302:19:19:27.409 302:19:19:27.526 302:19:19:27.672
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	302:19:19:33.984
Throttle up to 104.5 Percent Thrust ^a	ME-2 Command accepted ME-3 Command accepted ME-1 Command accepted	302:19:19:38.206 302:19:19:38.209 302:19:19:38.232
Throttle down to 72 Percent Thrust ^a	ME-2 Command accepted ME-3 Command accepted ME-1 Command accepted	302:19:20:12.607 302:19:20:12.609 302:19:20:12.633
Maximum Dynamic Pressure (g)	Derived ascent dynamic pressure	302:19:20:24
Throttle up to 104.5 Percent Thrust	ME-2 Command accepted ME-3 Command accepted ME-1 Command accepted	302:19:20:24.927 302:19:20:24.930 302:19:20:24.953
Both RSRM's Chamber Pressure at 50 psi ^a	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	302:19:21:31.744 302:19:21:32.024
End RSRM ^a Action ^a Time	LH SRM chamber pressure mid-range select RH SRM chamber pressure mid-range select	302:19:21:34.294 302:19:21:34.684
SRB Physical Separation ^a	LH rate APU B turbine speed - LOS	302:19 21:36.384
SRB Separation Command	SRB separation command flag	302:19:21:38
3g Acceleration	Total load factor	302:19:26:57.1
Throttle Down for 3g Acceleration ^a	ME-2 command accepted ME-3 command accepted ME-1 command accepted	302:19:26:57.255 302:19:26:57.257 302:19:26:57.280
Throttle Down to 67 Percent Thrust ^a for Cutoff	ME-2 command accepted ME-3 command accepted ME-1 command accepted	302:19:27:48.776 302:19:27:48.778 302:19:27:48.801
SSME Shutdown ^a	ME-2 command accepted ME-3 command accepted ME-1 command accepted	302:19:27:55.216 302:19:27:55.218 307:19:27:55.242
MECO	MECO command flag MECO confirm flag	302:19:27:56 302:19:27:57
ET Separation	ET separation command flag	302:19:28:15
APU Deactivation	APU-1 GG chamber pressure APU 2 GG chamber pressure APU 3 GG chamber pressure	302:19:34:18.704 302:19:34:31.598 302:19:34:39.142

^aMSFC supplied data

**TABLE I.- STS-95 SEQUENCE OF EVENTS
(Continued)**

Event	Description	Actual time, G.m.t.
OMS-1 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Not performed - direct insertion trajectory flown
OMS-1 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	
OMS-2 Ignition	Right engine bi-prop valve position Left engine bi-prop valve position	302:20:01:31.5 302:20:01:31.7
OMS-2 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	302:20:06:37.1 302:20:06:37.3
Payload Bay Doors (PLBDs) Open	PLBD right open 1	302:20:43:20
	PLBD left open 1	302:20:44:39
SPARTAN Grapple	Payload captured	305:17:27:14
SPARTAN Unberth	Payload select 1 latch 3A indication	305:18:03:17
SPARTAN Release	Payload captured	305:19:00:12
OMS-3 Ignition	Right engine bi-prop valve position Left engine bi-prop valve position	307:17:21:11.2 N/A
OMS-3 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	307:17:21:23.8 N/A
SPARTAN Capture	Payload captured	307:20:47:49
SPARTAN Berth	Payload select 1 latch 4A indication	307:21:04:51
SPARTAN Ungrapple	Payload captured	307:21:10:32
SPARTAN Grapple	Payload captured	308:14:38:40
SPARTAN Unberth	Payload select 1 latch 5A indication	308:15:37:08
SPARTAN Berth	Payload select 1 latch 4A indication	308:17:38:50
SPARTAN Ungrapple	Payload captured	308:17:44:49
Flight Control System Checkout APU 2 Start APU 2 Stop	APU 2 GG chamber pressure	310:13:11:30.131
	APU 2 GG chamber pressure	310:13:16.58.478
Payload Bay Doors Close	PLBD left close 1	311:13:10:15
	PLBD right close 1	311:13:11:58
APU Activation for Entry	APU-2 GG chamber pressure	311:15:47:58.069
	APU-1 GG chamber pressure	311:16:19:32.500
	APU-3 GG chamber pressure	311:16:19:36.417
Deorbit Burn Ignition	Left engine bi-prop valve position	311:15:52:54.2
	Right engine bi-prop valve position	311:15:52:54.2
Deorbit Burn Cutoff	Left engine bi-prop valve position	311:15:57:41.4
	Right engine bi-prop valve position	311:15:57:41.4
Entry Interface (400K feet)	Orbital altitude above reference ellipsoid	311:16:32:24
Blackout end	Data locked	No blackout
Terminal Area Energy Mgmt.	Major mode change (305)	311:16:57:14

**TABLE I.- STS-95 SEQUENCE OF EVENTS
(Concluded)**

Event	Description	Actual time, G.m.t.
Main Landing Gear Contact	RH main landing gear tire pressure 2	311:17:03:30
	LH main landing gear tire pressure 2	311:17:03:31
Main Landing Gear Weight on Wheels	LH main landing gear weight on wheels	311:17:03:31
	RH main landing gear weight on wheels	311:17:03:35
Nose Landing Gear Contact	NLG LH tire pressure 1	311:17:03:40
Nose Landing Gear Weight On Wheels	NLG weight on wheels 1	311:17:03:40
Drag Chute Deployment	Drag chute deploy 1 CP volts	Not deployed
Drag Chute Jettison	Drag chute jettison 1 CP Volts	Not deployed
Wheel Stop	Velocity with respect to runway	311:17:04:30
APU Deactivation	APU-1 GG chamber pressure	311:17:20:43.065
	APU-2 GG chamber pressure	311:17:20:51.219
	APU-3 GG chamber pressure	311:17:20:58.753

TABLE II.- STS-95 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-95-V-01	Loss of Drag Parachute Door	302:19:19 G.m.t. CAR 95RF01 Prelaunch IPR 96V-0001	During the main engine ignition sequence at approximately T-5 seconds, ground-based photography showed the drag chute door detach from the Orbiter and impact the rim of SSME 1 during its downward descent. In-flight evaluation of the condition led to a decision to not deploy the parachute for landing. Initial postlanding inspections showed that the drag chute remained in place undisturbed throughout the flight. Follow-up inspections to determine the condition of the parachute and other components in the drag parachute compartment are being performed as is an investigation and failure analysis to determine the cause of the door failure.
STS-95-V-02	RCS Thruster L3L Failed Off, Failed Leak	310:14:10 G.m.t. 07:18:50 MET CAR 95RF03 IPR 96V-0002	During the RCS hot-fire, the digital autopilot (DAP) was configured to fire thruster L3L for 320 msec. The operation was, however, only sustained for 240 msec, at which point the redundancy management (RM) deselected the thruster because of low chamber pressure. Subsequent analysis of the data signature indicated that the oxidizer pilot valve may have only partially opened. After the failure, the thruster's oxidizer and fuel temperatures dropped to 28 °F and 42 °F, respectively, indicating leakage through the oxidizer valve. This leak was confirmed by a subsequent divergence between the fuel and oxidizer quantities, and the left manifold 3 isolation valve was closed to prevent further propellant loss. The thruster was installed during the last Orbiter Maintenance Down Period (OMDP) of OV-103 after nominal processing through White Sands for checkout and flushing. Since the OMDP, the thruster has flown four flights including STS-95 and had accumulated 35 firings totaling 20 seconds of operation, typically operating in third priority. The thruster KSC: Thruster L3L will be removed for repair and replaced. The two other left manifold 3 thrusters will also be removed and replaced, in accordance with standard procedures invoked whenever a manifold is opened.
STS-95-V-03	Forward RCS Fuel Tank Temperature Decreased	311:16:30 G.m.t. 08:21:10 MET CAR 95RF05 IPR 96V-0003 and 0004	The forward RCS fuel tank temperature began to decrease unexpectedly during entry. This indicated temperature decrease could have been caused by a propellant leak, so after wheels stop, the forward RCS was secured as a precaution. After 30 minutes of sniff checks and monitoring of system parameters failed to indicate any propellant leakage, the forward RCS tank isolation valves were opened to partially relieve manifold pressures ranging from 570 to 670 psia. This action left the manifold pressures 50 to 60 psia higher than tank pressure. After an additional 80 minutes, the forward RCS manifolds 1 through 4 were opened when the manifold pressures were nearly equal to those in the tank. This was done to prevent valve bounce. Low manifold pressures resulting from post-entry cool down can result in manifold pressures that are lower than the tank pressure, and this may lead to the possibility of thruster valve bounce when the manifold valves are opened. The vernier manifold was left closed, however, because this manifold has no pressure measurement. Post-landing, the tank temperature measurement eventually reached and continued to erroneously indicate 3 to 4 °F.

TABLE II.- STS-95 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-95-V-03 (Continued)	Forward RCS Fuel Tank Temperature Decreased		KSC: Documentation was written to investigate the temperature measurement problem and to check out the system because of high manifold pressures that were allowed to occur post-landing. KSC investigated the condition prior to the scheduled removal of the forward RCS module for the STS-96 flow. Subsequent troubleshooting and systems checkout will be performed in the Hypergolic Maintenance Facility.
STS-95-V-04	TPS Protrusion on Left OMS Pod	303:04:24 G.m.t. 00:09:04 MET CAR 95RF02 PR TLP-01-29-2116	The crew reported that a portion of the TPS on the left OMS pod was protruding about 45 degrees from its normal position. This was later confirmed by RMS cameras while the arm was still stowed. A subsequent RMS payload bay survey identified the protrusion as a piece of TPS blanket, along with its attached carrier panel, and it was approximately 3 by 10 inches in size and located at X=1506, Z=480. In-flight evaluation of the condition determined that the entry heating effects in this area would not impact flight operations or safety. Post-landing inspections of the area were made and repairs are being made.
STS-95-V-05	Failure of SIGI/PDI DECOM RS232 Data Cable (GFE)	303:18:05 G.m.t 00:22:46 MET	Communications between the SIGI (DTO 700-15) and the Payload Data Interleaver (PDI) Decommutator (DECOM) payload and ground support computer (PGSC) could not be established via the RS232 data cable. This condition would have impacted the availability of Orbiter state vector data from the PDI DECOM to the SIGI. The backup cable stowed in a middeck locker was used to replace the original cable and nominal data transfer was established. 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. Mission Evaluation Room (MER) Daily Reports
5. MER Mission Summary Report
6. MER Problem Tracking List
7. MER Event Times
8. Subsystem Manager Reports/Inputs
9. MOD Systems Anomaly List
10. MSFC Flash Report
11. MSFC Event Times
12. MSFC Interim Report
13. Crew Debriefing comments
14. Shuttle Operational Data Book
15. STS-95 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
ACTEX	activated carbon ion exchange
ACVS	Automatic Targeting and Reflective Alignment Concept (AutoTrac) Computer Vision System
ADSEP	Advanced Organic Separations
AFRSI	advanced flexible reusable surface insulation
AGHF	Advanced Gradient Heating Facility
APCF	Advanced Protein Crystallization Facility
APU	auxiliary power unit
ARPCS	atmospheric revitalization pressure control subsystem
ARS	atmospheric revitalization subsystem
ASC	Astroculture
ATCS	active thermal control system
BRIC	Biological Research in Canisters
CCIF	camera control interface unit
CCPL	cryogenic capillary pumped loop
CCTV	closed circuit television
CDVA	Commercial Protein Crystal Growth-Vapor Diffusion Apparatus
CGBA	Commercial Generic Bioprocessing Apparatus
CGEL/CDOT	Structural Studies of Colloidal Suspension/Colloidal Disorder-Order Transition
CIBX	Commercial Instrumentation Technology Associates Biomedical Experiment
CPL	Capillary Pumped Loop
CPM	cell performance monitor
CRIM	commercial refrigerator/incubator module
CRYOTSU	Cryogenic Thermal Storage Unit
CTSW	cryogenic thermal switch
DMHS	dome-mounted heat shield
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
ΔP	differential pressure
ΔT	differential time
ΔV	differential velocity
ECG	electrocardiogram
ECLSS	Environmental Control and Life Support System
EI	entry interface
EMU	extravehicular mobility unit
ENOSE	Electronic Nose (experiment)
EO	ET/Orbiter
EORF	Enhanced Orbiter Refrigerator Freezer
EPDC	electrical power distribution and control
e.s.t.	eastern standard time
ET	External Tank
EUV	Extreme Ultraviolet

EVA	extravehicular activity
EXCP	experiment circuit panel
FAST	Facility for Adsorption and Surface Tension Experiment
FMBMT	flex bearing mean bulk temperature
FCE	flight crew equipment
FCMS	fuel cell monitoring system
FCS	flight control system
FCV	flow control valve
FES	flash evaporator system
FIB	flexible insulation blanket
FJPS	field joint protection system
FOFE	Fiber Optic Flight Experiment
FP	Fish Package
FSS	fixed service structure
ft/sec	feet per second
FUV	Far Ultraviolet
g	gravity
GAS	Get-Away Special
GH ₂	gaseous hydrogen
GIRA	galley iodine removal assembly
G.m.t.	Greenwich mean time
GN ₂	gaseous nitrogen
GO ₂	gaseous oxygen
GPC	general purpose computer
GPS	Global Positioning System
GUCP	ground umbilical carrier plate
H ₂	hydrogen
HOST	Hubble Space Telescope Orbital System Test Platform
HPFTP	high pressure fuel turbopump
HPOTP	high pressure oxidizer turbopump
HTD	Human Exploration and Development of Space Technology Demonstration
IEH	International Extreme Ultraviolet Hitchhiker
IFM	in-flight maintenance
IMU	inertial measurement unit
INS	inertial navigation system
I_{sp}	specific impulse
ISS	International Space Station
IVHM	Integrated Vehicle Health Monitoring
JSC	Johnson Space Center
keas	knots estimated air speed
km	kilometer
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt/hour
LAN	local area network
lbm	pound mass
lb/min	pound per minute
LCC	Launch Commit Criteria
LED	light emitting diode
LH ₂	liquid hydrogen

LIRS	low iodine removal system
LMSMS&S	Lockheed Martin Space Mission Systems and Services
LO ₂	liquid oxygen
MADS	Modular Auxiliary Data System
MAGR	miniature airborne GPS receiver
MC	midcourse correction (rendezvous maneuver)
MECO	main engine cutoff
MEPS	Microencapsulation Electrostatic Processing System
MET	mission elapsed time
MGBX	Microgravity Science Glovebox
MPES	mission peculiar experiment support hardware
MPS	main propulsion system
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NC	nominal correction (rendezvous maneuver)
NCS	NICMOS cooling system
NH	nominal height (rendezvous maneuver)
nmi.	nautical mile
NPS	Naval Postgraduate School
NPSP	net positive suction pressure
NSTS	National Space Transportation System (i.e., Space Shuttle Program)
OAA	Orbiter access arm
OCA	Orbiter Communications Adapter
OI	Operational Instrumentation
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OPF	Orbiter Processing Facility
OSVS	Orbiter Space Vision System
OSVU	Orbiter Space Vision Unit
PANSAT	Petite Amateur Navy Satellite
PCF	Protein Crystallization Facility
PCG-STES	Protein Crystal Growth-Single Locker Thermal Enclosure System
PCMUEP	Phase Change Upper End Plate
PGSC	payload and general support computer
PI	Principal Investigator
PMBT	propellant mean bulk temperature
POR	point of reference
ppm	parts per million
PPO ₂	partial pressure oxygen
PRSD	power reactant storage and distribution
psi	pound per square inch
psia	pound per square inch absolute
psid	pound per square inch differential
QD	quick disconnect
RCS	reaction control subsystem
RF	radio frequency
RM	redundancy management
RME	Risk Mitigation Experiment
RMS	remote manipulator system

RSRM	Reusable Solid Rocket Motor
RTV	room temperature vulcanizing (material)
S&A	safe and arm
SAREX	Shuttle Amateur Radio Experiment
SEH	Solar Extreme Ultraviolet Hitchhiker
SIGI	Space Integrated Global Positioning System/Inertial Navigation System
SLF	Shuttle Landing Facility
SLWT	Super Light Weight Tank
S/N	serial number
SOLCON	Solar Constant Experiment
SPA	servo power amplifier
SPARTAN	Shuttle Pointed Autonomous Research Tool for Astronomy
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSCS	Space-to-Space Communications system
SSD/MOMO	Self-Standing Drawer/Morphological Transition and Model Substances
SSME	Space Shuttle main engine
SSOR	Space-to-Space Orbiter Radio
SSR	solid state recorder
SSVEO	Space Shuttle Vehicle Engineering Office
STA	Shuttle training aircraft
STAR-LITE	Space Telescope for Astronomical Research
STS	Space Transportation System
SWAR	sea water activated release
TI	terminal phase initiation (rendezvous maneuver)
TPS	thermal protection system/subsystem
TSM	tail service mast
TVC	thrust vector controller
UV	Ultraviolet
UVSTAR	Ultraviolet Spectrograph Telescope for Astronomical Research
VDA	Vapor Diffusion Apparatus
Vdc	Volts direct current
VFEU	Vestibular Function Experiment Unit
VGS	video guidance system
WLC	White Light Coronagraph
WSB	water spray boiler
WVS	wireless video system