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STS-59 SPACE SHUTTLE MISSION REPORT

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NOTE

The STS-59 Space Shuttle Mission Report was prepared from inputs received from the Orbiter Project Office as well as other organizations. The following personnel may be contacted should questions arise concerning the technical content of this document.

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STS-59

SPACE SHUTTLE

MISSION REPORT

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INTRODUCTION

The STS-59 Space Shuttle Program Mission Report summarizes the Payload activities as well as the Orbiter, External Tank (ET), Solid Rocket Booster (SRB), Redesigned Solid Rocket Motor (RSRM), and the Space Shuttle main engine (SSME) systems performance during the sixty-second flight of the Space Shuttle Program and sixth flight of the Orbiter vehicle Endeavour (OV-105). In addition to the Orbiter, the flight vehicle consisted of an ET designated as ET-63; three SSME's which were designated as serial numbers 2028, 2033, and 2018 in positions 1, 2, and 3, respectively; and two SRB's which were designated BI-065. The RSRMs that were installed in each SRB were designated as 360W037A (welterweight) for the left SRB, and 360H037B (heavyweight) for the right SRB.

This STS-59 Space Shuttle Program Mission Report fulfills the Space Shuttle Program requirement as documented in NSTS 07700, Volume VIII, Appendix E. That document requires that each major organizational element supporting the Program report the results of their hardware evaluation and mission performance plus identify all related in-flight anomalies.

The primary objective of the STS-59 mission was to successfully perform the operations of the Space Radar Laboratory-1 (SRL-1). The secondary objectives of this flight were to perform the operations of the Space Tissue Loss-A (STL-A) and STL-B payloads, the Visual Function Tester-4 (VFT-4) payload, the Shuttle Amateur Radio Experiment-II (SAREX-II) experiment, the Consortium for Materials Development in Space Complex Autonomous Payload-IV (CONCAP-IV), and the three Get-Away Special (GAS) payloads.

The STS-59 mission was planned as a nominal 9-day + 1-day mission with 2 contingency days available should Orbiter contingency operations or weather avoidance be required. The sequence of events for the STS-59 mission is shown in Table I, and the official Orbiter Project Office Problem Tracking List is shown in Table II. The official Government Furnished Equipment (GFE) Problem Tracking List is shown in Table III, and the MSFC Problem Tracking List is shown in Table IV. In addition, the Integration and Payload in-flight anomalies are referenced in the applicable sections of the report. Appendix A lists the sources of data, both formal and informal, that were used in the preparation of this document. Appendix B provides the definition of acronyms and abbreviations used in this document. All times are given in Greenwich mean time (G.m.t.) as well as mission elapsed time (MET).

The six-person crew for this sixty-second flight of the Space Shuttle Program consisted of Sidney M. Gutierrez, Col., U. S. Air Force, Commander; Kevin P. Chilton, Col., U. S. Air Force, Pilot; Jerome Apt, Ph.D., Civilian, Mission Specialist 1; Michael Richard Clifford, Lt. Col., U. S. Army, Mission Specialist 2; Linda M. Godwin, Ph.D., Civilian, Payload Commander and Mission Specialist 3; and Thomas D. Jones, Ph.D., Civilian, Mission Specialist 4. STS-59 was the third space flight for Mission Specialist 1, the second space flight for the Commander, Pilot, Mission Specialist 2, and Mission Specialist 3; and the first space flight for the Mission Specialist 4.

MISSION SUMMARY

The STS-59 mission was scheduled for liftoff at 8:06 a.m. e.d.t. on April 8, 1994; however, the weather conditions were not acceptable for launch. The STS-59 countdown proceeded nominally up to the T-9 minute hold, which was lengthened because of the overcast cloud conditions existing at the launch site at the planned launch time. Late in the 2.5-hour launch window, the cloud conditions became acceptable; however, increased wind speeds accompanied the clearing conditions. As the launch window closed, the winds were such that crosswinds at the Shuttle Landing Facility (SLF) were in excess of the 15-knot limit should a Return-to-Launch-Site (RTLS) abort be required. As a result, the launch was scrubbed and rescheduled for Saturday, April 9, 1994, at 7:05 a.m. e.d.t.

The launch countdown for the second launch attempt proceeded nominally with no unplanned holds. The on-time liftoff of STS-59 for a 57-degree inclination orbit occurred at 099:11:05:00.020 G.m.t. (7:05 a.m. e.d.t. on April 9, 1994). There were no significant anomalies during the ascent phase.

All SSME and RSRM start sequences occurred as expected and the launch phase performance was nominal in all respects. SRB separation, entry, deceleration, and water impact occurred as anticipated, with both SRBs being successfully recovered. Performance of the SSMEs, ET, and main propulsion system (MPS) was normal. An evaluation of the vehicle performance during ascent was made using vehicle acceleration and preflight propulsion data. From these data, the average flight-derived engine specific impulse (Isp) for the time period between SRB separation and 3-g throttling was 452.0 seconds as compared to an MPS tag value of 452.77 seconds.

Following ascent, the auxiliary power unit (APU) 2 lube oil return temperature increased above the 250 °F nominal control temperature due to anomalous water spray boiler (WSB) 2 performance. When the APU 2 lube oil return temperature reached 305 °F, the crew switched from the WSB 2A to the 2B controller, and when the temperature reached 323 °F, APU 2 was shut down. No indication of WSB 2 cooling was noted. Also, the lube oil return temperature for APU 3 reached 283 °F before WSB 3 cooling was noted. Cooling began while still operating on the WSB 3A controller and the expected over-cooling condition occurred and was followed by nominal operation.

The orbital maneuvering subsystem (OMS) -1 maneuver was not required because of the direct insertion trajectory that was flown. The OMS-2 maneuver was performed at 099:11:40:10.3 (00:00:35:10.3 MET). The maneuver duration was 100.2 seconds and the ΔV was 163.5 ft/sec. The resultant orbit was 121.3 by 120.5 nmi.

The first orbit-adjust firing was performed at 099:15:10:00 G.m.t. (00:04:05:00 MET) using two +X reaction control subsystem (RCS) thrusters. The 13.4-second firing produced a ΔV of 3.2 ft/sec.

The mission design established the STS-59 mission as a 9-day + 1-day + 2-contingency-day mission. In light of this, the "go" was given during flight day 1 activities for an additional day on-orbit, extending STS-59 to a 10-day mission.

A second orbit-adjust firing was performed at 100:12:04:00 G.m.t. (01:00:59:00 MET). The multi-axis RCS firing lasted 15.048 seconds and resulted in a ΔV of 3.7 ft/sec.

The third orbit adjust firing was performed at 102:11:30 G.m.t. (03:00:25 MET). The firing was 14.02 seconds in duration and provided a ΔV of 3.3 ft/sec.

The fourth orbit adjust firing was performed at 104:13:46 G.m.t. (05:02:41 MET). The 13-second firing was retrograde in direction and provided a ΔV of 3.1 ft/sec.

APU 2 was used for flight control system (FCS) checkout, starting at 107:14:43 G.m.t. (08:03:38 MET). APU run-time was 12 minutes 2 seconds and 25 lb of fuel were consumed. All APU subsystem parameters were nominal during the checkout. About 7 minutes 47 seconds after APU start, lube oil spray cooling with the WSB 2B controller occurred when the lube oil return temperature reached 250 °F, and no obvious over-temperature or delay in cooling was noted. Approximately 2 1/2 minutes after cooling began, the crew switched to the WSB 2A controller and cooling was nominal. As a result of this successful test, WSB 2 was used for entry with no constraints.

The RCS hot-fire test began at 107:15:08:25 G.m.t. (08:04:03:25 MET) and ended at 107:15:14:10 (08:04:09:10 MET). A review of the thruster data indicated satisfactory operation of all thrusters.

The third fuel cell purge of the mission was performed at 107:22:04 G.m.t. (08:10:59 MET), 96 hours after the second purge. This was the first time in the Space Shuttle Program that the maximum interval of 96 hours has been achieved. The performance decay was 0.2 volt on each fuel cell.

All stowage activities in preparation for entry were completed for the first landing opportunity of the first scheduled landing day. The payload bay doors were closed at 109:12:14:55 G.m.t. (10:01:09:55 MET) with dual-motor times noted for both doors and all latches.

The first planned landing opportunity at 11:51 a.m. e.d.t. on April 19, 1994, at the SLF, was waived because of the cloud conditions in the SLF area. The second opportunity was also waived because of the unfavorable and dynamic weather conditions in the landing area as well as potential crosswind violations at the SLF. As a result, the landing was planned for April 20, 1994, at Kennedy Space Center (KSC) (weather permitting) or Edwards Air Force Base. The payload bay doors were reopened at 109:16:39:20 G.m.t. (10:05:34:20 MET).

All deorbit preparation activities for the second landing day opportunity were completed, and the payload bay doors were closed at 110:11:51:49 G.m.t. (11:00:46:49 MET). The first landing opportunity at KSC was waived because of no-go weather conditions, and the landing was retargeted for Edwards Air Force Base on the following orbit.

The deorbit maneuver for the first landing opportunity at Edwards Air Force Base was initiated at 110:16:00:34.9 G.m.t. (11:04:55:34.9 MET). The maneuver was approximately 135 seconds in duration and the ΔV was 234.5 ft/sec. Entry interface occurred at 110:16:22:11 G.m.t. (11:05:17:11 MET).

Main landing gear touchdown occurred at the Edwards Air Force Base on concrete runway 22 at 110:16:54:30 G.m.t. (11:05:49:30 MET) on April 20, 1994. The Orbiter drag chute was deployed satisfactorily at 110:16:54:41 G.m.t., and nose landing gear touchdown occurred 4 seconds after drag chute deployment. The drag chute was jettisoned at 110:16:55:12 G.m.t. with wheels stop occurring at 110:16:55:23 G.m.t. With the exception of greater-than-average main landing gear tire wear, the rollout was normal in all respects. The flight duration was 11 days 05 hours 49 minutes 30 seconds.

PAYLOADS

The payloads for the STS-59 mission consisted of the Space Radar Laboratory-1, the Space Tissue Loss-A and -B Experiments, the Visual Function Tester-4, the Shuttle Amateur Radio Experiment-II, the Consortium for Materials Development in Space Complex Autonomous Payload-IV, and three Getaway Special (GAS) experiments.

SPACE RADAR LABORATORY-1

The Space Radar Laboratory-1 consisted of a set of dedicated Earth observation payloads that were used to study vegetation, hydrology, tectonics, topography, and global air pollution. The SRL-1 instruments performed exceptionally well during the 11-day mission. The Shuttle Imaging Radar-C (SIR-C) performed flawlessly throughout the entire mission, as did the X-band Synthetic Aperture Radar (X-SAR) after a problem encountered during activation was resolved.

The Payload High Rate Recorders (PHRRs) performed well, even though some procedural modifications were required before the recorders would operate properly. The Applied Physics Laboratory (APL) sub-experiment also performed flawlessly and was a complete success. The strategy to follow the pre-mission ground track was executed so well that the last radar data takes occurred within one-half minute of the pre-mission planned time, and the look angle of the radar changed less than 0.5 degree from the planned.

The radar experiments had approximately 97-percent successful data takes when compared with the number planned. Of the more than 400 sites where data were planned to be taken during the mission, 19 sites were designated as "supersites." A 99-percent success rate was achieved in collecting data from the "supersites." The radar experiments produced over 94 hours of radar data recorded on 165 digital data tapes on the PHRRs. These data consist of swaths taken over 44 countries during 850 data-takes, and these data cover an area in excess of 43.75 million square miles (70 million square kilometers).

The high-rate downlink and subsequent data flow to the Mission Control Center (MCC) and Jet Propulsion Laboratory (JPL) worked very well. The JPL ground products system processed approximately 20 scenes using the high-precision processor, three scenes using data from all three frequencies, and five special products. Numerous X-SAR X-band passes were produced on the real-time processor and special image products for display and evaluation were produced.

Anomalies that were identified in the SRL-1 were the failure of one C-band panel (out of 18), the failed X-SAR circuit that provides protection to the high-power amplifier, the PHRR 1 crinkling tape problem, and transient commanding problems with the PHRRs. The C-band panel will probably be replaced between flights, the failed X-SAR circuit will be examined during turnaround activities to determine whether to fly as-is or repair, and the PHRR problems will be evaluated for corrective action.

The Measurement of Air Pollution from Satellites (MAPS) experiment also performed flawlessly. The MAPS experimenters were pleased with the stability of the pallet Freon loop, which provided superb instrument thermal stability throughout the mission. The mission concluded with 211 hours of MAPS data. Their mission was 100-percent successful.

SPACE TISSUE LOSS/NATIONAL INSTITUTE OF HEALTH - CELLS

The Space Tissue Loss/National Institute of Health - Cells (STL/NIH-C) experiment provided data on the effects of microgravity on muscle, bone, and endothelial cells to validate models of biochemical and functional loss induced by microgravity stress. The STL experiment evaluated cytoskeleton, metabolism, membrane integrity and protease activity in target cells, in addition to testing tissue-loss pharmaceuticals for efficacy.

The STL-A and STL-B parts of the STL/NIH-C experiment were initialized on flight day 1 as planned and were configured for entry on flight day 10 as planned. Temperature readings throughout the flight indicated that both units performed nominally. Real-time downlink video from the STL-B internal microscope demonstrated a new scientific capability to monitor on-orbit sample status without major impacts to the crew timeline. Additional video of the contents of STL-B was recorded onboard for postflight evaluation. The crew also downlinked a video tutorial of the STL/NIH-C activities and objectives.

VISUAL FUNCTION TESTER-4

The VFT-4 experiment measured the near and far point of clear vision of the human eye, as well as the ability of the eye to change focus within the range of vision.

The daily VFT-4 data-takes were completed by the crew as expected. No anomalies were identified with the equipment. On two occasions (flight day 1 and 6), the crew provided a downlink video tutorial of the VFT-4 operations.

SHUTTLE AMATEUR RADIO EXPERIMENT-II

The SAREX-II was used to communicate on the two-meter amateur radio band with schools and radio operators around the world. All school contacts planned for this mission were successfully accomplished using the SAREX-II radio equipment. The American Radio Relay League/Amateur Radio Satellite Corporation (ARRL/AMSAT) reported that there was more press coverage on this flight than for any previous flight. The school contacts included St. Bernard High School in Playa Del Rey, California; Kanawha Elementary School in Davisville, West Virginia; Anthony Elementary School in Anthony, Kansas; Deep Creek Middle School in Baltimore, Maryland; Ealy Elementary in West Bloomfield, Michigan; Country Club School in San Ramon, California; Paltama Senior High School in Paltama, Finland; Ogilvie School in Northhampton, Australia; and the Boy Scouts from Alcetal School in Richardson, Texas. On April 13, using telebridge connections, the crew wished the Mir (Russian Spacecraft) a belated "Happy Cosmonaut's Day". Also, on April 15, 1994, the crew spoke with Astronauts Bonnie Dunbar and Ken Cameron in Star City, Russia.

CONSORTIUM FOR MATERIALS DEVELOPMENT IN SPACE COMPLEX AUTONOMOUS PAYLOAD-IV

The CONCAP-IV was contained in a standard GAS canister mounted on a GAS bridge assembly in the payload bay. The CONCAP-IV grew crystals and thin films through physical vapor transport, and provided for a continuation of this experiment which has been flown on previous Space Shuttle flights.

The CONCAP-IV was initialized on flight day 1 as planned. Final operations to purge the system with nitrogen and deactivate were performed on flight day 10 in preparation for entry. Postflight analysis will determine the success of this experiment.

GETAWAY SPECIALS

Activation of all GAS canisters was completed on flight day 1 at 099:17:22 G.m.t. (00:06:17 MET). Deactivation of the G-20[illegible] GAS canister (Freezing and Crystallization of Water in Spaceflight) occurred on flight day 1 at 099:19:10:25 G.m.t (00:08:05:25 MET). The second GAS canister to be deactivated was G-300 (Thermal Conductivity Measurements on Liquids in Microgravity) and that occurred on flight day 4 at 102:18:37:30 G.m.t. (03:07:32:30 MET). The third GAS canister, G-458 (Microgravity's Influence on Small Fruiting Bodies) was deactivated on flight day 9 at 107:22:00:35 G.m.t. (08:10:55:35 MET). Success of all three GAS experiments will be determined through postflight analysis, and the results will be published in other documentation.

VEHICLE PERFORMANCE

SOLID ROCKET BOOSTERS

The SRB prelaunch countdown was normal, and no SRB Launch Commit Criteria (LCC) or Operations and Maintenance Requirements and Specification Document (OMRSD) violations occurred.

Analysis of the flight data indicates nominal performance of all SRB subsystems. A 2-percent rise in the left SRB tilt hydraulic reservoir fluid level (3 seconds in duration) was noted during the prelaunch gimbal test following hydraulic power-up and the initial drop in reservoir fluid level. The level was nominal for the remainder of the flight, although minor fluctuations were noted during the roll maneuver. This response has been seen on previous flights, and appears to be a characteristic of the thrust vector control (TVC) system during startup or a small amount of air trapped in the system. The characteristic had no adverse effect on systems performance.

Both SRBs were successfully separated from the ET at 126.14 seconds after liftoff. Reports from the recovery area, based on visual sightings, indicate that the deceleration subsystems performed as designed. Both SRBs were recovered and returned through Port Canaveral to KSC for inspection and refurbishment.

During the postflight inspection, an in-flight anomaly was noted when the K5NA was found separated from the Hypalon and primer at the booster separation motor (BSM) support brackets on the right and left aft skirts (Flight Problem STS-59-B-01).

The inspection also revealed an indentation in the instafoam on the forward face of the right External Tank attachment (ETA) ring near the aft integrated electronics assembly (IEA) cover (Flight Problem STS-59-I-02).

REDESIGNED SOLID ROCKET MOTORS

The prelaunch countdown RSRM performance was satisfactory with no LCC or OMRSD violations.

Power up and operation of the field-joint and igniter-joint heaters were accomplished routinely. The field-joint heaters operated for 11 hours 9 minutes (21 percent of the LCC time frame) to maintain the field joints in their normal operating temperature range. The igniter-joint heaters operated for 17 hours 45 minutes (41 percent of the LCC time frame) to maintain the igniter joints in their normal operating temperature range.

For this flight, the low-pressure heated ground purge in the SRB aft skirt was operated intermittently for 5 hours 49 minutes to maintain the case/nozzle-joint temperatures within the required LCC ranges. The purge was changed to high pressure to inert the SRB aft skirt prior to launch. As a result of the purge operation, the calculated flex bearing mean bulk temperature was an acceptable 82 °F.

Data indicate that the flight performance of both RSRMs was well within the allowable performance envelopes, and was typical of the performance observed on previous flights. The following table shows some of the more significant RSRM flight data based on the propellant mean bulk temperature (PMBT) of 71 °F.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 71 °F		Right motor, 71 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10^6 lbf-sec	65.99	65.95	66.12	65.87
I-60, 10^6 lbf-sec	175.76	174.92	176.06	174.86
I-AT, 10^6 lbf-sec	297.03	296.21	297.02	296.60
Vacuum Isp, lbf-sec/lbm	268.50	267.80	268.50	268.20
Burn rate, in/sec @ 60 °F at 625 psia	0.3694	0.3691	0.3699	0.3689
Burn rate, in/sec @ 71 °F at 625 psia	0.3723	0.3718	0.3728	0.3717
Event times, seconds[a]				
Ignition interval	0.233	N/A	0.229	N/A
Web time[b]	109.2	109.5	109.0	109.0
Separation cue, 50 psia	118.9	118.9	118.7	119.1
Action time[b]	121.0	121.0	120.7	120.9
Separation command	123.8	124.1	123.6	124.1
PMBT, °F	71.00	71.00	71.00	71.00
Maximum ignition rise rate, psia/10 ms	90.4	N/A	90.4	N/A
Decay time, seconds (59.4 psia to 85 K)	2.8	2.8	2.8	2.5
Tailoff imbalance impulse differential, Klbf-sec	Predicted N/A		Actual 88.7[c]	

Notes:
[a] Times are referenced to ignition command time.
[b] Those items are referenced to lift-off time (ignition interval).
[c] Impulse imbalance = left motor - right motor

Postflight inspection of the motors indicated nominal performance. However, a gas path was found through the left-hand nozzle-to-case joint polysulfide at the 204-degree location. Soot was observed up up to the wiper O-ring from the 202-degree to 210-degree locations. No soot or heat effects were observed past the wiper O-ring. The wiper O-ring was eroded a maximum of 0.008-inch deep at the gas-path location. Gas paths through the nozzle-to-case joint polysulfide have been observed on five previous RSRM flight motors. There was no heat effect to metal parts or the primary O-ring. Testing and analysis have verified that the nozzle-to-case joint can tolerate the occurrence of a single polysulfide gas path aligned with a wiper O-ring defect, and a worst-case thermal analysis has verified that the joint is fail-safe for multiple gas paths through the polysulfide and wiper O-ring.

EXTERNAL TANK

All objectives and requirements associated with ET propellant loading and flight operations were met. All ET electrical equipment and instrumentation functioned satisfactorily. ET purge and heater operations were monitored and all performed properly. No ET LCC or OMRSD violations were identified.

The nose-cone purge heater and temperature control system operated successfully. The primary controller failed at the start of the nose-cone purging; therefore, the secondary controller was used throughout the entire nose-cone purge procedure. The primary-controller power relay was jumpered during the L-3 hour hold, allowing the controller to be used as a backup should the secondary controller have failed.

Typical ice/frost formations were observed on the ET during each countdown. There was no observed ice or frost on the acreage areas of the ET. Nominal quantities of ice or frost were present on the liquid oxygen (LO_2) and liquid nitrogen (LH_2) feedlines and on the pressurization line brackets. These observations were acceptable per NSTS 08303. No anomalous thermal protection system (TPS) conditions were noted during the final walk-down inspection performed by the Ice/Frost Red Team.

The ET pressurization system functioned properly throughout engine start and flight. The minimum LO_2 ullage pressure experienced during the ullage pressure slump was 14.4 psid.

ET separation was confirmed, and the ET was photographed by the crew after separation. The Development Test Objective section contains a detailed discussion of the results of the ET photography. The postflight predicted impact point was approximately 111 nmi. uprange of the preflight prediction.

SPACE SHUTTLE MAIN ENGINE

The postponement of the launch for one day enabled the inspection of the high pressure oxidizer preburner pump volute vanes, and these were found satisfactory for flight. All tanking and prelaunch preparations were completed satisfactorily.

All SSME parameters appeared to be normal throughout both prelaunch countdowns and were typical of prelaunch parameters observed on previous flights. Engine ready was achieved at the proper time, all LCC were met, and engine start and thrust buildup were normal.

All Interface Control Document (ICD) start and shutdown transient requirements were met with the exception of total propellant consumption during the start of SSME 3. SSME 3 (s/n 2018) exceeded the maximum allowable total propellant consumption during start by 102 lbm. The violation is attributed to the time required to meet steady-state requirements; however, the time from engine start to steady-state thrust was 4.68 seconds, which is within the ICD limits.

Flight data indicate that SSME performance during mainstage, throttling, shutdown, and propellant dumping operations was normal. Engine cutoff times for SSME 1, 2, and 3 were 519.37, 519.48, and 519.60 seconds, respectively. The specific impulse (I_{sp}) was rated as 452.01 seconds based on trajectory data. Space Shuttle main engine cutoff (MECO) occurred 513.0 seconds after liftoff.

The high-pressure fuel turbopump (HPFTP) temperatures were well within specification throughout engine operation. The SSME 3 channel A and channel B differential temperature (ΔT) for the high pressure oxidizer turbopump (HPOTP) turbine discharge was greater than 200 °F (Flight Problem STS-59-E-1). This represents a 7.2-sigma difference when compared with the flight data base. The cause is believed to be associated with a hardware degradation condition that necessitated plugging three adjacent oxidizer preburner posts prior to STS-59. The plugging would have created a localized area of low mixture ratio that affected the Channel A measurement and not the Channel B measurement. The HPOTP temperatures for SSME 1 and 2 were satisfactory; and except for the temperature previously described in this paragraph, SSME 3 temperatures were satisfactory.

SSME 1 had two pressure measurements that spiked (Flight Problem STS-59-I-01). The HPFTP coolant liner pressure spiked at engine start + 83 seconds, and the fuel system purge pressure spiked at engine start plus 91.5 seconds. The time and amplitude of these spikes match those caused by ground radar noise.

SSME 1 experienced a 174g peak-to-peak "pop" at engine start plus 1.43 seconds. This level is 1g below the OMRSD limit, and as a result, a flatness check of the preburner faceplate has been recommended.

The hot-gas injection pressure measurement on SSME 1 and 2 became steady-state at engine start plus 260 seconds. This phenomenon has been observed on previous flights, and has been attributed to ice formation in the sensing line.

SHUTTLE RANGE SAFETY SYSTEM

The Shuttle Range Safety System (SRSS) closed-loop testing was completed as scheduled during each 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 and flight.

As planned, the SRB S&A devices were safed, and the SRB system power was turned off prior to SRB separation. The ET system remained active until ET separation from the Orbiter.

ORBITER SUBSYSTEMS

Main Propulsion System

The overall performance of the MPS was nominal with no in-flight anomalies noted.

During the prelaunch LO_2 umbilical plate gap setup, the required supply pressure to obtain 0.25 psig in the gap was 640 psig, which violates the 550-psig maximum requirement. An exception was issued for this condition, as a visual inspection did not reveal any leak paths that might cause higher-than-normal supply pressure. Vehicle inspections of the umbilical and pyrotechnic canister areas will be performed.

During both countdowns, LO_2 and LH_2 loading was performed as planned with no stop-flows or reverts. No LCC or OMRSD violations were noted. Throughout preflight operations, no significant hazardous gas concentrations were detected. The maximum hydrogen concentration level in the Orbiter aft compartment during the final countdown occurred shortly after start of fast-fill and was approximately 163 ppm (corrected), which compares favorably with previous data for this vehicle.

A comparison of the calculated propellant loads at the end of replenish versus the inventory (planned) loads results in a loading accuracy of -0.02 percent for LH_2 and -0.01 percent for LO_2. Both of these values were within the required MPS loading accuracy.

Ascent MPS performance appeared to be completely normal. Data indicate that the LO_2 and LH_2 pressurization systems performed as planned, and that all net positive suction pressure (NPSP) requirements were met throughout the flight. Reconstructed data from engine and MPS parameters closely matched the actual ET ullage pressure measurements. The minimum LO_2 ullage pressure experienced during the period of the ullage pressure slump was 13.5 psid.

The gaseous hydrogen (GH_2) flow control valves (FCVs) performed nominally. All three FCVs had been refurbished before flight by the vendor. No sluggishness in the operation of the valves was noted during the flight.

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

Helium usage during the engine purge was 56.6 lbm. Data show that the 750-psia regulator pressure on SSME 2 decreased slightly near the end of the purge because of low supply pressure. The multiple entry attempts and wave-offs depleted the bottle supply to a lower-than-normal amount. During the purge, the supply pressure fell to approximately 700 psi, which is below the regulator control band. The regulator performance was as expected and no violations occurred as a result of the lower pressures.

Reaction Control Subsystem

The RCS performed nominally throughout the flight. A total of 3920.5 lbm of RCS propellants was consumed during the flight. In addition, during the OMS interconnect operations, the RCS used 2517.5 lbm of OMS propellants.

During prelaunch operations, oxidizer vapors were released when removing the universal throat plug adapter (UTPA) from R3A to install the rain cover, and vapors were noticed behind the rain cover during a prelaunch inspection. Vapors appeared behind the L4L rain cover similar to L3D. Injector temperatures were nominal during ascent for all RCS thrusters.

Four orbit-adjust maneuvers were performed to maintain a repeatable ground track throughout the mission. The first orbit-adjust firing was performed at 099:15:10:00 G.m.t. (00:04:05:00 MET) using two +X RCS thrusters. The 13.4-second firing produced a ΔV of 3.2 ft/sec. The second orbit-adjust firing was performed at 100:12:04:00 G.m.t. (01:00:59:00 MET). The multi-axis RCS firing lasted 15.048 seconds and resulted in a ΔV of 3.7 ft/sec. The third orbit-adjust firing was performed at 102:11:30 G.m.t. (03:00:25 MET). The firing was 14.02 seconds in duration and provided a ΔV of 3.3 ft/sec. The fourth and final orbit-adjust firing was performed at 104:13:46 G.m.t. (05:02:41 MET). The 13-second firing was retrograde in direction and provided a ΔV of 3.1 ft/sec.

The RCS hot fire began at 107:15:08:25 G.m.t. (08:04:03:25 MET) and ended at 107:15:14:10 (08:04:09:10 MET). A review of the thruster data indicated satisfactory operation of all thrusters.

During the aft RCS redundant circuit verification test after landing, the right RCS fuel manifold 4 isolation valve did not indicate closed when the switch was taken to the closed position (Flight Problem STS-59-V-08). The valve was cycled open, then closed, and then open with the same symptoms of no closed indication with nominal open indications. The manifold pressure data indicate the valve was actually closed. Postflight troubleshooting isolated the failure to the microswitch in the actuator. The actuator was replaced and the retest was satisfactory.

Orbital Maneuvering Subsystem

The OMS performed nominally during the two maneuvers that occurred in which 7,258.0 lbm of oxidizer and 4,368.0 lbm of fuel were consumed. In addition, a total of 2517.5 lbm of OMS propellants was used by the RCS during three periods of interconnect operations.

The OMS-1 maneuver was not required because of the direct insertion trajectory that was flown. The OMS-2 maneuver was performed at 099:11:40:10.3 G.m.t. (00:00:35:10.3 MET). The maneuver duration was 100.2 seconds and the ΔV was 163.0 ft/sec. The resultant orbit was 121.3 by 120.5 nmi.

The deorbit maneuver for the first landing opportunity at Edwards Air Force Base was initiated at 110:16:00:34.9 G.m.t. (11:04:55:34.9 MET). The maneuver was approximately 135.6 seconds in duration and the ΔV was 233.7 ft/sec.

During the OMS-2 firing (after the 13.8-second lockout), the left OMS fuel total-quantity indication rose steadily to 64 percent. This indication was biased high approximately 8 percent at the time of launch, and this bias remained through the deorbit maneuver as the level tracked along the aft probe. Following the previous flight of this vehicle, the aft fuel probe was replaced because it had been biased high for several flights. The forward probe had been operating correctly. Prior to STS-59, the fuel tank was loaded and the condition of the forward probe was noted. Data review indicates that there may be a broken wire in the forward probe of the tank.

Also, immediately following the lockout during the OMS-2 maneuver, the right OMS oxidizer total-quantity indication jumped up to 65 percent and then decreased at a normal rate. During the deorbit firing, the total channel decreased throughout the ungageable lockout time period and then shifted down to approximately 18 percent from where it appeared to track normally. Data review indicates that the forward probe electronics may be the cause of the problem. Troubleshooting of these gaging problems will be performed; however, failures of the gaging system are not uncommon and repair prior to the next flight is not required.

Power Reactant Storage and Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem met all requirements of the mission in providing reactants for the fuel cells and oxygen for crew breathing. A total of 2929 lb of oxygen and 354 lb of hydrogen was consumed during the mission. The 118 lbm of oxygen used by the crew for breathing is included in that total. Reactants remaining at landing could have sustained the mission for two days at the average power level of 15.1 kW.

At 101:23:05 G.m.t. (02:12:00 MET) the hydrogen (H2) tank 5 check valve did not reseat as expected after the H2 tank 5 heaters were turned off and the tank 4 heaters were taken to AUTO (Flight Problem STS-59-V-03A). Instead of 100 percent of the fuel cell reactant being supplied by tank 4, minus the amount contributed by the other tanks due to boiloff, the open tank 5 check valve allowed 25 percent of the flow to be supplied by tank 5, based on the quantity decrease in H_2 tanks 4 and 5.

Hydrogen tank 5 was configured for high flow (fuel cell purging) at 103:22:08 G.m.t. (04:11:03 MET) for approximately one hour in an attempt to clear contamination that may have caused its check valve to fail open. This attempt was unsuccessful and control was switched back to H_2 tank 4. H_2 tank 4 continued to be used to depletion. At 104:23:20 G.m.t. (05:12:15 MET), the pressure in H_2 tank 4 had decayed down to the tanks 1 and 2 heater-on set point, even though the heaters remained on in tank 4 (because the tank was at the residual quantity of 2.4 percent). With H_2 tanks 1 and 2 controlling the manifold pressure and feeding the fuel cells and H_2 tank 5, the H_2 tank 5 check valve suddenly seated at 105:03:47:49 G.m.t. (05:16:42:49 MET). The resultant manifold pressure spike caused by the sudden stop of flow into H_2 tank 5 was not seen by the other tanks, indicating that all of the check valves were closed. The H_2 tank 5 check valve worked nominally for the remainder of the mission, but since it failed to check for an extended period of time, the valve was removed and sent to the vendor for failure analysis.

Beginning at 105:00:23 G.m.t. (05:13:18 MET), the pressure observed in PRSD H2 tank 2 was higher than usual during several heater cycles on H2 tanks 1 and 2 following the nominal depletion of H2 tank 4 (Flight Problem STS-59-V-03B). H_2 tank 2 reached its heater-off set point of 224 psia while H_2 tank 1 pressure and the manifold pressure had only risen to 210 psia. This condition was caused by the tank 2 outlet check valve being stuck shut. The check valve cracked nominally for the next two cycles, then on the next cycle temporarily stuck closed again. After these cycles, the check valve operated nominally for the rest of the mission. No action will be taken against this check valve.

At 106:16:30 G.m.t. (07:05:25 MET), with heaters cycling in oxygen (O_2) tank 3, the O_2 tank 1 check valve stuck closed (Flight Problem STS-59-V-03C). Since the heat leak into tank 1 was not able to boil off reactants to the manifold, the pressure in tank 1 rose about 18 psia. The check valve did not crack at the normal 3 to 5 psid, preventing the oxygen from boiling off to the manifold. At

106:20:54 G.m.t. (07:09:49 MET), the check valve opened at 19 psid and the tank pressure dropped back down to 833 psia. The O_2 tank 1 check valve operated properly for the remainder of the mission. Since this check valve has exhibited similar behavior in the past, it will be replaced and sent to the vendor for failure analysis.

Fuel Cell Powerplant Subsystem

The fuel cell powerplant (FCP) subsystem performed nominally in providing 4069 kWh of electrical power at an average power level of 15.1 kW and a load of 495 amperes. The FCP subsystem consumed 354 lbm of hydrogen and 2811 lbm of oxygen and produced 3165 lbm of water during the mission.

The fuel cell 1 hydrogen flowmeter indication (V45R0170A) was erratic. This is the first occurrence of this anomaly for this particular flowmeter, but similar flowmeters have frequently exhibited this behavior. No action will be taken until the fuel cell is returned to the vendor for maintenance.

Five fuel cell purges were performed, and these occurred at approximately 00:23:00, 04:11:00, 08:11:00, 09:16:00, and 10:15:00 MET. The third fuel cell purge of the mission, performed at 107:22:04 G.m.t. (08:10:59 MET), was 96 hours after the second purge. This was the first time in the Space Shuttle Program that the maximum interval of 96 hours has been achieved.

The actual fuel cell voltages at the end of the mission were as predicted for fuel cell 1, 0.15 volt above the prediction for fuel cell 2, and 0.2 volt above the prediction for fuel cell 3.

Auxiliary Power Unit Subsystem

The APU performance during the mission was satisfactory with one anomaly identified. The following table delineates the run-time and propellant consumption as well as the serial number of each APU flown.

Flight Phase	APU 1 (S/N 204)		APU 2 (S/N 311)		APU 3 (S/N 410)	
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	22:20	52	20:16	54	22:27	56
FCS checkout			12:02	25[b]		
Entry[a]	59:54	105	73:50	147	60:17	117
Total[a]	82:14	157	106:08	226	82:44	173

Notes:
[a] APU's 1, 2, and 3 ran for 15 minutes after landing. The postlanding shutdown order was 1, 2, and 3, with 12 seconds between 1 and 2 and 13 seconds between 2 and 3. No hydraulic load tests were performed.
[b] The run-time was extended so that the APU 2 temperatures would be high enough to verify WSB 2 proper operation.

Following ascent, the APU 2 lube oil return temperature increased above the 250 °F nominal control temperature due the lack of lube oil cooling from WSB system 2 with either the WSB A or B controller. APU 2 was shut down early after ascent when the APU 2 lube oil outlet temperature reached 328 °F and the bearing temperature 1 had reached 343 °F. These temperatures did not violate any limits. This early shutdown pre-empted following the requirements of Development Test Objective (DTO) 414 for STS-59, which specified a shutdown order of APU 3, APU 1, and APU 2 following ascent. However, the shutdown sequence of APU 2, APU 1, and APU 3 did satisfy the general requirements of DTO 414. Discussion of this anomaly is found in the Hydraulics/Water Spray Boiler Subsystem section of the report.

During first-day operations following ascent at 099:23:19 G.m.t. (00:12:14 MET), the APU 3 fuel pump drain line temperature 2 measurement (V46T0370A) dropped to 43 °F without the selected heater string cycling on as expected. The fault detection and annunciation (FDA) limit of 48 °F was previously lowered to 43 °F in anticipation of the temperature falling below the FDA limit, since this APU's system A heaters have a history of cycling low. Just before the FDA limit was exceeded, the APU 3 tank and line heaters were switched from A AUTO to B AUTO at 099:23:20 G.m.t. (00:12:15:00 MET). Immediately following the selection of the B heater string, the heaters cycled on. Nominal temperatures were observed after the heaters were switched.

It was suspected that the APU 3 drain line system A heater had not failed, and to verify this condition, the APU 3 tank and line heaters were switched from B AUTO back to A AUTO at approximately 100:15:01 G.m.t. (01:03:56 MET). The APU 3 drain line heaters subsequently cycled on at 100:15:46 G.m.t. (01:04:41 MET), verifying satisfactory operation of the system A heaters.

APU 2 was used for FCS checkout, starting at 107:14:43 G.m.t. (08:03:38 MET). APU run-time was 12 minutes 2 seconds and 25 lb of fuel were consumed. All APU subsystem parameters were nominal during the checkout.

During the normal pressure rise of APU 2 gearbox GN_2 bottle pressure because of heat from the APU operation, an abrupt downward shift of 5 psi occurred at about 170 psia at a constant rate for about 10 seconds, after which tracking resumed normally but biased low (Flight Problem STS-59-V-09). After normal peaking and subsequent decreasing with temperature during soakback, the bottle pressure suddenly began a 5-psi upward shift at a constant rate for approximately 2 minutes before abruptly resuming to track normally. This same signature was observed on all three STS-59 runs of APU 2 (S/N 311). A review of previous data indicates that this occurred during the confidence run for this APU prior to STS-61 as well as both runs of the APU during the mission. STS-61 was the first flight of S/N 311 as an improved APU. The cause of this signature is believed to be instrumentation related, and the APU will be flown as-is.

Hydraulics/Water Spray Boiler Subsystem

Hydraulics and WSB prelaunch performance during both countdowns was nominal.

During ascent, WSB 1 operated nominally, and WSB 2 and WSB 3 had anomalous performance. WSB 2 showed no indication of spraying during ascent (Flight Problem STS-59-V-06). The APU 2 lube oil return temperature increased to 305 °F, well above the nominal 250 °F control temperature, at which time the crew switched from WSB controller 2A to WSB controller 2B. No spraying occurred while operating on controller 2B as evidenced by the data. The APU 2 lube oil temperature continued to climb and when it reached 323 °F (APU bearing temperature = 348 °F), APU 2 was shut down. Approximately 2 minutes after APU shutdown, the WSB 2 spray logic was deactivated in accordance with normal procedures. During this 2-minute period, no evidence of spray cooling was found in the data. As a result of the early shutdown of APU 2, the planned APU shutdown order (3, 1, and 2) was not met. However, the actual shutdown sequence (APU 2, 1, and 3) did satisfy the general requirement for DTO 414. No back-driving of the speedbrake power drive unit (PDU) was noted.

The lube oil return temperature for APU 3 reached 283 °F before WSB 3 cooling was noted during ascent. Cooling began while still operating on the WSB 3A controller and the expected over-cooling condition occurred and was followed by nominal operation.

About 7 minutes 47 seconds after APU 2 start for FCS checkout, lube oil spray cooling with the WSB 2B controller occurred when the lube oil return temperature reached 250 °F, and no obvious over-temperature or delay in cooling was noted. Approximately 2 1/2 minutes after cooling began, the crew switched to the WSB 2A controller. About 30 seconds later, a minor over-cool condition was observed with the temperature of the lube oil decreasing to 245 °F, but all other indicators of APU operation were nominal. This over-cool condition has been seen before and is not a concern for APU operation. As a result of this successful test, WSB 2 was used during entry with no constraints.

Hydraulic performance during entry was nominal with the exception of a WSB 1 minor lube oil over-cool condition of 16 °F (1 °F more than allowed). The condition has been observed several times on previous missions, but it is not a concern. All reservoir quantities, temperatures, and pressures were normal during entry. Lube oil and hydraulic cooling for WSB 2 and WSB 3 was normal, and water usage was within specification.

The postlanding checks revealed that the ΔP indicator on hydraulic system 3 was tripped, and it is not known whether the condition was caused by excessive return pressure. This is the fifth incidence of tripping on system 3 on OV-105. Evaluation is continuing to determine the cause of the tripping.

Electrical Power Distribution and Control

The electrical power distribution and control (EPDC) subsystem performed satisfactorily. All data analyzed showed nominal voltage and current signatures, and no specified limits were exceeded.

Environmental Control and Life Support System

The atmospheric revitalization system (ARS) performed nominally throughout the mission. The cabin fan ΔP appeared to be lower than that indicated on STS-61, the previous flight of OV-105, and this condition has been attributed to the additional cooling provided to the in-cabin payloads. The ARS avionics bay water coldplate outlet temperature peaked at 85.2 °F in bay 1, 89.5 °F in bay 2, and 83.3 °F in bay 3. The ARS avionics bay 1, 2, and 3 air outlet temperatures peaked at 104.5 °F, 104.5 °F, and 87.0 °F, respectively.

Two lithium hydroxide (LiOH) canister failures occurred. After performing a LiOH canister changeout at 102:12:20 G.m.t. (03:01:15 MET), the crew reported that canister 9 (S/N 224), which had just been removed, was split. There was no loss of LiOH into the cabin atmosphere. The crew also reported that the canister was not split when installed, and that it was dry both before installation and after removal. The canister was wrapped and stowed in the LiOH storage box.

At approximately 108:02:36 G.m.t. (08:15:31 MET), the crew reported that a second LiOH canister (25) had a split outer shell. This particular LiOH canister (S/N 285) is from the same lot as the canister that was found split earlier in this flight. The crew also reported that they had no trouble removing, bagging or stowing the canister.

There have been two prior canister failures during flight (STS-51 and STS-56), and the failure analysis concluded that the canister shell material was too thin due to over-milling. Severe pitting corrosion from the chemical milling process weakened the LiOH canister shell. The two previous in-flight failures and canisters 9 and 25 on this flight are all from the same lot of canisters. The failure potential of the canister shells is a known condition and the decision was made to fly as-is. Worst case effects of the failure mode were evaluated and it was determined that the Nomex LiOH bag would contain the LiOH, and the canister could not become jammed in the ARS.

The active thermal control system (ATCS) operation was satisfactory throughout the mission with the exception of the flash evaporator system (FES) feedline heater failure. The ATCS successfully supported payload cooling requirements by the crew placing both Freon cooling loops (FCLs) in the payload position at 099:13:30 G.m.t. (00:02:25 MET). The FCLs were returned to the interchanger position at 109:06:43 G.m.t. (09:19:38 MET). For the extension day, FCL 2 was placed in the payload position from 109:18:26 G.m.t. (10:07:21 MET) to 110:06:49 G.m.t. (010:19:44 MET).

At 103:05:40 G.m.t. (03:18:35 MET), the FES system A accumulator and high-load feedline temperatures (V63T1892A and V63T1895A) drifted down to ambient (50 to 60 °F) (Flight Problem STS-59-V-04). The feedline heaters are controlled by a common thermostat which is located on the accumulator line. The Orbiter was maintained in a warm attitude throughout the flight and as a result, the temperature of these lines never fell below the FDA limit of 50 °F. At 104:19:08 G.m.t. (05:08:03 MET), the system 2 heaters were activated in accordance with the normal timeline and performance was nominal for the remainder of the flight. Postflight testing did not repeat the anomaly.

The radiator coldsoak provided cooling during entry through landing plus 26 minutes when ammonia system A was activated using the secondary controller. The coldsoak lasted longer than usual, and this was possibly caused by the large uninsulated mass of the SRL-1 in the payload bay. Ammonia system A controlled the Freon evaporator outlet temperature to 33 °F for 9 minutes at which time ground equipment began cooling.

The atmospheric revitalization pressure control system (ARPCS) performed normally throughout the duration of the flight. During the redundant component check, the pressure control configuration was switched to the alternate system. Both systems operated nominally.

The supply water and waste management systems performed normally throughout the mission. Supply water was managed through the use of the FES and the overboard dump systems. The supply water dump line temperature was maintained between 70 and 100 °F throughout the mission with the operation of the line heater. Four supply water dumps were performed at an average dump rate of 1.41 percent/minute (2.3 lb/min).

Waste water was gathered at the predicted rate. Six waste water dumps were performed at an average dump rate of 1.95 percent/minute (3.23 lb/min). The waste water dump line temperature was maintained between 52 and 79 °F throughout the mission with the operation of the line heater.

The waste collection system (WCS) performed adequately throughout the mission with no anomalies noted.

During the crew debriefing, the crew reported that the grommet at the opening to the wet trash (Volume F) compartment came out of its retainer and was pushed into the bag (Flight Problem STS-59-V-11). This same failure mode has been experienced on a number of flights. A potential fix is being evaluated that would bond the grommet at the retainer.

Smoke Detection and Fire Suppression System

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

Airlock Support System

Use of the airlock support system components was not required because there was no extravehicular activity (EVA). The active-system-monitor parameters indicated normal output throughout the flight.

Avionics and Software Subsystems

The performance of the integrated guidance, navigation and control subsystems during all phases of the flight was nominal.

At approximately 100:04:15 G.m.t. (00:17:10 MET), the crew reported that the expected audio tone associated with a time-tone message was not heard when requested via the data processing system (DPS) specialist function 2 (Spec 2) TIME display. At approximately 101:03:35 G.m.t. (01:16:30 MET), the crew reported another such occurrence. During one occurrence, the crew was keying a hand-held microphone, which disables the speaker when the tone was annunciated; during the other occurrence, the crew was in the middeck and only the flight deck speaker was powered because of dual shift operations, and as a result, the crew did not notice the 1-second tone. Data evaluation from these two time periods shows that the primary avionics software system (PASS) correctly generated the light and tone.

The SRL-1 payload required tight pointing and low maneuver rates of the on-orbit digital autopilot (DAP). Prior to flight, a known problem was identified within the DAP that could allow the Zero Doppler Steering (ZDS) maneuvers to complete late (up to twice as long as expected) or too soon, resulting in payload pointing errors as large as 3.5 degrees. Since the maneuvers were to be completed continually throughout the flight, a patch was implemented in the flight software which successfully prevented the precision loss and the maneuver-completion dispersions.

At 107:18:59 G.m.t. (08:07:54 MET), the crew attempted to select DAP A, but only contact 3 was set high. Since contacts 1 and 2 were set low, the redundancy management (RM) deselected contact 3. The crew's second attempt to select DAP A was successful as the remaining two contacts on the push-button were functioning normally. The crew confirmed that they had depressed the DAP push-button lightly on the first attempt. This is an explained condition that occurs when the DAP push-button is not fully depressed, and has been seen on previous Shuttle missions (STS-4, STS-9, and STS-32).

The three high accuracy inertial navigation system (HAINS) inertial measurement units (IMUs) as well as the star trackers performed in an excellent manner.

The FCS performance was nominal throughout the mission. During the FCS checkout, evidence of transient contamination was noted during the positive stimuli portion of the secondary actuator checks. When the 9.5 μA stimuli was put in the rudder channel 3 servo valve, the channel 3 secondary ΔP was slow to respond. After an initial increase to 1,100 psia, the pressure slowly dropped to 700 psia before rapidly increasing to 2,850 psia 1.44 seconds after the command. The channel bypass was as expected once the pressure rise occurred. Typically, the pressure rise and subsequent channel bypass should occur nearly instantaneously ($<$0.1 second). The system performed as expected during the negative stimuli portion of the test. Following this occurrence, the response was normal for the remainder of the mission. The anomalous response is indicative of silting or transient contamination of the flapper stage of the servo valve. A desilting procedure will be performed during turnaround.

A problem was discovered during deorbit preparations at 109:12:43:44 G.m.t. (10:01:38:44 MET), when nominally configured general purpose computer (GPC) 4 was processing systems management (SM) software and driving cathode ray tube (CRT) 4, and GPC 5 was processing backup flight system (BFS) software and driving CRT 3. An OPS 000 PRO to GPC 4 on CRT 2 was misinterpreted by the mission operations computer (MOC) as being commanded to the BFS on CRT 3. The command was actually made on CRT 2 and the SM GPC moded to OPS 0 as commanded, but the display on the ground showed keystrokes to the BFS. The cause of this incorrect indication on the ground display was that keystrokes are downlisted before the downlist header word change in some cases, and the MOC software interpreted the entry as being on CRT 3 instead of CRT 2.

The displays and controls subsystem performed acceptably in meeting all requirements placed on it. At 108:13:38 G.m.t. (09:02:33 MET), the crew reported that the units digit of the Ku-band range/elevation indicator on panel A2 was not illuminating (Flight Problem STS-59-V-07). The condition was most probably caused by a failure within the digital display unit, which has been removed and replaced.

The forward port payload bay floodlight exhibited signs of arcing in the data and never illuminated when power was applied at 109:00:02 G.m.t. (10:12:57 MET). The light was turned off for the remainder of the mission.

The crew also reported that the aft port payload bay floodlight did not come up to full brightness at 110:11:45 G.m.t. (11:00:40 MET) during payload bay door closure activities. The data in this instance also indicate possible arcing; however, after several minutes, the light did draw the correct amount of current and apparently came up to full brightness.

During landing, equivalent airspeed (EAS) dispersions at touchdown exceeded the expected results from simulations, which had predicted expected dispersions for a touchdown speed of 205 knots to be +5 to -10 knots. Preliminary data indicate a touchdown speed of 215.9 knots EAS. Correcting the EAS for runway distance dispersion reveals no significant problems with guidance energy management. The ground speed at touchdown was approximately 228 knots which is approximately 3 knots above the certified ground speed limit of the main tires (225 knots). By the time the vehicle was stopped, the ribs on both the left and right main tires had been damaged. The relationship of this damage to the off-nominal touchdown speed is being evaluated. This condition had no serious safety implication, but rather is an indication of the continuous learning process with the vehicles after only 61 actual landings.

The use of the beep or remote hand controller (RHC) trim derotation commands was tested for the first time on this flight. Derotation slapdown rates were in the predicted range of ground-based simulations; however, the expected steady-state derotation rate range of 1.8 to 2.1 deg/sec was exceeded by approximately 0.4 deg/sec (2.2 to 2.6 deg/sec). Analysis revealed that performance for both steady-state and final slapdown rates was within the band of system uncertainties, but was different enough from the expected values to require further study of the interaction of hardware and software systems during derotation. The beep trim initiation did provide a smoother command input and less dynamic tire loads interaction as expected; nevertheless, the entire area of slapdown rates is still being investigated for refinements in landing simulation models and performance sensitivity.

Communications and Tracking Subsystems

The communications and tracking subsystem performed nominally throughout the mission.

The Global Positioning System (GPS) receiver (DTO 700-8) was powered on at 098:22:50 G.m.t. (prior to first launch attempt) and performed nominally for approximately six hours. At that time, the status bit changed to 1 where it remained until the power was cycled following the scrub of the first launch attempt. Nominally, the status-bit state should toggle between state 1 and state 0. State 1 indicates that the receiver is powered and is tracking less than four satellites. State 0 indicates that the receiver is unpowered or the receiver is powered and tracking four or more satellites. The receiver operated nominally for four hours when it was powered on for the second launch attempt, but then the receiver bit again went to state 1 and remained there.

The receiver power was cycled prior to the second launch attempt; however, the receiver status bit remained in state 1. At the operational sequence (OPS) 101 to 102 transition (SRB ignition), the receiver state and channel status were reinitialized. At 099:11:16 G.m.t. (00:00:11 MET), the receiver status bit switched to 0, which indicated that four-satellite navigation was occurring.

The GPS receiver status bit changed from state 0 to state 1 at 100:10:43 G.m.t. (00:23:38 MET) and remained there for the rest of on orbit period (Flight Problem STS-59-V-05). Power cycling the preamplifier and the receiver at approximately 103:22:03 G.m.t. (04:10:58 MET) did not recover the stale GPS status bit. During the deorbit preparations for the first landing opportunity while transitioning from OPS 2 to OPS 3, the receiver state and channel status were reinitialized. As a result, the status bit began cycling as expected. Although there were some longer-than-expected stale periods of the status bit, the status bit did cycle throughout the remainder of the mission. Postflight, the fault-log was dumped and reviewed. The GPS internal software was identified as the most likely cause of the problem. A software update will be incorporated prior to the next flight of the GPS receiver (STS-68).

Early in the mission during SIR-C data takes (45 Mbps), using Ku-band channel 3 for data transmission, a degradation was noted in the operations recorder data being dumped simultaneously on Ku-band channel 2 (Flight Problem STS-59-P-01). During the mission, most of the payload data were being recorded onboard on the PHRRs. Therefore, the operational workaround was to avoid simultaneous dumps using channels 2 and 3. This had no mission impact. A limited amount of troubleshooting performed late in the mission indicates that there was no interference from channel 2 to channel 3, and channel 2 was degraded only on the Tracking and Data Relay Satellite (TDRS) West-2 South chain. Further troubleshooting will be performed during turnaround.

At 108:13:38 G.m.t. (09:02:30 MET), the crew reported that the units digit failed to illuminate in the Ku-band range/elevation indicator on panel A2 and that the fault light was illuminated (Flight Problem STS-59-V-07). This indicator is normally used when stowing the Ku-band antenna, but it is not required to stow the antenna. Postflight troubleshooting isolated the problem to the Ku-band range/elevation and range rate/azimuth digital display unit. The unit was removed and replaced.

Instrumentation Subsystems

The operational instrumentation subsystem performed satisfactorily throughout the mission with the exception of the modular auxiliary data system (MADS) recorder. The MADS recorder failed during an attempted GPS data-take at 101:23:15 G.m.t. (02:12:10 MET), and all data that were to be recorded on the MADS thereafter were lost, including on-orbit GPS data and all entry data (Flight Problem STS-59-V-02). All of the ascent engine data were recorded as well as a one-half hour GPS test data run early in the mission. Postflight troubleshooting isolated the failure to the recorder.

Structures and Mechanical Subsystems

All structures and mechanical subsystems performed satisfactorily during the mission. The landing and braking data are shown in the table on the following page.

At 099:11:06 G.m.t. (00:00:01 MET), near the point of maximum aerodynamic pressure (max q), the left main gear (LMG) door uplock proximity sensor indicated off for 10 seconds (i.e., door not uplocked) (Flight Problem STS-59-V-01). A second sensor, the LMG uplock indication, did not change state. Both of these indications provide a signal to the LMG/DOOR UPLOCK discrete, and

LANDING AND BRAKING PARAMETERS

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	1664	215.4	~3.5	n/a
Nose gear touchdown	7067	160.7	n/a	3.80

Braking initiation speed	107.6 knots (keas)
Brake-on time	28.3 seconds (sustained)
Rollout distance	10,691 feet
Rollout time	53.7 seconds
Runway	22 (concrete) at Edwards
Orbiter weight at landing	222,030.0 lb (landing estimate)

Brake sensor location	Peak pressure, psia	Brake assembly	Energy, million ft-lb
Left-hand inboard 1	1284	Left-hand outboard	13.09
Left-hand inboard 3	1296	Left-hand inboard	29.77
Left-hand outboard 2	*	Right-hand inboard	23.99
Left-hand outboard 4	1272	Right-hand outboard	19.64
Right-hand inboard 1	1140		
Right-hand inboard 3	1116		
Right-hand outboard 2	984		
Right-hand outboard 4	936		

* Intentionally inoperative brake pressure channel.

therefore, the discrete also went from uplocked to not uplocked. At the time of the indication, the data rate for the discrete was 1 Hz, and there were no apparent disturbances in either ac or dc power. The anomaly did not recur and the proximity switch rigging will be checked postflight. A similar event occurred for 12 seconds on STS-9 and was attributed to vibration at max q as well as the close tolerance on the rigging of the proximity switch. Postflight troubleshooting showed that the LMG door proximity switch required re-rigging. It was also determined that the right main gear (RMG) door proximity switch also required re-rigging.

Drag chute performance appeared to be satisfactory with no off-nominal wear or instability noted. All drag chute hardware was recovered and no signs of abnormal operation were noted. The failure of the MADS recorder will prevent the determination of loads during drag chute deployment and operation.

The postlanding inspection revealed that the inboard tires on the left and right main landing gear (MLG) sustained damage on the second rib from the respective MLG strut (i.e., outboard on the inboard tires) (Flight Problem STS-59-V-10). The cause of the damage, which was the worst seen with the commercial tread material in four landings on the concrete runway at Edwards Air Force Base. The cause of the damage is believed to have resulted from a combination of the high main landing gear touchdown velocity, a high-speed maneuver to the runway centerline and low-speed braking without antiskid protection.

The crew hatch outer window sustained an apparent micrometeorite impact. The damage site measured 1/4 inch in diameter and is located at the seven o'clock position of the window, one inch from the edge tiles. The window has been returned to Johnson Space Center (JSC) for analysis. Also, window 6 had one impact crater (0.029 inch by 0.023 inch by 0.0019 inch deep). The window will be replaced.

Orbiter windows 3 and 4 exhibited typical hazing. Less-than-normal haze was present on the other forward-facing windows (1, 2, 5, and 6). Surface wipes were taken from all windows for laboratory analysis, the report of which will be in separate documentation.

Integrated Aerodynamics, Heating and Thermal Interfaces

The ascent and entry aerodynamics were nominal with no problems. Active load relief on the outboard elevons was experienced at approximately Mach = 0.93 for the fourth time in six flights of OV-105. This load relief is caused by a shock traversing the upper surface of the elevon and causing a momentary spike in the elevon hinge moment. This condition is not considered anomalous; however, the condition is not predicted in the data base that includes only discrete Mach numbers of M = 0.90 and M = 1.05 in this regime.

During entry, DTO 254 - Part 2 "Subsonic Aerodynamics Verification" was performed during final approach at M = 0.55. The control-surface position and rate data as well as angle-of-attack data compare well with preflight performance predictions.

The integrated aerodynamic and plume heating was nominal during ascent; however, the SRB plume impinged on the gaseous oxygen vent arm on the launch pad and caused moderate damage to the arm. The vent arm was damaged on the STS-38 and STS-42 missions plus several other flights.

The prelaunch thermal interface temperatures were within design limits with no excessive temperatures noted on the vehicle.

Aerothermodynamics

The acreage heating was within limits, but reflects a high heat load. All structural temperatures and structural temperature rise rates were within the experience base, and the structural temperature rise on the left and right wings was symmetrical and within the experience base. The TPS damage was also well within the experience base. The loss of MADS data during entry prevented the normal evaluation of the aerothermodynamics.

Thermal Control Subsystem

The thermal control subsystem performed satisfactorily in maintaining all temperatures within the operational limits.

The FES system A accumulator and high-load feedline system 1 heater failed off. This anomaly is discussed in the Environmental Control and Life Support System section of this report.

Thermal Protection Subsystem

The TPS performed satisfactorily. Structural temperature response data show that the entry heating was above average, and the TPS performed as designed in preventing heating damage during ascent and entry. This above-average entry heating was expected, considering the high inclination (57°) of the flight, plus the Orbiter was on the descending node and the Orbiter was heavier than usual during entry. The overall boundary layer transition from laminar flow to turbulent flow can not be determined because of the failure of the MADS recorder. Based on the available operational instrumentation (OI) data, transition was non-symmetric on the vehicle.

The postlanding inspection of the TPS showed a total of 77 hits of which 19 had a major dimension of one inch or greater. A comparison of these numbers with statistics from previous missions indicates that both the total number of hits and the number of hits with a major dimension of one inch or greater were less than average.

The Orbiter lower surface sustained a total of 38 hits, of which 11 had a major dimension of one inch or greater. A total of 16 hits, in two clusters of eight, occurred just aft of the hydrogen umbilical. The most notable damage occurred to a group of four tiles on the body flap, just aft of the hinge line. The total damage occurred over four tiles, two of which were damaged in an area 4 inches by 1 inch by 3/8-inch deep and 3 inches by 2 inches by 3/8-inch deep. The nose landing gear door (NLGD) thermal barriers were in good condition, with a small 2-inch debonded area on the forward portion of the NLGD centerline thermal barrier.

The ET/Orbiter separation devices appeared to have functioned properly except for EO-2, which did not close properly. No flight hardware was found on the runway below the umbilicals after the ET doors were opened, but a loose wave spring was found resting against a Hi-Lock fastener on the LH_2 umbilical door. The wave spring is part of the EO-2 pyrotechnic separation device.

The number of tile damage sites on the base heat shield, attributable to the flame arrestment sparkler system, was less than normal with a majority of the hits occurring in the areas between engines 1-2 and 1-3. Three tile damage sites observed on the vertical tail stinger are attributable to drag chute deployment. Six toughened unipiece fibrous insulation (TUFI) tiles located on the triangular carrier panel between and below SSME 2 and 3 sustained no damage. This was the first flight of the TUFI tiles. The dome-mounted heat shield closeout blankets on all three SSMEs were in excellent condition.

FLIGHT CREW EQUIPMENT/GOVERNMENT FURNISHED EQUIPMENT

The flight crew equipment(FCE)/government furnished equipment operated acceptably, except for the galley water dispensing system.

The crew reported at 101:09:20 G.m.t. (01:22:15 MET) that gas bubbles were present in the galley hot and cold water (Flight Problem STS-59-F-01). Over the next several days, numerous in-flight maintenance (IFM) procedures were developed in an attempt to characterize and resolve the problem of gas in the galley water. The results of the initial troubleshooting activities performed by the crew indicated that no gas was being introduced into the galley water supply by the Orbiter supply water system. Also, the crew reported that they had observed what appeared to be a "venturi effect" when filling food and drink containers with water. The crew had gone to a configuration where cold water was obtained from the chilled water outlet using the contingency water dispenser (CWD). The crew found that there were more bubbles present when filling containers at a high flow rate. This venturi-effect theory was tested by having the crew place a globule of water around the needle/septum assembly as an empty drink bag was filled with water. The globule was drawn into the bag when using a high flow rate, which supported the theory.

The crew performed several IFM procedures to alleviate the problem of gas in the galley water. The first procedure involved sliding three pieces of rubber onto the galley rehydration station (RHS) needle and two pieces on the CWD needle to create a tighter seal between the package septum and the needle. The crew reported that the IFM worked well at low flow rates and appeared to decrease the number of bubbles present in the water. The crew decided to continue getting hot water from the galley through the RHS needle and cold water from the chilled water outlet through the CWD needle. This configuration allowed the crew to continue obtaining relatively gas-free drinking water at low flow rates.

The crew performed an additional IFM procedure which added a hard-tip straw to the needle of the CWD. The needle is end-ported, as opposed to the side-port of the RHS needle, and the CWD needle demonstrated the venturi effect in ground tests performed during the flight. The crew found that this change was an excellent fix to the venturi effect that had been experienced during previous uses of the CWD.

Subsequent IFM procedures were developed to test for gas in the galley water and to purge the galley, if gas was noted. The procedures also required a test for the venturi effect at the RHS needle (not being seen in ground tests), and if the venturi effect was observed, steps to minimize its effect at the RHS needle.

The IFM procedures for gas in the galley water were completed, and no gas bubbles were detected in either the chilled or hot galley water. Consequently, a galley purge was not performed. Initial results of the IFM procedure for determining if the venturi effect existed at the RHS needle were inconclusive. However, further troubleshooting did show that the venturi effect also existed at the RHS needle. For the remainder of the flight, the crew maintained the configuration in which chilled water was obtained from the chilled water outlet through the CWD needle (modified with the hard-tip straw), and hot water was obtained from the galley through the RHS needle (modified with the rubber grommets).

The crew reported that the lens sequence light of a Linhof camera was on and it should have been off (Flight Problem STS-59-F-02). No shutter motion occurred when the camera was triggered. Malfunction procedures were unsuccessful in recovering camera operation. The problem was isolated to the camera body (S/N 1003) and the camera was stowed for the remainder of the mission. The second Linhof camera remained available for use.

REMOTE MANIPULATOR SYSTEM

The remote manipulator system (RMS) was flown on this mission but was not planned for use nor was it used. The manipulator position mechanisms were rolled out to provide clearance for the SRL-1 when it was being moved into operational position.

CARGO INTEGRATION

The cargo integration hardware operated satisfactorily with no anomalies identified.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

A total of 16 development test objectives (DTOs) and 14 detailed supplementary objectives (DSOs) were assigned to the STS-59 mission. Data were obtained on 11 of the 16 DTOs and all of the DSOs.

DEVELOPMENT TEST OBJECTIVES

DTO 254 - Subsonic Aerodynamics Verification - Doublets were performed as planned during entry with the data recorded and downlinked for postflight analysis. The data have been given to the sponsor for evaluation, and the results will be reported in separate documentation.

DTO 301D - Ascent Wing Structural Capability - This was a data-only DTO, and data were recorded during ascent for this DTO. These data have been given to the sponsor for evaluation, and the results will be reported in separate documentation.

DTO 305D - Ascent Compartment Venting Evaluation - This was a data-only DTO, and data were recorded during ascent for this DTO. These data have been given to the sponsor for evaluation, and the results will be reported in separate documentation.

DTO 306D - Descent Compartment Venting Evaluation - This was a data-only DTO, and the failure of the MADS recorder prevented the recording of any data for this DTO.

DTO 307D - Entry Structural Capability - This was a data-only DTO, and the failure of the MADS recorder prevented the recording of any data for this DTO.

DTO 312 - External Tank Thermal Protection System Performance - A total of 36 exposures of the STS-59 ET was acquired using the Nikon camera with a 300 mm lens and a 2X extender (Methods 1 and 3). The exposure was good on all frames, but the focus was variable.

A probable divot is visible on the -Y axis of the ET at the LH_2 tank/intertank interface below the forward left SRB attachment point. A probable divot is also visible on the LH_2 tank TPS aft of the left leg jackpad of the forward bipod. Four probable divots are visible on the -Z side of the ET (far side) along the LH_2 tank/intertank interface.

Seven minutes of excellent quality video of the STS-59 ET (after separation) was acquired from the crew compartment. Typical charring on the ET aft dome is visible. The SRB BSM burn scars on the LO_2 tank appeared similar to previous missions. Four prominent white marks (probably divots) are visible on the far side (-Z) of the ET along the LH_2 intertank interface. A white piece of debris (probably frozen hydrogen) is visible traveling with the ET. The tumble rate of the ET was calculated from the video to be 0.97 deg/sec.

DTO 414 - Auxiliary Power Unit Shutdown Test - The planned shutdown sequence for this DTO (APU 3, APU 1, and APU 2) was not performed due to the freeze-up of

WSB 2, and the resulting early shutdown of APU 2 following ascent. The alternate sequence was performed (APU 2, APU 3, and APU 1), and the data were downlinked for analysis. There was no indication of speedbrake power drive unit back-driving. The results of the analysis will be reported in separate documentation.

DTO 521 - Orbiter Drag Chute System - This DTO was not performed as the drag chute was used in an operational manner rather than as required by the DTO. Also, because of the MADS recorder failure, data for loads determination were not recorded.

DTO 653 - Evaluation of the MK 1 Rowing Machine - This DTO was performed and the crew has debriefed the sponsor. The results of the evaluation will be reported in separate documentation.

DTO 656 - Payload and General Support Computer Single Event Upset Monitoring - This DTO was performed and the results have been given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

DTO 663 - Acoustical Noise Dosimeter Data - The crew collected data as required for this DTO. These data have been given to the sponsor for evaluation, and reporting in separation documentation.

DTO 664 - Cabin Temperature Survey - Data were collected by the crew for this DTO. These data have been given to the sponsor for evaluation. The results of that evaluation will be reported in separate documentation.

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

DTO 674 - Thermoelectric Liquid Cooling System Evaluation - The equipment for this DTO was set up for launch and entry. The crew evaluation of this equipment will be given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DTO 700-8 - Global Positioning System Development Flight Test - The GPS receiver was powered on at 098:22:50 G.m.t. (prior to first launch attempt) and performed nominally for approximately six hours. At that time, the status bit toggled to state 1 where it remained until the power was cycled following the scrub of the first launch attempt. Nominally, the status-bit state should toggle between state 1 and state 0. State 1 indicates that the receiver is powered and tracking less than four satellites. State 0 means that the receiver is unpowered or the receiver is powered and tracking four or more satellites. The receiver operated nominally for four hours when it was powered on for the second launch attempt, but the receiver bit again went to state 1 and remained there. The receiver power was cycled prior to the second launch attempt; however, the receiver status bit remained in state 1. At the OPS 101 to 102 transition (SRB ignition), the receiver state and channel status were reinitialized. At 099:11:16 G.m.t. (00:00:11 MET), the receiver status bit switched to 0, which indicated that four-satellite navigation was occurring.

The GPS receiver status bit changed from state 0 to state 1 at 100:10:43 G.m.t. (00:23:38 MET) and remained there throughout the on-orbit period (Flight Problem STS-59-V-05). Power cycling the preamplifier and the receiver at approximately 103:22:03 G.m.t. (04:10:58 MET) did not recover the stale GPS status bit. During the deorbit preparations for the first landing opportunity while transitioning from OPS 2 to OPS 3, the receiver state and channel status were reinitialized. As a result, the status bit began cycling as expected. Although there were some longer-than-expected stale periods of the status bit, the status bit did cycle throughout the remainder of the mission. During postflight turnaround operations, the receiver fault-log was dumped and reviewed.

Since most of the on-orbit data as well as all of the entry data were lost because of the MADS failure, this DTO was not completed. The data collected were given to the sponsor for evaluation. The results of that evaluation will be reported in separate documentation.

DTO 805 - Crosswind Landing Performance - Wind conditions were not suitable to satisfy the requirements of this DTO.

DETAILED SUPPLEMENTARY OBJECTIVES

DSO 326 - Window Impact Observations - This DSO was completed by the crew. The crew reported that the egress hatch window had a micrometeorite impact crater about 1/4 inch in diameter in the lower left quadrant at the 7 o'clock position, about one inch from the edge tiles. The window has been returned to JSC for analysis.

DSO 483 - Back Pain in Microgravity - The crew provided data on this DSO to the sponsor. The analysis of these data will be published in a separate report.

DSO 487 - Immunological Assessment of Crew Members - Data for this DSO were collected from the crew during preflight and postflight operations. These data will be evaluated by the sponsor, and the results will be published in separate documentation.

DSO 488 - Measurement of Formaldehyde Using Passive Dosimetry - Data were collected for this DSO, and these data have been given to the sponsor for evaluation. The results of that evaluation will be published in a separate report.

DSO 603B - Orthostatic Function during Entry, Landing, and Egress - Data were collected for this DSO, and these data have been given to the sponsor for evaluation. The results of this evaluation will be published in separate documentation.

DSO 604 - Visual-Vestibular Integration as a Function of Adaptation - Data were collected throughout the flight for this DSO. These data have been given to the sponsor for evaluation, and the results of that evaluation will be published in separate documentation.

DSO 608 - Effects of Space Flight on Aerobic and Anaerobic Metabolism During Exercise - Data were collected for this DSO. These data have been given to the sponsor for evaluation, and the results of that evaluation will be published in separate documentation.

DSO 611 - Air Monitoring Instrument Evaluation and Atmosphere Characterization (Microbial Air Sampler-II Configuration) - Data were collected with the Microbial Air Sampler (MAS) -II, and these data have been given to the sponsor for evaluation. The results of that evaluation will be reported in separate documentation.

DSO 624 - Preflight and Postflight Measurement of Cardiorespiratory Responses to Submaximal Exercise - Data were collected prior to the flight and after the flight as well as during exercise sessions throughout the flight. These data have been given to the sponsor for evaluation, and the results of that evaluation will be reported in separate documentation.

DSO 626 - Cardiovascular and Cerebrovascular Responses to Standing Before and After Space Flight - Data were collected for this DSO, and these data have been given to the sponsor for evaluation. The results of that evaluation will be reported in separate documentation.

DSO 802 - Educational Activities - The crew accomplished the requirements of this DSO. The data for this DSO have been given to the sponsor for evaluation, and the results of that evaluation will be published in separate documentation.

DSO 901 - Documentary Television - The crew accomplished the requirements of this DSO. The data (video tapes) are being reviewed by the sponsor, and any documentation of the results will be in a separate report.

DSO 902 - Documentary Motion Picture Photography - The crew accomplished the requirements of this DSO. The data are being reviewed by the sponsor, and any documentation of the results will be in a separate report.

DSO 903 - Documentary Still Photography - The crew accomplished all requirements of this DSO and provided many excellent pictures of Earth for evaluation. The sponsor is evaluating the photographs, and any documentation of the results will be in separate documentation.

PHOTOGRAPHY AND TELEVISION ANALYSIS

LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS

On launch day, 24 videos of the launch and ascent operations were reviewed, and anomalies were noted. Following launch day, 55 films of the launch and ascent operations were also reviewed. No anomalies were identified from the review of these films.

ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS

No formal review of the on-orbit photography was requested, except for the DTO 312 - ET TPS Performance - photography and video taken after ET separation by the crew. The results of that review are reported in the Development Test Objectives Section of this report.

LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSIS

Four videos plus NASA Select (composite of all other video images) and 15 films of the landing operations at Dryden Flight Research Center (DFRC) were received and reviewed for anomalies. No anomalies were identified.

TABLE I.- STS-59 SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
APU Activation	APU-1 GG chamber pressure	099:11:00:10.09
	APU-2 GG chamber pressure	099:11:00:11.91
	APU-3 GG chamber pressure	099:11:00:13.25
SRB HPU Activation[a]	LH HPU system A start command	099:11:04:32.090
	LH HPU system B start command	099:11:04:32.250
	RH HPU system A start command	099:11:04:32.410
	RH HPU system B start command	099:11:04:32.570
Main Propulsion System Start[a]	Engine 3 start command accepted	099:11:04:53.445
	Engine 2 start command accepted	099:11:04:53.580
	Engine 1 start command accepted	099:11:04:53.711
SRB Ignition Command (lift-off)	SRB ignition command to SRB	099:11:05:00.020
Throttle Up to 100 Percent Thrust[a]	Engine 3 command accepted	099:11:05:03:886
	Engine 2 command accepted	099:11:05:03.900
	Engine 1 command accepted	099:11:05:03.912
Throttle Down to 67 Percent Thrust[a]	Engine 3 command accepted	099:11:05:27.406
	Engine 2 command accepted	099:11:05:27.421
	Engine 1 command accepted	099:11:05:27.432
Maximum Dynamic Pressure (q)	Derived ascent dynamic pressure	099:11:05:52
Throttle Up to 104 Percent Thrust[a]	Engine 3 command accepted	099:11:06:00.847
	Engine 2 command accepted	099:11:06:00.861
	Engine 1 command accepted	099:11:06:00.873
Both SRM's Chamber Pressure at 50 psi[a]	LH SRM chamber pressure mid-range select	099:11:06:58.660
	RH SRM chamber pressure mid-range select	099:11:06:59.020
End SRM Action[a]	RH SRM chamber pressure mid-range select	099:11:07:01.110
	LH SRM chamber pressure mid-range select	099:11:07:01.200
SRB Separation Command	SRB separation command flag	099:11:07:04
SRB Physical Separation[a]	LH rate APU A turbine speed LOS	099:11:07:06.140
	RH rate APU A turbine speed LOS	099:11:07:06.140
Throttle Down for 3g Acceleration[a]	Engine 3 command accepted	099:11:12:28.852
	Engine 2 command accepted	099:11:12:28.868
	Engine 1 command accepted	099:11:12:28.882
3g Acceleration	Total load factor	099:11:12:34.6
Throttle Down to 67 Percent Thrust[a]	Engine 3 command accepted	099:11:13:26.773
	Engine 2 command accepted	099:11:13:26.789
	Engine 1 command accepted	099:11:13:26.804
MECO	Command flag	099:11:13:33
Engine Shutdown[a]	Engine 3 command accept	099:11:13:33.053
	Engine 2 command accept	099:11:13:33.069
	Engine 1 command accept	099:11:13:33:084
MECO	Confirm flag	099:11:13:34

[a]MSFC supplied data

TABLE I.- STS-59 SEQUENCE OF EVENTS (Continued)

Event	Description	Actual time, G.m.t.
ET Separation	ET separation command flag	099:11:13:53
APU Deactivation	APU-2 GG chamber pressure	099:11:20:27.51
	APU-1 GG chamber pressure	099:11:22:30.42
	APU-3 GG chamber pressure	099:11:22:39.94
OMS-1 Ignition	Left engine bi-prop valve position	Not performed - direct insertion trajectory flown
	Right engine bi-prop valve position	
OMS-1 Cutoff	Left engine bi-prop valve position	
	Right engine bi-prop valve position	
OMS-2 Ignition	Left engine bi-prop valve position	099:11:40:10.4
	Right engine bi-prop valve position	099:11:40:10.6
OMS-2 Cutoff	Left engine bi-prop valve position	099:11:41:50.6
	Right engine bi-prop valve position	099:11:41:50.6
Payload Bay Doors Open	PLBD right open 1	099:12:32:10
	PLBD left open 1	099:12:33:28
Flight Control System Checkout		
APU Start	APU-2 GG chamber pressure	107:14:42:59.76
APU Stop	APU-2 GG chamber pressure	107:14:55:02.25
Payload Bay Doors Close	PLBD left close 1	109:12:12:54
	PLBD right close 1	109:12:14:37
Payload Bay Doors Reopen	PLBD right open 1	109:16:38:01
	PLBD left open 1	109:16:39:20
Payload Bay Doors Close (Second Time)	PLBD left close 1	110:11:50:23
	PLBD right close 1	110:11:51:50
APU Activation For Entry	APU-2 GG chamber pressure	110:15:55:41.20
	APU-1 GG chamber pressure	110:16:09:24.65
	APU-3 GG chamber pressure	110:16:09:26.52
Deorbit Maneuver Ignition	Left engine bi-prop valve position	110:16:00:35.1
	Right engine bi-prop valve position	110:16:00:35.3
Deorbit Maneuver Cutoff	Left engine bi-prop valve position	110:16:02:50.7
	Right engine bi-prop valve position	110:16:02:50.7
Entry Interface (400K)	Current orbital altitude above reference ellipsoid	110:16:22:12
Blackout Ends	Data locked at high sample rate	No blackout

TABLE I.- STS-59 SEQUENCE OF EVENTS (Concluded)

Event	Description	Actual time, G.m.t.
Terminal Area Energy Management	Major mode change (305)	110:16:48:22
Main Landing Gear Contact	LH MLG tire pressure	110:16:54:30
	RH MLG tire pressure	110:16:54:30
Main Landing Gear Weight On Wheels	LH MLG weight on wheels	110:16:54:30
	RH MLG weight on wheels	110:16:54:30
Drag Chute Deploy	Drag chute deploy 1 CP Volts	110:16:54:41.5
Nose Landing Gear Contact	NLG tire pressure	110:16:54:46
Nose Landing Gear Weight On Wheels	NLG WT on Wheels -1	110:16:54:46
Drag Chute Jettison	Drag chute jettison 1 CP Volts	110:16:55:11.8
Wheels Stop	Velocity with respect to runway	110:16:55:23
APU Deactivation	APU-1 GG chamber pressure	110:17:09:19.13
	APU-2 GG chamber pressure	110:17:09:31.25
	APU-3 GG chamber pressure	110:17:09:43.96

TABLE II.- STS-59 ORBITER PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-59-V-01	Left Main Landing Gear Door Uplock Indication Temporarily Lost	099:11:06 G.m.t. 000:00:01 MET IM 59RF03 IPR 68V0004	At approximately 1 minute MET, the left main landing gear (LMG) door uplock indication (V51X0116X) was lost for approximately 10 seconds. The LMG up-indication (V51X0100X) was not lost. Both of these indications provide a signal to the LMG/door up indication (V51X0115E), and therefore, it too was lost when the door uplock indication was lost. All indications were nominal during the remainder of the mission. A similar event occurred for 12 seconds on STS-9. It was attributed to vibration at maximum dynamic pressure (max q) and the close tolerance on the rigging of the proximity switch. Dryden Flight Research Center reported that the latch mechanism looked good. KSC: The LMG door-uplock proximity sensor has been re-rigged.
STS-59-V-02	No Tape Motion on MADS Recorder	101:23:15 G.m.t. 02:12:10 MET IM 59RF04 IPR 68V0006	At 101:23:15 G.m.t.,the MADS recorder was powered up and the recorder placed in the record mode in preparation for the GPS trouble-shooting data take. At the time the recorder was activated, it began recording on pass 1 in the forward direction at 15 ips. Indications of tape motion, record, incrementing tape motion, forward direction and BITE good were all received on the downlink. After about 1 minute of recording time, the tape position reached 99.8 percent, tape motion stopped, and the track sequence status BITE went low, indicating that the MADS control module had switched the recorder into pass 2 and recording could proceed in the reverse direction. However, tape motion did not continue. A series of commands were issued that cycled power and commanded the recorder to run at 15 ips and at 60 ips in both the forward and reverse directions in an attempt to obtain tape motion; however it was not successful. An IFM was prepared to attempt to restart the recorder. The IFM was performed at 103:00:35 G.m.t., but it was unsuccessful. A second attempt to recover the MADS recorder at 107:00:00 G.m.t. was also unsuccessful. KSC: The MADS recorder was removed and sent to the vendor for repair
STS-59-V-03	A. H2 Tank 5 Check Valve Failed to Seat	101:23:05 G.m.t. 02:12:00 MET IM 59RF05 IPR 68V0007	H2 tank 5 check valve did not reseat properly after switching to tank 4 at 101:23:05 G.m.t. (02:12:00 MET). H2 tank 5 pressurized along with H2 tank 4, but only the H2 tank 4 heaters were being activated. H2 tank 5 was configured for high flow (fuel cell purging) at 103:22:35 G.m.t. for approximately one hour in an unsuccessful attempt to recover the check valve by flushing possible contaminants. After switching back to H2 tank 4 heaters, tank 5 pressure continued to track tank 4. During a heater-on cycle on H2 tanks 1 and 2, the H2 tank 5 check valve seated itself at 105:03:48 G.m.t. KSC: Replace with available spare.
	B. H2 Tank 2 Check Valve Sticky	105:00:23 G.m.t. 05:13:18 MET IM 59RF09	The H2 tank 2 check valve stuck closed during three consecutive pressure cycles (105:00:23, 105:00:52 and 105:01:12 G.m.t). The H2 tank 2 check valve performed nominally during the remainder of the mission. KSC: No action is required.

TABLE II.- STS-59 ORBITER PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-59-V-03 (Cont'd)	C. O2 Tank 1 Check Valve Sticky	106:16:30 G.m.t. 07:05:25 MET IM 59RF10 FCP-5-07-0060	At approximately 106:16:30 G.m.t. (7:05:25 MET), with heaters cycling in O2 tank 3 (manifold pressure was cycling between 840 and 880 psia), the O2 tank 1 check valve stuck closed. Since heat leak into O2 tank 1 was not able to boil off reactants to the manifold, the pressure rose from 835 to 853 psia. At 106:20:54 G.m.t. (7:09:49 MET), the check valve opened and the pressure dropped back down to 830 psia. The O2 tank 1 check valve performed nominally during the remainder of the mission. During two previous flights, sticking had been noted with this check valve (S/N 61). An IFA was taken on STS-33 (V-08) and sticking was noted on STS-41. KSC: Replace with available spare.
STS-59-V-04	FES Supply A Accum/Hi Load Line System 1 Heater Failed	103:05:29 G.m.t. 03:18:24 MET IM 59RF08 IPR 68V0015	The FES supply A accumulator/hi-load line system 1 heater failed off. The environment of the attitudes being flown maintained the line temperature above 50°F. Reconfiguration to the system 2 heaters was done at the nominally planned time (05:08:00 MET), and the system 2 heaters performed nominally. KSC: The anomaly could not be repeated. The feedline heater will be flown as-is.
STS-59-V-05	GPS Status Bit Not Changing State LEVEL III CLOSURE	098:11:00 G.m.t. Prelaunch IPR 68V0003	For the April 8th launch attempt, the GPS was powered on at approximately L-12 hours. Approximately 6 hours after power up, the GPS status bit (V74X8500E) stopped changing state - the bit was continuously indicating 1. This data bit shows 1 if the GPS is on and not tracking four satellities. The data bit shows 0 if the GPS is off or it is on and tracking four satellities. Experience shows that on the pad, the bit should change state every 3 to 10 minutes. A power cycle of the receiver following the launch scrub recovered the GPS; however, it subsequently stopped changing state. The receiver operated nominally for four hours when it was powered on for the second launch attempt. However, at that time, the receiver bit again went to state 1. A subsequent power cycle about 1.5 hours prior to launch did not recover the GPS. At the OPS 101 to 102 transition, the receiver reinitialized its state and channel status. At 11 minutes MET, the receiver status bit switched to 0. The GPS performed nominally until 100:10:42 G.m.t. (04:07:48 MET), when once again the bit status went to state 1 and did not change. At 103:18:53 G.m.t. (04:07:48 MET) the power to the lower GPS preamp was swapped from MNA to MNC for troubleshooting and was returned to MNA at 103:22:02 G.m.t. (04:10:57 MET). The GPS receiver was then powered down for one minute at 103:22:03 G.m.t. (04:10:58 MET). Neither of these steps recovered the static GPS status bit, and no data from this troubleshooting were recorded due to the MADS recorder failure. The static GPS status bit recovered following the OPS 2 to 3 transition on the day prior to landing (landing attempt waived-off due to weather). KSC: The problem is believed to be in the GPS receiver software. The software will be updated.

TABLE II.- STS-59 ORBITER PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-59-V-06	WSB 2 Failed to Cool	099:11:21 G.m.t. 00:00:16 MET IM 59RF01	Cooling was never seen on WSB 2 during ascent. When the APU 2 lube oil return temperature reached approximately 305°F, the crew switched from the A to the B controller. APU 2 was shut down when the lube oil return temperature reached 323°F. The bearing temperature reached 348°F at APU 2 shutdown and 373°F following soakback. A hard freeze of the WSB 2 core is suspected. APU 2 was used for FCS checkout and its run time (~12 min) was extended to determine the health of WSB 2. WSB 2 performed nominally on the A and B controllers. WSB 2 performed on the B controller during entry. KSC: No action is required.
STS-59-V-07	Ku-band Range/Elevation Indicator Failed <u>LEVEL III CLOSURE</u>	108:13:35 G.m.t. 09:02:30 MET IM 59RF12	At 108:13:38 G.m.t., the crew reported that the units digit failed to to illuminate in the Ku-band range/elevation indicator on panel A2 and that the fault light was illuminated. This indicator is normally used for Ku-band stow, but is not required to perform stowage. KSC: The DDU has been removed and replaced.
STS-59-V-08	R RCS Fuel Manifold 4 Isolation Valve Failed to Indicate Closed	110:17:18 G.m.t. 11:06:13 MET IM 59RF14 IPR 68V0009	During the postlanding redundant circuit verification testing, the right RCS fuel manifold 4 isolation valve did not indicate closed when the switch was cycled to the closed position. The crew cycled the switch to open and back to close with the same result. Manifold pressure data indicates that the valve closed each time. Most probably, a failure of the position indication microswitch occurred. The valve is currently in the open position and open is the position during ferry flight. The isolation valve actuator can be replaced in the OPF. KSC: The actuator has been removed and replaced.
STS-59-V-09	Unexplained APU 2 Gearbox GN2 Bottle Pressure Changes <u>Level III Closure</u>	APU 2 Runs IM 59RF15	When an APU is run, the gearbox GN2 bottle pressure increases with the increasing temperature of the APU. During each run of APU 2 (ascent, FCS c/o, and entry), an unexplained pressure transient was noted during the pressure rise and during its subsequent decay following APU shutdown. In each case, when the pressure rose into the 160 to 170 psia range, an approximate 5 psia drop was noted over a period of 5 to 10 seconds, followed by a typical looking increase to a range of 190 to 200 psia. During the subsequent pressure decrease, when the pressure dropped into the 160 psia range, a pressure rise of approximately 5 psia over a several minute period was noted followed by a typical looking decay. This same phenomenon was noted during the APU 2 confidence run prior to STS-61 and the ascent and entry runs during STS-61, the previous flight of OV-105 and this APU (S/N 311). KSC: No action is required. Will fly as-is.

TABLE II.- STS-59 ORBITER PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-59-V-10	LH and RH Inboard Tire Damage	110:16:55 G.m.t IM 59FR16 IPR 68V0019	Both the left- and right-hand inboard MLG tires sustained tire damage on the 2nd rib from the strut (i.e., outboard on the inboard tires). When tire damaga does occur, it typically occurs at the location where it was seen on this flight. However, the tire damage sustained during STS-59 appears greater than that seen on the three previous landings at Edwards since the new commercial tread rubber tire was put in use. The cause of the damage is being investigated. KSC: The tires were removed and sent to the vendor.
STS-59-V-11	Wet Trash (Volume F) Grommet Failure LEVEL III CLOSURE		During the crew debriefing, the crew reported that the grommet at the opening to the wet trash (Volume F) compartment came out of its retainer and was pushed into the bag. This same failure mode has occurred on several flights. KSC: The grommet will be bonded to the retainer.

TABLE III.- STS-59 GFE PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-59-F-01	Gas in the Galley Water	101:10:33 G.m.t. 01:23:38 MET	On flight day 2, the crew reported gas in the galley hot and cold water. A procedure was run by the crew to sample the galley water (hot and cold), and the water straight from supply water tank A. The procedure appears to have indicated that there was no gas in the water supplied to the galley. A test was done to determine if air was being drawn into the bag around the needle at the septum hole. A globule of water placed external to the bag around the septum was drawn into the bag when the bag was filled, supporting a theory that cabin air was being introduced through the septum as the bag was filled. High flow rate of water increased the amount air introduced into the bag by this "venturi" effect. An IFM was developed to provide a better seal between the needle and the septum using rubber blocks installed on the galley RHS and the contingency water dispenser (CWD). The crew reported less gas in dispensed water in both cases. The crew prefers to continue using the galley for hot water and the CWD for cold water. The crew noted that using low flow rates is the most effective means of reducing gas in the water. Additional on-orbit troubleshooting tends to substantiate the venturi-effect theory.
STS-59-F-02	Linhof Camera Failure	107:09:00 G.m.t. 07:21:55 MET	The crew reported that the lens sequence light on one of the Linhof cameras was on and it should have been off. Malfunction procedures were unsuccessful in recovering the camera. The problem was isolated to the camera body, serial number 1003. There are two Linhof cameras on board.

TABLE IV.- MSFC ELEMENTS PROBLEM TRACKING LIST

Problem/Title	Element	Description	Comments/Status
STS-59-B-01 LH and RH Aft Skirts K5NA Separated from Hypalon and Primer at BSM Bracket	SRB (USB) A15986	Left-hand and right-hand aft skirts have K5NA separated from Hypalon and Primer at the BSM Support Brackets.	Hypalon is on the booster trowelable ablator (BTA) and primer is on the metal substrate. The failure of K5NA-to-Hypalon bond most probably due to improper surface preparation on the substrate. An action to evaluate STS-65 hardware resulted in rework on the right-hand SRB at same location.
STS-59-E-01 ME-3 HPOTP Turbine Discharge Temperature Anomaly	Main Engine 3 Rocketdyne A15973	SSME 3 High Pressure Oxidizer Turbopump (HPOTP) Turbine Discharge Temperature Measurements had a 218 °F difference during mainstage, and this represents a 7.2 σ compared to the flight database.	Review of flight data shows that the measurements began to diverge at approximately engine start + 3.5 seconds, and remained separated throughout the flight. Channel B was close to the predicted value and Channel A was reading 150 °F low. The most probable cause for the low indication is additional hydrogen caused by plugging three adjacent oxidizer preburner oxidizer posts prior to STS-59 (MR-2018-0261). The three plugged posts are located in an area that would affect Channel A and not Channel B. This scenario is still under investigation.
STS-59-I-01 ME-1 Single Point Spikes on Two Pressure Measurements	Main Engine 3 Rocketdyne A15939 A15940	Main Engine 1 Experienced Single-point spikes on two pressure measurements	The high pressure fuel turbopump (HPFTP) Coolant Liner Pressure spiked at engine start plus 83 seconds, and the fuel system purge pressure spiked at 91.5 seconds. The remainder of the flight showed no additional spiking. The time and amplitude of the spikes match thoses believed to be caused by ground radar noise. Ref. Integration IFA STS-52-I-1 which was closed as an unexplained anomaly. At that time, spikes were observed on 28.5-degree inclination flights and were never observed on 57-degree inclination flights. The Range Safety radar attentuation schedule for radar site 19.17 was modified and spikes were no longer observed on 28.5-degree inclination flights. Both sensors are the -100 configuration which has shown less susceptibility to contamination than the -200 configuration.
STS-59-I-02 Indentation of Instafoam on ET Attachment Ring	SRB	Indentation in Instafoam on Forward Face of Right ETA Ring near the aft IEA Cover	Postflight inspection of the SRB showed an indentation in the instafoam covering the forward face of the right ETA ring near the aft IEA cover.

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 Daily Reports
4. MER Daily Reports
5. MER Mission Summary Report
6. MER Quick Look Report
7. MER Problem Tracking List
8. MER Event Times
9. Subsystem Manager Reports/Inputs
10. MOD Systems Anomaly List
11. MSFC Flash Report
12. MSFC Event Times
13. MSFC Interim Report
14. Crew Debriefing comments
15. Shuttle Operational Data Book

ACRONYMS AND ABBREVIATIONS

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

APL	Applied Physics Laboratory
APU	auxiliary power unit
ARPCS	atmospheric revitalization pressure control system
ARRL/AMSAT	American Radio Relay League/Amateur Radio Satellite Corporation
ARS	atmospheric revitalization system
ATCS	active thermal control subsystem
BFS	backup flight system
BSM	booster separation motor
CONCAP-IV	Consortium for Materials Development in Space Complex Autonomous Payload-IV
CRT	cathode ray tube
CWD	contingency water dispenser
DAP	digital autopilot
deg/sec	degree per second
DFRC	Dryden Flight Research Center
ΔP	differential pressure
DPS	data processing system
DSO	Detailed Supplementary Objective
DTO	Development Test Objective
ΔT	differential time
ΔV	differential velocity
EAS	equivalent air speed
EPDC	electrical power distribution and control subsystem
e.d.t.	eastern daylight time
ET	External Tank
ETA	External Tank attachment
EVA	extravehicular activity
FCE	flight crew equipment
FCL	freon coolant loop
FCP	fuel cell powerplant
FCS	flight control system
FCV	flow control valve
FDA	fault detection annunciation
FES	flash evaporator system
ft/sec	feet per second
GAS	Getaway Special
GFE	Government furnished equipment
GH_2	gaseous hydrogen
G.m.t.	Greenwich mean time
GO_2	gaseous oxygen
GPC	general purpose computer
GPS	Global Positioning System
H_2	hydrogen
HAINS	High Accuracy Inertial Navigation System
HPFTP	high pressure fuel turbopump
HPOTP	high pressure oxidizer turbopump
ICD	Interface Control Document

IEA	integrated electronics assembly
IFM	in-flight maintenance
IMU	inertial measurement unit
Isp	specific impulse
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
keas	knots equivalent air speed
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt hours
lbm	pound mass
LCC	Launch Commit Criteria
LESC	Lockheed Engineering and Sciences Company
LH_2	liquid hydrogen
LiOH	lithium hydroxide
LMG	left main gear
LO_2	liquid oxygen
lube	lubrication
MADS	modular auxiliary data system
MAPS	Measurement of Air Pollution from Satellites
MAS	Microbial Air Sampler
max q	maximum dynamic pressure
Mbps	megabits per second
MCC	Mission Control Center
MECO	main engine cutoff
MET	mission elapsed time
Mir	Russian Space Station
MLG	main landing gear
MOC	Mission Operations Computer
MPS	main propulsion system
NASA	National Aeronautics and Space Administration
NLGD	nose landing gear door
nmi.	nautical mile
NPSP	net positive suction pressure
NSTS	National Space Transportation System
O_2	oxygen
OI	operational instrumentation
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OPS	operational sequence
PASS	primary avionics software system
PHRR	Payload High Rate Recorder
PMBT	propellant mean bulk temperature
ppm	parts per million
PRSD	power reactant storage and distribution
RCS	reaction control subsystem
RHC	rotation hand controller
RHS	rehydration station
RM	redundancy management
RMG	right main gear
RMS	remote manipulator system
RSRM	Redesigned Solid Rocket Motor
RTLS	Return to Launch Site (abort)

S&A	safe and arm
SAREX-II	Shuttle Amateur Radio Experiment-II
SIR-C	Shuttle Imaging Radar-C (band)
SLF	Shuttle Landing Facility
SM	systems management
S/N,s/n	serial number
SRB	Solid Rocket Booster
SRL-1	Space Radar Laboratory-1
SRSS	Shuttle Range Safety System
SSME	Space Shuttle main engine
STL-A, -B	Space Tissue Loss -A, -B
STL/NIH-C	Space Tissue Loss/National Institute of Health - Cells
STS	Space Transportation System
TDRS	Tracking and Data Relay Satellite
TPS	thermal protection subsystem/thermal protection system
TUFI	toughened unipiece fibrous insulation
TVC	thrust vector control
UTPA	universal throat plug adapter
VFT-4	Visual Function Tester-4
WCS	Waste Collection System
WSB	water spray boiler
XSAR	X (band) Synthetic Aperture Radar
ZDS	Zero Doppler Steering

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