NASA-CR-199570F

NASA-CR-199570

NSTS-08294

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STS-68 SPACE SHUTTLE MISSION REPORT

NASA-CR-199570
19960001493

(NASA-CR-199570) STS-68 SPACE SHUTTLE MISSION REPORT (Lockheed Engineering and Sciences Co.) 58 p

N96-11500

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G3/16 0068431

January 1995

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

NOTE

The STS-68 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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NSTS 08294

STS-68

SPACE SHUTTLE

MISSION REPORT

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January 1995

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INTRODUCTION

The STS-68 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-fifth flight of the Space Shuttle Program and the seventh flight of the Orbiter vehicle Endeavour (OV-105). In addition to the Orbiter, the flight vehicle consisted of an ET that was designated ET-65; three SSMEs that were designated as serial numbers 2028, 2033, and 2026 in positions 1, 2, and 3, respectively; and two SRBs that were designated BI-067. The RSRM's that were installed in each SRB were designated as 360W040A for the left SRB, and 360W040B for the right SRB.

This STS-68 Space Shuttle Program Mission Report fulfills the Space Shuttle Program requirement as documented in NSTS 07700, Volume VIII, Appendix E. The requirement that is stated in that document is that each major organizational element supporting the Program will report the results of their hardware (and software) evaluation and mission performance, plus identify all related in-flight anomalies.

The primary objective of this flight was to successfully perform the operations of the Space Radar Laboratory-2 (SRL-2). The secondary objectives of the flight were to perform the operations of the Chromosome and Plant Cell Division in Space (CHROMEX), the Commercial Protein Crystal Growth (CPCG), the Biological Research in Canisters (BRIC), the Cosmic Radiation Effects and Activation Monitor (CREAM), the Military Application of Ship Tracks (MAST), and five Get-Away Special (GAS) payloads.

The STS-68 mission was planned with a 10-day duration plus 1 extension day plus 2 contingency days, which were available for weather avoidance or Orbiter contingency operations. The sequence of events for the STS-68 mission is shown in Table I, and the 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 Marshall Space Flight Center (MSFC) Problem Tracking List is shown in Table IV. In addition, the Integration and Payload in-flight anomalies are referenced in applicable sections of the report. Appendix A lists the sources of data, both formal and informal, that were used in the preparation of this report. Appendix B provides the definition of acronyms and abbreviations used 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 STS-68 consisted of Michael A. Baker, Capt., U. S. Navy, Commander; Terrence W. Wilcutt, Major, U. S. Marine Corps, Pilot; Steven L. Smith, Mission Specialist 1; Daniel W. Bursch, Cdr., U. S. Navy, Mission Specialist 2; Peter J. K. Wisoff, Ph.D., Mission Specialist 3; Thomas D. Jones, Ph. D., Payload

Commander and Mission Specialist 4. STS-68 was the third space flight for the Commander; the second flight for Mission Specialist 2, Mission Specialist 3, and Mission Specialist 4; and the first space flight for the Pilot and Mission Specialist 1.

MISSION SUMMARY

The first launch attempt of the STS-68 mission on August 18, 1994, ended at 230:10:53:58.157 G.m.t. [1.8 seconds prior to Solid Rocket Booster (SRB) ignition], when the SSMEs were shut down. SSME 3 high pressure oxidizer turbine (HPOT) discharge temperature A exceeded the Launch Commit Criteria (LCC) redline of 1560 °R. As a result, the vehicle was returned to the Vehicle Assembly Building (VAB) and all three SSMEs were replaced.

The second launch attempt of the STS-68 mission resulted in an on-time launch at 273:11:16:00.011 G.m.t. (6:16 a.m. c.d.t.) on September 30, 1994, after a countdown with no unplanned holds. Main engine cutoff (MECO) occurred at 273:11:24:35 G.m.t. (00:00:08:35 MET), after a nominal launch phase.

All SSME and RSRM start sequences occurred as expected and launch phase performance was satisfactory in all respects. First stage ascent performance was as expected. SRB separation, entry, deceleration, and water impact occurred as anticipated. Both SRBs were recovered and returned to Kennedy Space Center (KSC) for refurbishment. Performance of the SSMEs, ET, and main propulsion system (MPS) was nominal.

The water spray boiler (WSB) system 2 gaseous nitrogen (GN_2) regulator had two periods of internal out-of-specification leakage when the isolation valves were opened during the prelaunch time-frame. The isolation valves were closed in accordance with nominal procedures to decrease the sensitivity of the GN_2 tanks to internal regulator leakage. This internal leakage did not impact the mission.

The planned direct-insertion trajectory was flown, and no orbital maneuvering subsystem (OMS) -1 maneuver was required. The OMS-2 maneuver was performed at 273:11:51:09 G.m.t. (00:00:35:09 MET). The maneuver was 99 seconds in duration with a ΔV of approximately 160 ft/sec, and the orbit achieved was 119.7 by 119.4 nmi.

The payload-bay-door (PLBD) opening sequence was completed satisfactorily at 273:12:49:44 G.m.t. (00:01:33:44 MET).

At 273:19:54 G.m.t. (00:08:38 MET), Ku-band channel 2 data (operations recorder dump) were degraded because of interference between channels 2 and 3 . Ku-band channel 3 was active at the time with high-rate data from Space-borne Imaging Radar-C (SIR-C) and X-Band Synthetic Aperture Radar (X-SAR). At 273:20:18 G.m.t. (00:09:02 MET), channel 2 data were dumped again with nominal results. The impact was minimal since channel 2 operations recorder dumps were avoided when payload data were being downlinked on channel 3.

A 34-minute waste water dump was initiated at 275:05:32 G.m.t. (01:18:16 MET). A total of 108.8 lb of water was dumped in a single dump cycle with no problems. The dump rate was a nominal 2.01 percent/minute.

At approximately 278:04:50 G.m.t. (04:17:34 MET), the crew reported that a tile was missing along the inboard aft edge of the port-side overhead window (W8). An analysis showed that the loss of this tile would not impact on-orbit or entry operations.

A waste water dump was initiated at 278:02:51 G.m.t. (04:15:35 MET) and was completed 45 minutes later without problems. Two cycles were required, and both had nominal dump rates of approximately 2.0 percent/minute. A total of 106.5 lb of waste water was dumped.

At 278:17:59:56 G.m.t. (05:06:43:56 MET), the left aft reaction control system (RCS) thruster L5D oxidizer injector temperature became erratic. A thruster-fail message was annunciated and the thruster was deselected by the redundancy management (RM). A general purpose computer memory (GMEM) WRITE was applied that lowered the oxidizer leak detection temperature of the vernier thrusters to approximately 0 °F, with the fuel leak detection temperature remaining at 130 °F. Attitude control was returned to the vernier thrusters, and the thruster functioned nominally for the remainder of the mission.

Primary RCS thruster L3D failed off after operating successfully for numerous pulses. The RCS RM annunciated a fail-off condition when three consecutive 80-millisecond firings had chamber pressures of less than 10 psia. There was no indication of a leak, and the thruster remained deselected for the remainder of the mission.

The consumables levels remained above the mission plan, and this enabled the Mission Management Team (MMT) to fulfill the request of the Payloads Community on flight day 6 and extend the mission one day for additional science activities.

After the flash evaporator system (FES) feedline heater reconfiguration to heater system 2 at 278:15:15 G.m.t. (05:04:00 MET), the FES feedline A high-load line temperature went off-scale high (>250 °F) for nearly eight hours. The crew switched back to heater system 1 at 280:04:14 G.m.t (06:16:59 MET) and all temperature conditions became nominal.

A "BCE STRG 3 MTU" message was annunciated at 279:13:05 G.m.t. (06:01:49 MET). This message indicates a problem in the serial input/output (I/O) data path between the master timing unit (MTU) and the general purpose computer (GPC), including multiplexer/demultiplexer (MDM) flight critical forward (FF) 3. Two good accumulators still existed, and this failure did not impact the flight other than the loss of MTU redundancy.

A waste water dump was initiated at 280:08:08 G.m.t. (06:20:52 MET) and was completed satisfactorily 26 minutes later with no problems. Only one dump cycle was required, and the dump rate was nominal with 81.8 lb of waste water dumped. Also, two supply water dumps were successfully performed. The first of these dumps was initiated at 281:10:01 G.m.t. (07:22:45 MET) and during the 30-minute dump, 78.7 lb of supply water was dumped. The second dump was initiated at 282:11:00 G.m.t. (08:23:44 MET) and during the 30-minute dump, 76.4 lb of supply water was dumped.

WSB 1 GN_2 regulator pressure decayed slowly throughout the mission. When the WSB 1 GN_2 isolation valve was opened for entry, the system repressunzed and the regulator pressure reached 25.2 psia from the low of 16.8 psia that had been reached.

The flight control system (FCS) checkout was completed satisfactorily at 283:12:12:38 G.m.t. (10:00:56:38 MET), and auxiliary power unit (APU) 1 ran for 4 minutes 16.58 seconds. The APU operated nominally with 15 lb of fuel used during the checkout. Hydraulic system 1 was used in conjunction with APU 1 for the checkout, and the system performed nominally. The WSB 1 GN_2 isolation valve was left closed during the FCS checkout because of the GN_2 leak. Had APU 1 required spray cooling, the valve would have opened to accommodate spraying; however, the APU run-time was not long enough to require any WSB spray cooling of the APU lubrication oil. The maximum APU 1 lubrication oil temperature was 202 °F.

At 283:12:10 G.m.t. (10:00:54 MET), the rudder channel 3 secondary differential pressure required approximately 1.96 seconds to increase to the failure-detection level (bypass) during the positive-stimulus portion of the secondary-actuator check in the FCS checkout procedure.

A simultaneous supply and waste water dump was performed nominally, with the supply dump beginning at 283:13:50 G.m.t. (10:01:34 MET). A total of 40.1 lb of supply water was dumped from tanks B, C, and D during the 16-minute dump. The waste water dump was initiated 12 minutes into the supply water dump at 283:14:02 G.m.t. (10:02:46 MET), and a total of 126.9 lb of waste water was dumped during the 39-minute dump.

All stowage and deorbit preparations were completed in preparation for entry. The payload bay doors were successfully closed and latched at 284:12:06:13 G.m.t. (11:00:50:13 MET). The first landing opportunity was waved off because of the dynamic weather at KSC that was trending toward unacceptable landing conditions. A decision was made to land at Edwards Air Force Base, and the deorbit maneuver was initiated at 284:16:07:19 G.m.t. (11:04:51:19 MET), and the maneuver was 138.5 seconds in duration with a ΔV of 239.1 ft/sec.

Entry was completed satisfactorily, and main landing gear touchdown occurred at the Edwards Air Force Base concrete runway 22 at 284:17:02:08 G.m.t. (11:05:46:08 MET) on October 11, 1994. The Orbiter drag chute was deployed satisfactorily at 284:17:02:11 G.m.t., and nose landing gear touchdown occurred 10 seconds later. The drag chute was jettisoned at 284:17:02:45 G.m.t., with wheels stop occurring at 284:17:03:10 G.m.t. The rollout was normal in all respects. The flight duration was 11 days 05 hours 46 minutes 08 seconds.

The WSB 3 GN_2 regulator pressure was noted to be decreasing at a rate of 0.26 psi/minute beginning at 284:17:18:41 G.m.t., about 16 minutes after landing. The postlanding video also showed what appeared to be water dripping from the area of the centerline latch for the Orbiter/ET doors. The postlanding inspection determined the source of this water to be WSB 3.

PAYLOADS

The Space Radar Laboratory -2 (SRL-2) consisted of a set of dedicated Earth observation payloads that were used to study vegetation, hydrology, tectonics, topography, and global air pollution. The SRL-2 payload is comprised of the Space-borne Imaging Radar-C/X-Band Synthetic Aperture Radar (SIR-C/X-SAR), and the Measurement of Air Pollution from Satellite (MAPS). These are the same instruments flown on STS-59 as the SRL-1 payload. Other payloads flown on STS-68 include the Biological Research in Canister (BRIC), the Military Applications in Ship Tracks (MAST), the Commercial Protein Crystal Growth (CPCG), the Chromosome and Plant Cell Division in Space Experiment (CHROMEX), and the Cosmic Radiation Effects and Activation Monitor (CREAM).

SPACE RADAR LABORATORY - 2

The imaging radar included in the SIR-C/X-SAR instruments provided the capability to obtain radar data over virtually any region of the Earth, regardless of weather or sunlight conditions. The SRL-2 flight was planned as a 10-day +2 day mission on a 57-degree inclination. However, energy conservation measures added the capability for another day to the mission, and this extra day was added to the mission at the request of the Scientific Community. As a result, the mission was 11 days in duration.

The SRL-2 instruments performed exceptionally well throughout the mission. The SIR-C performed flawlessly from the beginning as did the X-SAR. The Payload High Rate Recorders (PHRRs) performed acceptably, even though PHRR-1 was removed and replaced with an on-orbit spare after the original recorder failed to play-back properly. It is expected that some of the data tapes recorded on PHRR-1 immediately prior to the detection of the problem will not provide useful data.

The Applied Physics Laboratory (APL) sub-experiment also performed flawlessly and was a complete success. The radar experiments overall had a success rate of about 98.5 percent successful data takes against those attempted. For the supersites alone, the success rate was almost 99 percent. The strategy to follow a pre-mission planned ground track was executed so well that the last radar data takes occurred within one-half minute of the pre-mission predicted mission elapsed time and the look angle of the radar changed less than 0.5 degree from the pre-mission plan. In addition, the zero doppler steering maneuvers appear to have been very successful.

The SIR-C/X-SAR instruments produced over 110 hours of radar data that were written on 163 SIR-C and 36 X-SAR digital data tapes on the three PHRRs. During the 950 data-takes, the area of coverage was in excess of 83 million square kilometers. The total data-take swath length was two million kilometers (all data-take swaths summed as a contiguous data take). The APL experiment produced wave spectra over 1 million linear kilometers of ocean.

The high-rate downlink and subsequent flow to the Mission Control Center (MCC) and Jet Propulsion Laboratory (JPL) worked very well. The JPL ground products system processed approximately 40 scenes using the high-precision processor, three scenes using data from all three frequencies and numerous special products. X-SAR processed numerous X-band passes on the real-time processor and produced special image products for display and evaluation.

One of the bonuses of flying SIR-C/X-SAR for the second time was the opportunity to demonstrate a different data-gathering method called interferometry from the Shuttle platform. Scientists conducted the highly successful interferometry experiments during the last three days of the flight. The Scientists were able to generate digital elevation models (topography) of the Earth's surface. Fringes were found in scenes taken from the SRL-1 flight in April and the SRL-2 flight, as well as scenes taken on successive days during the SRL-2 mission. Changes in topography were found in Long Valley Caldera, California, and in Kilauea, Hawaii. Topographic maps were also produced of Mammoth Mountain, California. A digital elevation map (DEM) and a perspective image were produced for Mt. Etna in Sicily from the repeat-pass data.

The MAPS instrument performed flawlessly, as it did on the STS-59 mission. The experimenters were again extremely pleased with the stability of the thermal control loop, given the sun angles at the time of year that this mission was flown. The MAPS experiment was 100-percent successful and the data quality was excellent. At the conclusion of the mission, 256 hours of MAPS data had been accumulated, and it covered all of the planned correlative measurement sites. These data were enhanced by an excellent set of crew observations.

CHROMOSOME AND PLANT CELL DIVISION IN SPACE EXPERIMENT

STS-68 was the fifth flight of the CHROMEX experiments that examined the effects of microgravity on a wide range of physiological processes in plants. The experiment operations are flown in an automated plant growth unit, which is located on the Shuttle middeck. The crew performed daily status checks of the unit and it performed nominally throughout the flight.

COMMERCIAL PROTEIN CRYSTAL GROWTH EXPERIMENT

The CPCG experiment grew and retrieved crystals in microgravity as well as provided data on the dynamics of protein crystallization. The CPCG was activated at 273:18:05 G.m.t. (00:06:49 MET), and the timeline sequence was initiated 40 minutes later. Early in the mission, the commercial refrigerator/incubator module (CRIM) temperature was elevated because of higher-than-expected cabin temperatures. After the cabin temperatures returned to expected levels, the CRIM temperature stabilized and remained at that level throughout the remainder of the mission. The end of the mission timeline sequence was deleted at 284:04:27 G.m.t. (10:17:11 MET), and CPCG preparations for entry were completed seven minutes later.

BIOLOGICAL RESEARCH IN CANISTERS EXPERIMENT

STS-68 was the first flight of the BRIC experiment which provided data in the area of life sciences. The BRIC hardware is self-contained and requires neither Orbiter power nor any crew interface. Postflight evaluation is required to determine the success of the BRIC experiment.

COSMIC RADIATION EFFECTS AND ACTIVATION MONITOR EXPERIMENT

The CREAM experiment collected data on cosmic ray energy loss spectra, neutron fluxes, and induced radioactivity using active and passive monitors. The CREAM monitor was activated at 273:18:41 G.m.t. (00:07:25 MET), and the passive monitors were placed around the cabin about two minutes later. The crew moved the active monitor to the station 1 position at 275:13:01 G.m.t. (02:01:45 MET). It was then moved to the station 2 position at 277:18:42 G.m.t. (04:07:26 MET), to station 1 at 279:16:27 G.m.t. (06:05:11 MET), and to station 1 again at 281:20:18 G.m.t. (08:09:02 MET). The CREAM active monitor was stowed at 282:16:21 G.m.t. (09:05:05 MET), and the passive monitors were stowed prior to entry.

MILITARY APPLICATIONS OF SHIP TRACKS EXPERIMENT

The MAST experiment collected data on ship pollutants and their effects on the reflective properties of clouds. No MAST opportunities were scheduled in the preflight timeline, as MAST targets are dependent upon weather conditions. Upcoming MAST opportunities were submitted to the Flight Control team on each planning shift as agreed upon prior to flight. The crew reported completing nine MAST opportunities that included the Kamchatka peninsula, the Sea of Okhotsk, and the California coast.

GETAWAY SPECIALS

The GAS payloads consisted of seven experiments flown in three GAS canisters. The experiments were:

a. G-316 - One experiment provided data on the Effects of Microgravity on Survival, Mating, and Development of Milkweed Bug, and the second experiment provided data on the Microgravity Effects on Growth Quality and Size of Crystal of Rochelle Salt. The GAS canister G-316 was verified to be activated at 278:20:19 G.m.t. (05:09:03 MET). The G-316 canister was also powered down on flight day 12, as planned, for entry. The sponsor of this GAS canister is the contact for the results of this experiment.

b. G-503 - The G-503 canister contained four experiments, which were:

1. Microgravity and Cosmic Radiation Effects on Diatoms;
2. Concrete Curing in Microgravity;
3. Root Growth in Space; and
4. Microgravity Corrosion.

The G-503 GAS canister was verified to be activated at 273:20:11 G.m.t. (00:08:55 MET). Entry preparation activities were completed as planned on flight day 12. The sponsor of this GAS canister is the contact for the results of this experiment.

c. G-541 - The Study of Breakdown of Planar Solid/Liquid Interface during Crystal Growth - This experiment was commanded on at 273:20:19:35 G.m.t., and commanded off at 274:17:57:32 G.m.t. (01:06:41:32 MET). The sponsor is the contact for results of this experiment.

VEHICLE PERFORMANCE

An attempt was made to launch this vehicle on August 18, 1994; however, the launch was aborted at 230:10:53:59.157 G.m.t. As a result, the Space Vehicle was taken from the launch pad back to the VAB where the three main engines were changed. The successful launch of the STS-68 mission occurred at 273:11:16:00.011 G.m.t. on September 30, 1994. This section of the report discusses the launch abort as well as the flight.

SOLID ROCKET BOOSTER

Launch Abort

The SRB prelaunch countdown was normal for the launch attempt on August 18, 1994. There were no SRB Launch Commit Criteria (LCC) violations. One Operations and Maintenance Requirements and Specification Document (OMRSD) violation occurred when the left-hand System A Range Safety battery temperature dropped off-scale low. All other SRB systems performed as expected during the launch attempt.

Launch

All SRB systems performed nominally during the launch of the STS-68 vehicle. The countdown was normal and no SRB LCC or OMRSD violations occurred. For this flight, the low-pressure heated ground purge of the SRB aft skirt was used to maintain the case/nozzle joint temperatures within the required LCC ranges. At T-25 minutes, the purge was activated at high pressure to inert the SRB aft skirt.

One SRB-related in-flight anomaly occurred in conjunction with this flight. The left-hand SRB range safety system (RSS) throwaway cable assembly, which is used during ground test of the RSS, was found to have cuts in the cable jacket (Flight Problem STS-68-K-1). This anomaly has been assigned to the Kennedy Space Center for resolution.

Both SRBs were successfully separated from the ET at T + 123.96 seconds, and visual sighting reports from the recovery area indicate that the deceleration subsystems performed as designed. Both SRBs were observed during descent and after landing, both were observed floating approximately 15 miles from the retrieval ships.

REDESIGNED SOLID ROCKET MOTOR

Launch Abort

No RSRM LCC or OMRSD violations were identified during the launch abort countdown. Power up and operation of all igniter and field-joint heaters was accomplished nominally. All RSRM temperatures were maintained within acceptable limits throughout the countdown.

Launch

No RSRM LCC or OMRSD violations occurred during the launch countdown. Power up and operation of the igniter and field-joint heaters was accomplished nominally. All RSRM temperatures were maintained within acceptable limits throughout the countdown.

Field joint heaters operated for 11 hours 25 minutes (23 hours total including the launch abort). Power was applied to the heating element an average of 15 percent of the time during the LCC time-frame to maintain required temperature levels.

Igniter joint heaters operated for 18 hours 19 minutes (36 hours 9 minutes total including launch abort). Power was applied to the igniter heating elements an average of 29 percent of the LCC time frame to maintain proper temperatures.

The aft skirt thermal conditioning was operated periodically to maintain the flex bearing temperature above 60 °F and the nozzle-to-case joint temperature above 75 °F. To ensure all hazardous/combustible gases were removed from the aft compartment, the aft skirt purge was operated at high flow-rate from T-15 minutes through launch.

Data indicate that the flight performance of both RSRMs was well within the contract end item (CEI) specification limits, and was typical of the performance observed on previous flights. The RSRM propellant mean bulk temperature was 80 °F. The table on the following page presents the more detailed propulsion performance data for the RSRMs.

All available data were recorded, transmitted and analyzed, and no in-flight anomalies were identified from the data review. The postflight inspection of the motors also indicated nominal performance, with all joints performing as designed.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 80 °F		Right motor, 80 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10^6 lbf-sec	66.12	65.92	66.06	65.90
I-60, 10^6 lbf-sec	176.05	175.70	175.90	175.77
I-AT, 10^6 lbf-sec	296.93	297.16	296.90	296.60
Vacuum Isp, lbf-sec/lbm	268.6	267.9	268.6	268.3
Burn rate, in/sec @ 60 °F at 625 psia	0.3678	0.3685	0.3676	0.3682
Burn rate, in/sec @ 80 °F at 625 psia	0.3731	0.3738	0.3729	0.3735
Event times, seconds[1]				
Ignition interval	0.232	N/A	0.232	N/A
Web time[2]	108.9	108.8	109.0	108.6
Separation cue, 50 psia	118.6	118.4	118.7	118.5
Action time[2]	120.7	120.6	120.8	120.5
Separation command	123.6	123.4	123.6	123.4
PMBT, °F	80	80	80	80
Maximum ignition rise rate, psia/10 ms	90.4	N/A	90.4	N/A
Decay time, seconds (59.4 psia to 85 K)	2.8	2.9	2.8	2.8
Tailoff Imbalance Impulse	Predicted		Actual	
differential, Klbf-sec	N/A		202.0	

Impulse Imbalance = left motor minus right motor

[1] All times are referenced to ignition command time except where noted by a [2].

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

EXTERNAL TANK

Launch Abort

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

Typical ice/frost formations were observed on the ET during the countdown. There was no ice or frost observed on the acreage areas of the ET. Normal quantities of ice and/or frost were present on the liquid oxygen (LO_2) and liquid hydrogen (LH_2) feedlines and on the pressurization line brackets. All observations were acceptable per NSTS 08303. The Ice/Frost Red Team was not used because of a recent change to the LCC. The Debris team reported nothing unusual on the ET. The ET pressurization system functioned nominally throughout engine start.

Launch

The ET loading and flight performance was excellent. All flight objectives were accomplished. All ET electrical equipment and instrumentation operated properly. All ET purge and heater operations were monitored and all performed properly. No ET LCC or OMRSD violations occurred.

The nose cone purge heater and temperature control system operated satisfactorily. Measured nose cone flow-rate was within the Interface Control Document (ICD) requirements, as it has been since KSC installed a critical flow nozzle to limit the flow rate.

Typical ice/frost formations were observed on the ET during the countdown. There was no ice or frost observed on the acreage areas of the ET. Normal quantities of ice and/or frost were present on the LO_2 and LH_2 feedlines and on the pressurization line brackets, and some frost or ice was present along the LH_2 protuberance air load (PAL) ramps. All observations were acceptable per NSTS 08303. The Ice/Frost Red Team reported that no anomalous thermal protection system (TPS) conditions existed, although one acceptable crack did exist at the foam bridge between the vertical strut cable tray and its fitting and that was caused by joint rotation.

Propellant tank loading was nominal. All LO_2 and LH_2 tank ullage pressures were within acceptable limits throughout loading, prepressurization, and flight. Geyser prevention procedures provided excellent temperature margins throughout loading.

The ET pressurization system functioned nominally throughout engine start and flight. The minimum LO_2 ullage pressure experienced during the ullage-pressure slump was 14.2 psid.

ET separation occurred when commanded. ET entry and breakup occurred 17 nmi. uprange of the preflight prediction and within the expected footprint.

Postflight analysis of the film from the umbilical well cameras, as well as from the onboard camera operated by the crew in support of Development Test Objective (DTO) 312, revealed the following:

1. Two divots, approximately 10 to 12 inches in diameter, in or just forward of the LH_2-to-intertank splice on the -Z side of the ET;

2. A shallow divot, approximately 5 inches in diameter, in the LH_2 insulation aft of the intertank splice and outboard of the -Y bipod attachment.

3. Missing foam, approximately 10 inches in length, with probable exposed primer from an intertank stringer top near the +Z axis at approximately station XT-1050.

SPACE SHUTTLE MAIN ENGINES

Launch Abort

All SSME parameters appeared to be normal throughout the prelaunch countdown, and the parameters were typical of the prelaunch parameters observed on previous flights. Engine ready was achieved at the proper time and all LCC were met. An on-pad abort occurred at 230:10:53:58.157 G.m.t. because the SSME 3 (S/N 2032) high pressure oxidizer turbine (HPOT) discharge temperature channel A exceeded a pre-liftoff redline check resulting in a failure identification (FID) and subsequent engine shutdown (Flight Problem STS-68-E-01) From engine start command (ESC) plus 2.3 seconds through ESC plus 5.8 seconds, the HPOT discharge temperature must not exceed 1560 °R. The SSME-3 HPOT discharge temperature Channel A attained 1576 °R. The Channel B measurement attained 1530 °R, and that was also higher than predicted. Data review indicates that the data are valid.

SSME 3 was commanded to shut down at ESC plus 4.72 seconds. SSME 2 and SSME 1 subsequently shut down at ESC plus 5.80 seconds and 6.96 seconds, respectively. The shut downs were all nominal and placed the vehicle in a safe configuration.

The SSME 1 inspection following the abort revealed a crack in the turbine discharge sheet metal turnaround duct of the SSME 1 high pressure fuel turbopump (HPFTP) (Flight Problem STS-68-E-02). The crack was 4.5 inches long, with two cracks (0.8 inch and 0.9 inch long) running 90 degrees to the long crack, making a flap. The flap was deflected outboard touching the coolant liner. Degradation of the turbine performance would be small from this condition, and the engine is tolerant to particle generation of this size in this area.

Launch

All SSME parameters were normal throughout the countdown and were typical of prelaunch parameters observed on previous flights. Engine ready was achieved at the proper time, all LCC were met, and an on-time start and thrust buildup were normal.

Flight data indicate that SSME performance during mainstage, throttling, shutdown, and propellant dumping operations was normal. The specific impulse (Isp) was rated at 452.0 seconds. High pressure oxidizer turbopump (HPOTP) and HPFTP temperatures were well within specification throughout engine operation. MECO occurred at T+ 513.4 seconds. There were no FIDs or significant problems identified from the data.

A review of the launch data has revealed the following items of interest:

1. The SSME 1 HPOTP discharge temperature channel A shifted down at engine start plus 240 seconds. The shift is attributed to a reduction in HPOTP cavitation. This same condition was observed on STS-59 (previous flight of this pump) and is within the experience base.

2. The SSME 1 anti-flood valve skin temperature 2 failed high at engine start plus 95 seconds, and the no. 1 measurement was slow to respond. The most probable cause is that the sensors are debonded. The sensors will be replaced prior to the next flight of this engine.

3. The SSME 1 main combustion chamber (MCC) pressure channel A1 spiked to 84 psia at engine start plus 292 seconds. This was a single event spike and caused the channel to be temporarily disqualified for one major cycle. Even though the sensor operated properly for the remainder of the flight, it was removed and troubleshooting was performed. Microfocus X-ray identified a particle inside the sensor that could account for the spike. The sensor has been sent to the vendor for additional analysis.

4. The SSME 2 MCC hot gas injection pressure froze and recovered at engine start plus 270 seconds. This condition was within past experience.

5. The SSME 2 HPOTP system pressure dipped at engine cutoff plus 2.5 seconds. This condition is within the experience base.

SHUTTLE RANGE SAFETY SYSTEM

Launch Abort

The Shuttle Range Safety System (SRSS) closed-loop testing was completed as scheduled during the launch countdown. All SRSS safe and arm (S&A) devices were armed and system inhibits turned off at the appropriate times. All SRSS measurements indicated that the system operated throughout the launch abort countdown as expected with the exception of the left-hand System A battery temperature. The System A battery temperature dropped off-scale low (18 °F). An exception was written to the OMRSD requirement of 34.6 to 103.4 °F. All SRSS devices performed as planned for the on-pad launch abort.

Analysis of the battery temperature problem indicates that the measurement failed as a step-function, indicating an instrumentation failure. Voltage and current remained stable during the measurement failure. The failure signature indicates an intermittent open circuit for the temperature measurement (thermistor). The battery was removed and tests were performed to isolate the cause of the anomaly.

Launch

The SRSS closed-loop testing was completed as scheduled during the launch countdown. All SRSS S&A devices were armed and system inhibits turned off at the proper time. 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 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

Launch Abort: The overall performance of the MPS was as expected throughout the countdown and during engine start and shutdown. The LO_2 and LH_2 loading was performed nominally with no stop-flows or reverts. No OMRSD or LCC violations occurred.

Throughout the period of preflight operations, no significant hazardous gas concentrations were detected. The maximum hydrogen concentration level in the Orbiter aft compartment occurred shortly after start of fast-fill and was approximately 153 ppm, and that compares favorably with previous data for this vehicle.

A comparison of the calculated propellant loads at the end of replenish versus the inventory loads results in a loading accuracy of -0.026 percent for LH_2 and +0.035 percent for LO_2.

Launch: The overall performance of the MPS was nominal. No LCC or OMRSD violations occurred.

LH_2 loading operations were normal throughout the prelaunch time-frame and were performed as planned with no stop-flows or reverts. Analysis of the LH_2 loading system data showed the load to be 231,886 lbm at the end of replenish. A comparison with the planned load showed that an excess of 33 lbm was loaded, providing a loading accuracy of +0.01 percent, which is well within the required accuracy.

LO_2 loading operations were normal throughout the prelaunch time-frame and were performed without any stop-flows or reverts. Analysis of the LO_2 loading system data showed the load to be 1,388,337 lbm at the end of replenish. A comparison with the planned load showed that an excess of 508 lbm was loaded, providing a loading accuracy of +0.04 percent, which is well within the required accuracy.

Throughout the period of preflight operations, no significant hazardous gas concentrations were detected. The maximum hydrogen concentration level in the Orbiter aft compartment was approximately 150 ppm, and that compares favorably with previous data for this vehicle.

Ascent MPS performance was completely nominal and no anomalies were identified. 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. The gaseous hydrogen flow control valves performed nominally.

The MPS gaseous oxygen (GO_2) pressurization system failed the OMRSD File IX requirement for on-orbit decay. A determination of the amount of leakage from the oxygen pressurization system is made by measuring the pressure decay of the GO_2 manifold following manifold pressurization. The calculated on-orbit leakage was 34.8 scim, and the allowable leakage is 24.5 scim. Failure of this requirement will necessitate the performance of the GO_2 pressurization leakage check per the OMRSD File III to isolate the cause of the leakage.

The propellant dump and vacuum inerting operations were performed under the OI-22 software in a nominal manner. The propellant dump was initiated at MECO plus 122 seconds as planned, and the postflight analysis indicated nominal operations. The vacuum inerting was also nominal. This was the last flight of the OI-22 software.

In preparation for entry, the manifold repressurization was nominal. A total of 57.5 lb of helium (nominal), was used during entry on this vehicle.

Reaction Control Subsystem

The RCS performance was nominal; however, two anomalies were identified from the data. The RCS was interconnected to the left and right OMS, and during the interconnect operations the RCS used a total of 2533 lbm of OMS propellants. In addition, 4658.8 lbm of RCS propellants were consumed by the RCS.

During this flight, a successful attempt was made to obtain high-rate data on all RCS thrusters so that the RCS hot-fire prior to entry could be eliminated. All thrusters except F3F were verified with high-rate chamber pressure data. Since this thruster was not a high-priority thruster for entry, the RCS hot-fire was eliminated.

At 278:17:59:56 G.m.t. (05:06:43:56 MET), the left aft RCS thruster L5D oxidizer injector temperature became erratic (Flight Problem STS-68-V-02). A fuel leak message was annunciated and the thruster was deselected by the RM. Flight rules prohibit vernier operation with a vernier thruster deselected; consequently, the primary thrusters were used for vehicle attitude control. Data analysis showed that the data signature was typical of an intermittent open instrumentation sensor or wiring, most likely between the sensor and dedicated signal conditioner. A temporary workaround was implemented that allowed vernier operations only when real-time telemetry downlink of the L5D fuel injector temperature and chamber pressure (Pc) were available, and with data losses of no greater than 30 seconds. Subsequently, a more permanent workaround was implemented after verification in the Shuttle Avionics Integration Laboratory (SAIL) in which a GMEM WRITE was applied. The GMEM lowered the oxidizer leak detection temperature of the vernier thrusters to approximately 0 °F, with the fuel leak detection temperature remaining at 130 °F. Leak detection for all vernier thrusters was provided by the fuel injector temperature. Attitude control was returned to the vernier thrusters, and the thruster functioned nominally for the remainder of the mission.

At approximately 279:05:00 G.m.t. (05:17:44 MET), the left aft primary RCS thruster L3D was declared failed off and deselected by the RM after having been successfully fired 399 times. The failure occurred after three consecutive 80 ms pulses during which the chamber pressure never reached more than 10 psia (Flight Problem STS-68-V-03). There was no indication of a leak, and the thruster remained deselected for the remainder of the mission. Data review indicates that the thruster did not fire nominally. Injector thermal trends indicate propellant flow through both valves, but the data did not show the typical soak-back that is indicative of a nominal firing. Inertial measurement unit (IMU) vehicle rate data confirm low thrust output for the L3D firings.

Orbital Maneuvering Subsystem

The OMS performed nominally during the mission, completing two maneuvers - OMS-2 and the deorbit firing. The total firing time on the engines was 236.3 seconds, with 12,314 lbm of propellants being used. In addition, the RCS used 2533 lbm of the OMS propellants. Details of the two OMS firings are shown in the following table.

OMS FIRINGS

OMS firing	Engine	Time, G.m.t./MET	Firing duration, seconds	ΔV, ft/sec
OMS-2	Both	273:11:51:09:9 G.m.t. 00:00:35:09.9 MET	98.0	160.1
Deorbit	Both	284:16:07:19.3 G.m.t. 11:04:51:19.3 MET	138.3	239.2

Two minor problems were noted, neither of which affected the mission. The first was the left fuel total quantity meter reading high. The aft probe was reading correctly; however, the forward probe was not. The problem has been documented at KSC; however, corrective action will probably not be taken until this vehicle goes to Orbiter maintenance down period (OMDP).

Also, the right oxidizer total quantity reading was high. The aft probe was reading approximately the same value as total quantity. Preliminary analysis indicates that the aft probe and its electronics are suspect. This problem was initially noted on STS-59, and KSC documented it at that time for future corrective action.

Power Reactant Storage and Distribution Subsystem

The operations of the power reactant storage and distribution (PRSD) subsystem was nominal. A total of 3,061 lbm of oxygen was used, including 128 lbm that was consumed by the environmental control subsystems. Also, 369 lbm of hydrogen were used. Reactants remaining provided a mission extension capability of 54 hours at a mission average power level of 15.8 kW. There were no anomalies identified from the data for this subsystem.

At 280:03:16 G.m.t. (06:16:00 MET), usage was switched to hydrogen tanks 1 and 2 for the next 36 hours. During most of the cycles for the first 12 hours following the switch to tanks 1 and 2, hydrogen tank 2 pressure rose faster than the tank 1 pressure and manifold pressures when the heaters were on. This condition indicated that the hydrogen tank 2 check valve was sticking closed. However, the tank 2 pressure declined normally during the heater-off cycle, and this indicates that the check valve was opening enough to allow some flow and properly deplete the tank but not enough to increase manifold pressure. Similar behavior was noted for this same hydrogen tank 2 check valve during the previous flight of the OV-105 vehicle (STS-59). At 280:18:56 G.m.t. (07:07:40 MET), the manifold pressure abruptly rose approximately 8 psi from the tank 1 pressure to the tank 2 pressure. This indicated that the hydrogen tank 2 check valve suddenly opened or became unstuck. After this occurrence, hydrogen tanks 1 and 2 and the manifold pressures all tracked each other properly for the rest of the mission. There was no mission impact from this condition.

Fuel Cell Powerplant Subsystem

The fuel cell powerplant (FCP) subsystem performed nominally throughout the mission with no problems or anomalies identified in the data. The fuel cells generated 4,260 kWh of electricity at an average power level of 15.8 kW and the load was 516 amperes. The fuel cells consumed 2933 lbm of oxygen and 369 lbm of hydrogen, and generated 3302 lbm of water during the mission.

Main buses B and C were tied for most of the mission to support the payload. Five fuel cell purges were performed, occurring at approximately 24, 91, 163, 212, and 261 hours mission elapsed time. For this mission, the mean purge interval was only 59 hours. No purge interval of 96 hours was achieved because of the higher average load that led to a more rapid performance decay.

Auxiliary Power Unit Subsystem

The APU subsystem performed satisfactorily throughout the mission with no problems or anomalies identified from the data. The APUs were shut down after ascent in the 2, 1, and 3 order to fulfill the requirements of DTO 414, Sequence B. The results of the DTO are discussed in the Development Test Objectives section of this report.

During the scrubbed launch attempt, the APU 2 exhaust gas temperature (EGT) 1 rose sharply at start-up, then followed a normal profile but was biased high. This same behavior was also noted during the ascent and entry phases of the mission, but to a lesser extent.

All three APUs had the new water valves installed for their first flight. These valves are not life-limited because of corrosion. The previous design was subject to corrosion, which caused the bellows to stick open or closed; hence the valves were limited to a nine-month wetted life.

The APU 1 gearbox lubrication (lube) oil outlet temperature fault detection and annunciation (FDA) limit was lowered to provide an FDA message early and allow sufficient time for the crew to open the WSB GN_2 isolation valve that is opened for normal lubrication oil cooling operations (250 °F) during FCS checkout. However, opening the valve was not required.

The APU fuel consumption and run-time by APU position and serial number is shown in the following table.

Flight phase	APU 1 (S/N 403)		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	19:00	48	18:44	48	19:12	48
FCS checkout	04:16	15				
Entry[a]	59:52	116	74:32	141	59:56	116
Total[b]	83:08	179	93:16	189	79:08	164

[a]APUs ran for approximately 14 minutes 47 seconds after main gear touchdown.
[b]Totals do not include 5 minutes 53 seconds of operation during the launch abort. Each APU consumed 18 lbm of fuel during the launch abort operation.

Hydraulics/Water Spray Boiler Subsystem

The hydraulics/WSB subsystem met all requirements placed on the system; however several minor problems were noted.

During prelaunch operations, nominal performance was observed except for out-of-specification internal leakage on WSB system 2 GN_2 regulator after opening the GN_2 isolation valve during the prelaunch activities (Flight Problem STS-68-V-06). The first regulator leakage was about 42 sccm (redline limit is 10 sccm) over a 26-minute period following the first isolation valve opening. The second leakage was approximately 73 sccm over a 28-minute period just prior to launch. The isolation valves were closed whenever possible in accordance with nominal procedures to decrease the sensitivity of the GN_2 tanks to internal regulator leakage. Internal leakage has been observed in the past to be caused by a damaged balance stem O-ring.

The ascent operation of the hydraulics subsystem was nominal, and the performance of two of the three WSB systems was nominal. WSB system 3 exhibited a 24.5 °F APU lubrication oil overcool subsequent to spray start. This overcool is believed to have been caused by a slight freeze-up of the WSB spray bar.

On-orbit operation of the hydraulics/WSB subsystem was nominal except for WSB 1 GN_2 regulator which exhibited a low-pressure decay in regulator outlet pressure through the relief valve (Flight Problem STS-68-V-07). The decay began at 274:14:35 G.m.t. (01:03:19 MET) and continued for the remainder of the flight. Hydraulics/WSB system 1 was used for FCS checkout; however, no spray cooling was required because of the short run-time of the APU (4 minutes 16.58 seconds). The GN_2 isolation valve was kept closed during the FCS checkout to prevent loss of water because the regulator outlet pressure decay may have been due to water leak. The pressure decayed to 16.8 psia prior to entry; however, this WSB operated nominally throughout entry and landing.

At 283:12:10 G.m.t. (10:00:54 MET), the rudder channel 3 secondary differential pressure required approximately 1.96 seconds to increase to the failure-detection level (bypass) during the positive-stimulus portion of the secondary-actuator check in the FCS checkout procedure (Flight Problem STS-68-V-11). The channel should normally bypass in approximately 120 ms. The channel bypassed nominally during the negative-stimulus portion of the test. Data review showed a delay of 1.44 seconds on STS-59, less than one second on STS-57, less than 0.25 second on STS-54, and 0.15 second on STS-49. There were no delays apparent on STS-47 or STS-61.

During entry, the hydraulics subsystem performed satisfactorily. WSB system 1 performed nominally. WSB system 2 exhibited a maximum internal leakage of approximately 22 sccm after the GN_2 isolation valve was opened for entry.

The WSB 3 system 3 regulator pressure showed a rapid decay shortly after weight-on-wheels (WOW), indicating a leak (Flight Problem STS-68-V-10). This WSB had been stable throughout the mission. The GN_2 pressure dropped from 38.1 psia to 19.8 psia in just over one hour. Water was observed coming from the ET umbilical doors and centerline hinge while still on the runway. Total water leakage in to the aft compartment was estimated to be 88 lb (10.5 gallons). Approximately 0.5 lb of water remained in the tank. The postflight inspection revealed that the WSB 3 bottom and port side blankets were wet. System 3 was repressurized by cycling the GN_2 isolation valve during troubleshooting to pinpoint the leak. The water leak was isolated to a crack in the WSB system 3 APU lubrication oil spray valve on the inlet side. It has been determined that the crack resulted from contaminant that was introduced into the system, and the contaminant produced corrosion.

Electrical Power Distribution and Control Subsystem

The performance of the electrical power distribution and control (EPDC) subsystem was nominal throughout the mission with no problems or anomalies identified in the data. All data analyzed showed nominal voltage and current signatures, and no specified limits were violated during the mission.

Environmental Control and Life Support System

The environmental control and life support system (ECLSS) met all requirements of the mission in a satisfactory manner.

The active thermal control subsystem (ATCS) operation was nominal throughout the mission. After the FES feedline heater reconfiguration to heater system 2 at 278:15:15 G.m.t. (05:04:00 MET), the FES feedline A high-load line temperature went off-scale high (>250 °F) for nearly eight hours (Flight Problem STS-68-V-05). The FES feedline A accumulator line temperature measurement had been experiencing erratic cycling during the off-scale high periods and had maintained temperatures above the nominal thermostat control band. The heater on this line is controlled by the same thermostat as the heater on the high-load line, and it is possible that the heater system 2 thermostat is loose. The off-scale high condition was also repeated for shorter periods (1 to 3 hours), a signature that also occurred during STS-59. The crew switched back to heater system 1 at 280:04:14 G.m.t (06:16:58 MET) and all temperature conditions became nominal.

The ATCS successfully supported the payload cooling requirements by placing both Freon coolant loops (FCLs) to the payload mode at 273:13:29 G.m.t.

(00:02:13 MET). The FCLs were returned to the interchanger mode at 284:06:13 G.m.t. (10:18:57 MET).

The radiator coldsoak provided cooling during entry through touchdown plus 15 minutes when ammonia system B, which used the primary/GPC controller, was activated. Ammonia system B was deactivated after 17 minutes of operation when ground cooling was connected and placed in operation.

The supply water and waste management systems performed normally throughout the mission. Supply water was managed through the use of the FES and overboard dump systems. The supply water dump line temperature was maintained between 66 and 100 °F with the operation of the line heater. Three supply water dumps were made at an average dump rate of 1.59 percent/minute (2.9 lb/min).

Waste water was gathered at about the predicted rate. Four waste water dumps were made at an average dump rate of 1.9 percent/minute (3.13 lb/min). The waste water dump line temperature was maintained between 53 and 80 °F throughout the mission. The vacuum vent line temperature was maintained between 57 and 80 °F, while the nozzle temperature was maintained between 118 and 178 °F.

The waste collection system (WCS) performed adequately throughout the mission.

The atmospheric revitalization system (ARS) performance was nominal throughout the mission with no problems or anomalies identified. DTO 664 - Cabin Temperature Survey was performed with no problems.

The ARS pressure control system performed nominally throughout the duration of the mission. During the redundant component check, the pressure control configuration was switched to the alternate system. Both systems exhibited normal operation.

Airlock Support System

Use of the airlock support system and components was not required because no extravehicular activity (EVA) was planned or required. The active system monitor parameters indicated normal outputs throughout the duration of the flight.

Smoke Detection and Fire Suppression Subsystem

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

Avionics and Software Systems

During entry, the performance of the integrated guidance and navigation system was nominal. Entry navigation sensors all functioned nominally, and there were no failures or deselections by RM. There was no navigation measurement data editing. Drag measurement processing started at 222K ft and ended at 64.9K ft. TACAN station acquisition occurred at approximately 142K ft with the cone-of-confusion spanning the 64.9K ft to 8K ft range of altitude. Air data transducer assembly (ADTA) data incorporation started at approximately 77K ft and continued to approximately 15K ft. The microwave scanning beam landing system (MSBLS) processing in the navigation filter was initiated at approximately 15K ft, and all measurement residuals were nominal. The primary avionics software system-backup flight system (PASS-BFS) state vector comparison in UVW coordinates showed that both systems were performing and tracking as expected.

While flying a descending approach into Edwards, DTO 251 - Entry Aerodynamic Control Surfaces Test - Alternate Elevon Schedule - was successfully performed with all programmed test inputs (PTIs) satisfactorily completed. At the transition to approach/landing, DTO 254 - Subsonic Aerodynamics Verification - was satisfactorily completed. Drag chute deployment was completed prior to derotation in accordance with DTO 521 - Orbiter Drag Chute System.

A "BCE STRG 3 MTU" message was annunciated at 279:13:05 G.m.t. (06:01:49 MET). This message indicates a problem in the serial I/O data path between the MTU and the GPC, including MDM FF 3 (Flight Problem STS-68-V-04). The MTU built-in test equipment (BITE) word was nominal, thus indicating no MTU problems. An I/O reset and string 3 port mode were performed in an unsuccessful attempt to clear the problem. Two good accumulators still existed, and this failure did not impact the flight other than the loss of MTU redundancy. An MDM BITE Status Read (BSR) was performed at 284:06:50:36 G.m.t. (10:19:34:36 MET) and it showed a nominal value of 0000. An MDM BITE Test was then performed about two minutes later and it also showed a nominal value of AAAA 5555). This was followed by a second MDM BSR approximately five minutes later that again showed nominal values.

The flight control system performance was satisfactory except for one item. At 283:12:10 G.m.t. (10:00:54 MET), the rudder channel 3 secondary differential pressure required approximately 1.96 seconds to increase to the failure-detection level (bypass) during the positive-stimulus portion of the secondary-actuator check in the FCS checkout procedure (Flight Problem STS-68-V-11). This problem is discussed in the Hydraulics section of this report.

The performance of the three high accuracy inertial navigation system (HAINS) IMUs was very satisfactory throughout the prelaunch activities and the flight. The preflight alignment gyrocompass performance was exceptional with the largest mean relative errors being -34 arcseconds. The largest misalignment mean correction observed during the scrub and the launch preflight alignments was 11 arcseconds. Only one uplink adjustment of gyro drift and two small adjustments of the accelerometers were performed during the flight.

The star trackers operated nominally with no problems identified.

Displays and Controls Subsystem

At approximately 283:16:30 G.m.t. (10:05:54 MET), the crew reported that the tens digit on the Ku-band range rate/azimuth display on panel A2 was malfunctioning (Flight Problem STS-68-V-09). Only the upper left light-emitting diode (LED) was illuminated. When the lamp test was performed, all LEDs illuminated correctly. The crew used SPEC 201 for Ku-band stowing, which was completed nominally.

At 283:23:46 G.m.t. (10:12:30 MET), the crew turned on the forward port floodlight and numerous current spikes ranging from 9 to 12 amperes dc were noted on the mid power control assembly (PCA) main A bus. These spikes are evidence of a known arcing phenomenon. The light was powered off, and other lights were available; consequently, the loss of this light did not impact mission operations.

During configuration of the RCS to straight feed at 282:13:20:44 G.m.t. (09:02:04:44 MET), the crew reported that the left RCS 3/4/5 crossfeed valve talkback (indicator) showed barberpole when it should have indicated closed. The crew tapped the panel and reported that the talkback indication transitioned to closed. The data indicate a clean, simultaneous closure of both the fuel and oxidizer valves. This condition was documented during preflight activities and accepted as a fly-as-is condition.

Communications and Tracking Subsystems

The communications and tracking subsystem performed satisfactorily throughout the mission. The S-band communication link handover from the Wallops Island ground station to the Tracking and Data Relay (TDRS) satellite during ascent was nominal.

During the prelaunch time-frame at 273:07:00 G.m.t., TACAN 2 locked on in range but did not lock on in bearing while on the upper antenna and configured to KSC. When switched to the Patrick AFB TACAN beacon, TACAN 2 did not lock-on in bearing on the upper antenna. TACANs 1 and 3 performed nominally in both range and bearing, and while on the lower antennas all three TACANs operated nominally. Data review and analysis indicates that the cause of the TACAN 2 condition was poor signal because of multipath at the TACAN 2 upper antenna, combined with TACAN 2 having more sensitivity to such conditions.

At 273:19:54 G.m.t. (00:08:38 MET), Ku-band channel 2 data from an operations recorder dump were degraded (Flight Problem STS-68-I-01). Ku-band channel 3 was active at the time with high-rate data from SIR-C and X-SAR. At 273:20:18 G.m.t. (00:09:02 MET), channel 2 data were dumped again with nominal results. Channel 3 was not active at that time. This appears to be a repeat of the anomaly observed on this vehicle with the same payload during the STS-59 mission, and that anomaly was closed as an unexplained anomaly. The impact was minimal since channel 2 operations recorder dumps were avoided when payload data were being downlinked on channel 3. A troubleshooting plan was developed prior to flight to aid in determining the cause of the apparent interference. The Ku-band degradation troubleshooting procedure was performed at 279:18:20 G.m.t. (06:07:04 MET). The data collected during the test showed that the signature experienced during STS-59 was not duplicated. However, data from White Sands Ground Terminal (WSGT) and delog of Ku channel status from NASA Ground Terminal (NGT) were obtained and analyzed to isolate possible causes. The data analysis showed that 12 of 15 data-dropout incidents were directly related to operations recorder track changes, data gaps, or confirmed Applied Physics Laboratory recorder problems. Three incidents revealed severe degradation in channel 2 (operations recorder) data quality with no usable data, and these could not be correlated with track changes or data gaps. Data analysis showed that channel 3 contained the playback of SIR-C data during these three specific time periods when severe channel 2 degradation was observed. Channel 3 data were not affected. Also, all three instances were on the TDRS-West using the 2-south ground equipment chain for data processing.

During the Orbiter postflight crew debriefing, the crew reported continuous erratic readouts on the display panel and cathode ray tubes (CRTs) in SPEC 201 while performing the Ku-band stow procedures. The erratic readouts were noted while in the slow slew mode (0.4°/sec). The crew had been trained to expect erratic readouts in the fast-slew mode (20°/sec), and therefore, thought that the slew was "defaulting" to the fast mode. The crew noted this erratic behavior three times. Ku-band antenna stowage was performed during a dark pass without payload bay lights, so no visual report of the condition is available. Data show that the crew was hitting the alpha software stop, resulting in a 360 degree whip-around at 20 degrees/second to reach the requested position. Data show that this condition occurred five times. This scenario is a nominal occurrence.

Operational Instrumentation/Modular Auxiliary Data System

At approximately 282:08:50 G.m.t. (08:21:34 MET), degraded data were noted during playback of the Applied Physics Laboratory data on the payload recorder (Flight Problem STS-68-V-08). Track 2 had degraded data from the 68 to the 100 percent position, track 3 was degraded from the 29 to the 68 percent position, and track 4 was degraded from the 84 to the 100 percent position. The APL data were on Ku-band channel 2 and SRL high-rate data were on Ku-band channel 3 during part of these dumps. On-orbit troubleshooting was performed using different tape directions (forward and reverse) and dump ratios (1 to 1 and 16 to 1). This troubleshooting revealed that only tracks 1 and 5-14 were usable for the remainder of the mission.

During postlanding operations, operations recorder 2, track 8 would not dump in either the forward or reverse directions (Flight Problem STS-68-V-12). The failure indication was an unmodulated carrier. All other tracks dumped (4 through 7 and 9 and 10). Troubleshooting at KSC verified a bad track 8. The operations recorder will be removed, repaired and reinstalled.

Structures and Mechanical Subsystems

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

The drag chute performance was excellent, and the deployment was completed at the planned time in the Orbiter rollout. As a result, only light braking was needed to bring the vehicle to a stop. Test condition 4 of DTO 521-Orbiter Drag Chute System was completed with this landing.

Integrated Aerodynamics, Heating and Thermal Interfaces

The ascent and entry aerodynamics were nominal with no problems, anomalies, or unexpected conditions identified in the data.

During entry, all five PTIs required by DTO 251 Part 7 - Entry Aerodynamic Control Surfaces Test - Alternate Elevon Schedule were completed. Also, DTO 254 Part 4 - Subsonic Aerodynamics Verification was performed during the final approach. All aileron and rudder inputs were as expected for this DTO. Likewise, DTO 521 - Orbiter Drag Chute System performance was as expected.

The integrated heating during ascent and entry was nominal, based on the telemetry data and the plume appearance. The entry aerodynamic heating was nominal; however, postflight analysis and heating calculations are continuing as this is written.

The performance of the thermal interfaces was nominal with all temperatures remaining within limits, and there were no LCC violations.

Landing and Braking Parameters

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	3585	193.1	~ -1.0	N/A
Nose gear touchdown	7301	128.4	N/A	~4.4

Brake initiation speed	81.5 knots (keas)
Brake-on time	34.0 seconds
Rollout distance	8,490 feet
Rollout time	61.8 seconds
Runway	22 (Concrete) EAFB
Orbiter weight at landing	221,571 lb

Brake sensor location	Peak pressure, psia	Brake assembly	Energy, million ft-lb
Left-hand inboard 1	648	Left-hand outboard	10.05
Left-hand inboard 3	528	Left-hand inboard	12.54
Left-hand outboard 2	540	Right-hand inboard	11.45
Left-hand outboard 4	552	Right-hand outboard	8.60
Right-hand inboard 1	588		
Right-hand inboard 3	480		
Right-hand outboard 2	420		
Right-hand outboard 4	444		

Thermal Control Subsystem

The thermal control subsystem performance was nominal.

The FES primary accumulator line A thermostat cycled erratically at the upper end of its set-point range on the system 2 heater. The erratic cycling caused the high-load feedwater line to exceed the upper limit of 250 °F for an extended period of time (Flight Problem STS-68-V-05). This anomaly is discussed in greater detail in the Environmental Control and Life Support System section of this report.

Aerothermodynamics

The acreage heating during entry was within limits, and the local heating was nominal. The structural temperature rise was symmetrical on the right and left wings and within the experience base.

Thermal Protection Subsystem

The TPS performed satisfactorily. Based on structural temperature response data (temperature rise), the entry heating was above average. Boundary layer transition from laminar flow to turbulent flow occurred at 1379 seconds after entry interface on the forward centerline of the vehicle, and at 1335 seconds on the aft centerline of the vehicle. This is the latest that transition has occurred on all the flights with available data. Based on the two available right-to-left side thermocouple pairs on this vehicle, transition occurred 35 and 55 seconds, respectively, earlier on the left side of the vehicle, but still occurred much later than average.

Based on a postlanding inspection of the Orbiter, overall debris damage was below average. Data show 110 impacts with 15 having a major dimension of 1 inch or greater. The Orbiter lower surface sustained 59 hits (91 average) of which 9 had a major dimension of 1 inch or greater (14 average). Two damage sites, one near the LO_2 ET/Orbiter umbilical and the other near the nose landing gear door, had embedded debris. The debris was removed prior to ferry flight for analysis at KSC to determine the source.

At approximately 278:04:50 G.m.t. (04:17:34 MET), the crew reported that a tile was missing along the inboard aft edge of the port-side overhead window (W8) (Flight Problem STS-68-V-01). The fractured tile was identified as V070-390068-059. The majority of the tile appeared to be missing, with the fracture plane occurring at the densified layer. The remaining densified layer of tile material was seen in the video as a rough edge above the white folded ceramic sleeving. Video previously downlinked at 275:09:40 G.m.t. (01:22:24 MET) also showed that the tile was missing, and this downlink was almost 72 hours earlier than first reported. An analysis showed that the loss of this tile would not impact on-orbit or entry operations. The postflight analysis of this failure revealed that the tile had failed in-plane, and the strain isolation pad (SIP) and densified tile layer still remaining. This was the condition expected based on in-flight reports. No thermal degradation of the area was noted.

The largest damage site was on the right-hand OMS pod forward-facing surface and measured 5 inches by 5 inches by 2 inches. The right-hand OMS pod forward face tile was most probably damaged during ascent. Streamers were visible from the right OMS pod at approximately 36 seconds (Mach = 0.7) and they are considered evidence of debris impact. The crew downlinked video of the right OMS pod that showed two damaged tiles near the center leading edge of the pod. The analysis of the tile damage determined that the condition was not a safety-of-flight issue, and the damage did not impact the mission. The postflight inspection revealed a dime-sized burn-through of the forward-most tile's SIP, discolored graphite/epoxy, and charred filler bar. The inspections also revealed three damage sites on the upper PLBD flexible reusable surface insulation (FRSI) felt insulation. The location of the damaged areas indicates that the tile portion lost from around window 8 impacted the leading edge of the OMS pod.

The number of damage sites on the base heat shield was less than the number normally seen, and the majority of the hits were located near the center of the base heat shield. The dome-mounted heat shield closeout blankets on all three SSMEs were in excellent condition. The six toughened unipiece fibrous insulation (TUFI) tiles located on the carrier panel between engines 2 and 3 were not damaged.

The nose cap and chin panel areas were in good condition. The nose landing gear door (NLGD) thermal barriers (TB's) were in good condition with only minor fraying. Three tiles on the NLGD periphery had edge damages greater than 1 inch.

The crew reported streaking/smearing on windows W2, W3, W4, and W5. Windows 2, 3, 4, and 5 exhibited light hazing and streaks, with windows 3 and 4 showing more streaking than the other windows. The postflight assessment of the Orbiter window conditions concluded that the streaks/smearing was caused by the impact of the forward RCS thruster covers (butcher paper) during ascent.

Numerous small impact sites were noted on the perimeter tiles on windows 2, 3, 4, and 5. Seven tile damage sites, with two larger than one inch, were observed above and between windows 3 and 4.

REMOTE MANIPULATOR SYSTEM

The remote manipulator system (RMS) was not activated nor used during this mission.

FLIGHT CREW EQUIPMENT/GOVERNMENT FURNISHED EQUIPMENT

The flight crew equipment/Government furnished equipment (FCE/GFE) performed acceptably. The crew stated in the debriefing that there were no gas bubbles in the clear drink containers that were used to evaluate the galley water for gas. This Shuttle Orbiter Repackaged Galley (SORG) was the same one (S/N 1002) flown on STS-59 during which several problems were experienced with gas in the water.

Ten in-flight anomalies were written against the FCE/GFE hardware during STS-68. These are discussed in the following paragraphs.

At 273:18:06 G.m.t. (00:06:50 MET), during downlink of video from closed circuit television (CCTV) camera B, a smudge was noted in the lower right quadrant of the video image (Flight Problem STS-68-F-01). The video from this camera was usable and this problem did not impact television operations.

At 277:15:50 G.m.t. (04:04:34 MET), CCTV camera C exhibited horizontal lines in the video (Flight Problem STS-68-F-05). The image was a dark view of the Earth. When the payload bay came into light, the lines disappeared.

Video from CCTV camera D had a foggy area (Flight Problem STS-68-F-06). The area was a disc located in the center of the video image, and it gave the appearance of looking through fog.

Four Linhof camera and magazine anomalies occurred during the mission.

a. The crew reported at 275:00:30 G.m.t. (01:13:14 MET) that the Linhof camera had failed (Flight Problem STS-68-F-02). They performed the applicable malfunction procedure which included replacing the lens/body fuse. The camera function was not restored. The crew then changed the magazine and camera function was restored The film was removed from the inoperative magazine (S/N 1006) and stored. The inoperative magazine was marked and also stored.

b. The crew reported that the counter on a Linhof camera magazine (S/N 1005) had stopped working (Flight Problem STS-68-F-03); however, the camera and magazine appeared to be operating nominally when photographs were being taken.

c. The crew stated at 278:23:36 G.m.t. (05:12:20 MET) that the Linhof camera magazine S/N 1009 had a blown fuse (Flight Problem STS-68-F-07). The fuse was replaced and the magazine operated properly. The magazine subsequently blew another fuse. It was replaced and normal operation was recovered.

d. The crew reported at 283:16:59 G.m.t. (10:05:43 MET) that the Linhof power cable was providing power intermittently to the camera (Flight Problem STS-68-F-09). Postflight testing of the cable is required to resolve this problem.

At 277:15:24 G.m.t. (04:04:08 MET), the crew reported that the Hasselblad camera (S/N 1035) failed to operate (Flight Problem STS-68-F-04). The crew performed the appropriate malfunction procedure from the Photo/TV checklist and camera operation was restored by replacing a failed fuse in the camera body. The camera operated satisfactorily for the rest of the mission.

The crew reported that four of the six stereo headsets exhibited a shorted condition while in use with the portable compact disc player (Flight Problem STS-68-F-08).

The crew reported at 283:16:59 G.m.t. (10:05:43 MET) that two problems were noted with the two Nikon F4 cameras. Camera S/N 1004 had a diopter than was no longer adjustable (Flight Problem STS-68-F-10A). Camera S/N 1008 had a diopter that operated, but resistance was encountered at some point during the rotation (Flight Problem STS-68-F-10B).

CARGO INTEGRATION

The cargo integration hardware performance was nominal throughout the mission. No anomalous operation was noted or reported.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

A total of 16 Development Test Objectives (DTOs) and 15 Detailed Supplementary Objectives (DSOs) were defined for the STS-66 mission. Preliminary results are presented, where available, in the following paragraphs.

DEVELOPMENT TEST OBJECTIVES

DTO 251 - Entry Aerodynamic Control Surfaces Test - Alternate Elevon Schedule - All five programmed test inputs were performed during entry. Data have been given to the sponsor, and the results of the data analysis will be reported in separate documentation.

DTO 254 - Subsonic Aerodynamics Verification - The planned maneuvers during final descent were performed. The data from these maneuvers have been given to the sponsor. The results of the analysis will be published in separate documentation.

DTO 301D - Ascent Structural Capability Evaluation - This DTO was performed during the ascent phase of the mission. Postflight data evaluation is required as the data were recorded onboard the vehicle and the recorder cannot be dumped during flight. The data have been given to the sponsor for evaluation, and the results will be published in separate documentation.

DTO 305D - Ascent Compartment Venting Evaluation - This DTO was performed during the ascent phase of the mission. Postflight data evaluation is required as the data were recorded onboard the vehicle and the recorder cannot be dumped during flight. The data have been given to the sponsor for evaluation, and the results will be published in separate documentation.

DTO 306D - Descent Compartment Venting Evaluation - This DTO was performed during the entry phase of the mission. Postflight data evaluation is required as the data were recorded onboard the vehicle and the recorder cannot be dumped during flight. The data have been given to the sponsor for evaluation, and the results will be published in separate documentation.

DTO 307D - Entry Structural Capability - This DTO was performed during the entry phase of the mission. Postflight data evaluation is required as the data were recorded onboard the vehicle and the recorder cannot be dumped during flight. The data have been given to the sponsor for evaluation, and the results will be published in separate documentation.

DTO 312 - ET TPS Performance - Photography of the ET after separation was acquired with the Nikon camera that has a 300 mm lens and a 2X extender. Thirty-eight photographs of the ET were obtained, and the exposure and focus on all photographs were good. The first picture was taken approximately 13.7 minutes after liftoff and the last photograph was taken approximately 5 minutes later.

All aspects of the ET were imaged. The ET was in good condition. No unusual markings were observed. Four white marks (probable divots) are visible on the ET TPS:

a. A distinctive white mark is visible on the side of the ET away from the Orbiter (+Y/-Z axis) at the LH_2 tank/intertank interface;

b. A white mark is visible on the LH_2 tank TPS aft of the ground umbilical carrier plate (GUCP) (-Y axis);

c. A white mark is visible on the LH_2 tank TPS just aft of the LH_2 tank/intertank interface and in the -Y direction from the forward ET/Orbiter attach bipod; and

d. A white mark is visible on the aft third of the hydrogen tank on the -Y axis.

DTO 414 - APU Shutdown Test - The APUs were shut down in the order planned following ascent. No evidence of back-driving was noted in the data. The data from the DTO are being reviewed by the sponsor, and the results of that review and evaluation will be reported in separate documentation.

DTO 521 - Orbiter Drag Chute System - All activities required in test condition 4 were completed. As a result, this phase of the DTO was completed. The data are being evaluated and the results will be reported in separate documentation.

DTO 656 - Payload and General Support Computer (PGSC) Single Event Upset Monitoring - All activities planned for this DTO were completed. The data from the DTO are being reviewed by the sponsor and the results of that evaluation will be reported in separate documentation.

DTO 664 - Cabin Temperature Survey - All temperature measurements were made by the crew and the data have been given to the sponsor for evaluation. The results of that evaluation will be reported in separate documentation.

DTO 674 - Thermo-Electric Liquid Cooling System Evaluation - The activities scheduled dunng ascent and descent were performed. The data have been given to the sponsor for evaluation. The results of that evaluation will be reported in separate documentation.

DTO 700-8 - Global Positioning System Development Flight Test - The DTO hardware performed nominally throughout the mission. System re-initialization commands were required to reset the hardware because of a known software problem which is being corrected for all future flights. The data from this DTO have been given to the sponsor and the results of that evaluation will be reported in separate documentation.

DTO-805 - Crosswind Landing Performance - Conditions to satisfy this DTO were not present; consequently, this DTO was not performed.

DTO 1119 - Orbiter Evaluation of Reduced MILA S-Band Uplink Power During Ascent (500 W) - All activities in support of this DTO were completed and the data were collected and given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DETAILED SUPPLEMENTARY OBJECTIVES

DSO 317 - Collection of Shuttle Humidity Condensate for Analytical Evaluation - Three samples of condensate were collected as planned. These samples have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DSO 326 - Window Impact Observations - The windows were inspected daily and a status report was given to the Mission Control. These reports were given to the sponsor along with data from a detailed postflight inspection. The data will be evaluated and the results of the evaluation will be reported in separate documentation.

DSO 484 - Assessment of Circadian Shifting in Astronauts by Bright Light - All planned activities were scheduled and completed. The results of the activities were given to the sponsor, and the evaluation of the results will be reported in separate documentation.

DSO 487 - Immunological Assessment of Crewmembers - All planned activities were scheduled and completed. The data have been given to the sponsor for evaluation, and the results of the evaluation will be reported in separate documentation.

DSO 491 - Characterization of Microbial Transfer Among Crewmembers During Space Flight - All planned activities were scheduled and completed. The data have been given to the sponsor for evaluation, and the results of the evaluation will be reported in separate documentation.

DSO 603B - Orthostatic Function During Entry, Landing and Egress - All planned activities were completed during entry, landing and egress. The data were given to the sponsor for evaluation, and the results of the evaluation will be reported in separate documentation.

DSO 604 - Visual-Vestibular Integration as a Function of Adaptation - All planned activities were scheduled and completed. The data have been given to the sponsor for evaluation, and the results of the evaluation will be reported in separate documentation.

DSO 605 - Postural Equilibrium Control During Landing/Egress - All planned activities were completed during landing and egress. The data were given to the sponsor for evaluation, and the results of the evaluation will be reported in separate documentation.

DSO 614B - The Effect of Prolonged Space Flight on Head and Gaze Stability During Locomotion - All planned activities were scheduled and completed. The data have been given to the sponsor for evaluation, and the results of the evaluation will be reported in separate documentation.

DSO 621 - In-Flight Use of Florinef to Improve Orthostatic Intolerance Postflight- All planned activities were scheduled and completed. The data have been given to the sponsor for evaluation, and the results of the evaluation will be reported in separate documentation.

DSO 624 - Preflight and Postflight Measurement of Cardiorespiratory Responses to Submaximal Exercise - Exercise-activity measurements as well as preflight and postflight testing were scheduled throughout the flight and these were completed. Data were collected for the sponsor's 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 - All planned preflight and postflight activities were completed. The data have been given to the sponsor for evaluation, and the results of the evaluation will be reported in separate documentation.

DSO 901 - Documentary Television - Video was taken throughout the mission and the downlinks as well as the onboard tapes have been given to the sponsor for evaluation. The results of that analysis will be presented in separate documentation.

DSO 902 - Documentary Motion Picture Photography - Motion pictures were taken throughout the mission. The films have been given to the sponsor for evaluation, and the results of that analysis will be reported in separate documentation

DSO 903 - Documentary Still Photography - Still photographs were taken throughout the mission. The film has been given to the sponsor for evaluation, and the results of that evaluation will be reported in separate documentation.

PHOTOGRAPHY AND TELEVISION ANALYSIS

LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS

The STS-68 mission was launched from Complex 39 A on October 11, 1994. On launch day, 22 videos of the launch activities were reviewed, and no anomalies were found. On the days following the launch, 53 of 54 planned films were reviewed. One camera did not run properly and the film was not of use for evaluation. Several films were rescreened in an effort to find events that related to the damage to the right OMS pod and the smears on the forward windows. No definitive evidence of the debris causing the damage was found.

In addition, 38 images of the ET after separation were obtained by the crew in support of DTO 312. The results of the analysis of those frames are presented in the Development Test Objectives section of this report.

Three rolls of STS-68 umbilical well camera film were evaluated at JSC, and these consisted of one roll of 35mm from the LO_2 umbilical camera and two rolls of 16mm from the LH_2 umbilical well. The 35mm film had good exposure and focus on the sun-lit portions of the ET (LO_2 umbilical and +Y side of ET were in shadow). The 16mm films also have good exposure and good focus. The ET separation sequence from the 16mm films had variable exposure and good focus. Timing data were not present on the 35mm film, but it was present on the 16mm films. The analysis revealed no anomalies in any of the films.

ON-ORBIT PHOTOGRAPHY AND VIDEO ANALYSIS

The crew downlinked video of the right OMS pod that showed two damaged tiles near the center leading edge of the pod. The analysis of the tile damage determined that the condition was not a safety-of-flight issue, and the damage did not impact the mission.

A tile was missing along the inboard aft edge of the port-side overhead window (W8) (Flight Problem STS-68-V-01). The fractured tile was identified as V070-390068-059. The majority of the tile appeared to be missing with the fracture plane occurring at the densified layer. The remaining densified layer of tile material was seen in the video as a rough edge above the white folded ceramic sleeving. The video review showed that the tile was missing in video downlinked at 275:09:40 G.m.t. (01:22:24 MET), which was almost 72 hours earlier than first reported. An analysis showed that the loss of this tile would not impact on-orbit or entry operations.

LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSIS

Landing occurred on concrete runway 22 at Edwards Air Force Base on October 11, 1994. Six videos of the Orbiter's approach and landing phase were reviewed, and no anomalies were detected. In addition 15 landing films were reviewed, and these, likewise, did not show any anomalies.

TABLE I.- STS-68 MISSION EVENTS

Event	Description	Actual time, G.m.t.
	Launch Abort	
APU Activation	APU-1 GG chamber pressure	230:10:49:10.65
	APU-2 GG chamber pressure	230:10:49:11.83
	APU-3 GG chamber pressure	230:10:49:12.60
SRB HPU Activation[a]	LH HPU System A start command	230:10:53:32.170
	LH HPU System B start command	230:10:53:32.290
	RH HPU System A start command	230:10:53.32.450
	RH HPU System B start command	230:10:53:32.610
Main Propulsion System Start[a]	ME-3 Start command accepted	230:10:53:53.437
	ME-2 Start command accepted	230:10:53:53.558
	ME-1 Start command accepted	230:10:53:53.679
Main Propulsion System Stop[a]	ME-3 Shutdown	230:10:53:58.157
	ME-2 Shutdown	230:10:53:59.358
	ME-1 Shutdown	230:10:54:00.638
APU Deactivation	APU-1 GG chamber pressure	230:10:55:04.06
	APU-2 GG chamber pressure	230:10:55:04.81
	APU-3 GG chamber pressure	230:10:55:06.04
	Launch	
APU Activation	APU-1 GG chamber pressure	273:11:11:11.33
	APU-2 GG chamber pressure	273:11:11:12.18
	APU-3 GG chamber pressure	273:11:11:12.99
SRB HPU Activation[a]	LH HPU System A start command	273:11:15:32.621
	LH HPU System B start command	273:11:15:32.781
	RH HPU System A start command	273:11:15.32.621
	RH HPU System B start command	273:11:15:32.781
Main Propulsion System Start[a]	ME-3 Start command accepted	273:11:15:53.459
	ME-2 Start command accepted	273:11:15:53.549
	ME-1 Start command accepted	273:11:15:53.682
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	273:11:16:00.011
Throttle up to 104 Percent Thrust[a]	ME-1 Command accepted	273:11:16:03.803
	ME-3 Command accepted	273:11:16:03.819
	ME-2 Command accepted	273:11:16:03.825
Throttle down to 67 Percent Thrust[a]	ME-1 Command accepted	273:11:16:27.323
	ME-3 Command accepted	273:11:16:27.340
	ME-2 Command accepted	273:11:16:27.346
Maximum Dynamic Pressure (q)	Derived ascent dynamic pressure	273:11:16:51
Throttle up to 104 Percent[a]	ME-1 Command accepted	273:11:17:00.444
	ME-3 Command accepted	273:11:17:00.461
	ME-2 Command accepted	273:11:17:00.466
Both SRM's Chamber Pressure at 50 psi[a]	RH SRM chamber pressure mid-range select	273:11:17:58.531
	LH SRM chamber pressure mid-range select	273:11:17:58.571

[a]MSFC supplied data

TABLE I.- STS-68 MISSION EVENTS (Continued)

Event	Description	Actual time, G.m.t.
End SRM[a] Action[a]	RH SRM chamber pressure mid-range select	273:11:18:00.751
	LH SRM chamber pressure mid-range select	273:11:18:00.801
SRB Physical Separation[a]	LH rate APU turbine speed - LOS	273:11:18:03.491
	RH rate APU turbine speed - LOS	273:11:18:03.491
SRB Separation Command	SRB separation command flag	273:11:18:04
Throttle Down for 3g Acceleration[a]	ME-1 command accepted	273:11:23:30.374
	ME-3 command accepted	273:11:23:30.389
	ME-2 command accepted	273:11:23:30.394
3g Acceleration	Total load factor	273:11:23:30.2
Throttle Down to 67 Percent Thrust[a]	ME-1 command accepted	273:11:24:27.015
	ME-3 command accepted	273:11:24:27.031
	ME-2 command accepted	273:11:24:27.035
SSME Shutdown[a]	ME-1 command accepted	273:11:24:33.415
	ME-3 command accepted	273:11:24:33.431
	ME-2 command accepted	273:11:24:33.435
MECO	MECO command flag	273:11:24:34
	MECO confirm flag	273:11:24:35
ET Separation	ET separation command flag	273:11:24:54
APU Deactivation	APU-2 GG chamber pressure	273:11:29:55.80
	APU 1 GG chamber pressure	273:11:30:10.57
	APU 3 GG chamber pressure	273:11:30:25.07
OMS-1 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Not performed - direct insertion trajectory flown
OMS-1 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	
OMS-2 Ignition	Left engine bi-prop valve position	273:11:51:09.9
	Right engine bi-prop valve position	273:11:51:10.0
OMS-2 Cutoff	Left engine bi-prop valve position	273:11:52:48.2
	Right engine bi-prop valve position	273:11:52:48.2
Payload Bay Doors (PLBDs) Open	PLBD right open 1	273:12:48:24
	PLBD left open 1	273:12:49:44
Flight Control System Checkout		
APU Start	APU-1 GG chamber pressure	283:12:08:21.81
APU Stop	APU-1 GG chamber pressure	283:12:12:38.39
Payload Bay Doors Close	PLBD left close 1	284:12:03:41
	PLBD right close 1	284:12:06:13
APU Activation for Entry	APU-2 GG chamber pressure	284:16:02:23.71
	APU-1 GG chamber pressure	284:16:16:59.54
	APU-3 GG chamber pressure	284:16:17:01.90
Deorbit Burn Ignition	Left engine bi-prop valve position	284:16:07:19.3
	Right engine bi-prop valve position	284:16:07:19.3
Deorbit Burn Cutoff	Left engine bi-prop valve position	284:16:09:38.0
	Right engine bi-prop valve position	284:16:09:38.0

[a] MSFC supplied data.

TABLE I.- STS-68 MISSION EVENTS
(Continued)

Event	Description	Actual time, G.m.t.
Entry Interface (400K feet)	Current orbital altitude above	284:16:29:46
Blackout end	Data locked (high sample rate)	No blackout
Terminal Area Energy	Major mode change (305)	284:16:56:02
Main Landing Gear Contact	LH main landing gear tire pressure 1 RH main landing gear tire pressure 2	284:17:02:08 284:17:02:08
Main Landing Gear Weight on Wheels	LH main landing gear weight on wheels RH main landing gear weight on wheels	284:17:02:08 284:17:02:09
Drag Chute Deployment	Drag chute deploy 1 CP Volts	284:17:02:10 6
Nose Landing Gear Contact	NLG LH tire pressure 1	284:17:02:21
Nose Landing Gear Weight On Wheels	NLG weight on wheels 1	284:17:02:21
Drag Chute Jettison	Drag chute jettison 1 CP Volts	284:17:02:45.3
Wheel Stop	Velocity with respect to runway	284:17:03:10
APU Deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	284:17:16:52.06 284:17:16:55.97 284:17:16:57.64

TABLE II.- ORBITER PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-68-V-01	Missing Tile Along Aft Edge of Port Overhead Window	278:04:50 G.m.t. 04:17:34 MET CAR 68RF08	At approximately 278:04:50 G.m.t. (04:17:34 MET), the crew reported that a tile was missing along the inboard aft edge of the port side overhead window (W8). Video showed the remaining densified layer of tile material as a rough edge above the white folded ceramic sleeving. There were no on-orbit or entry thermal concerns. (Video downlinked at 275:09:40 G.m.t. shows the tile missing.) Visual inspection at Dryden Flight Research Center (DFRC) verified that the densified layer of the tile was intact. There is no evidence of over-temperature of the structure. Remaining damaged tile material to be removed and shipped to Rockwell/Downey for evaluation.
STS-68-V-02	RCS Vernier Thruster L5D Oxidizer Temperature Erratic.	278:17:59 G.m.t. 05:06:43 MET CAR 684RF01 IPR 67V-0005	At 278:17:59 G.m.t. (05:06:43 MET), the left aft RCS thruster L5D oxidizer injector temperature became erratic. A fuel leak message was annunciated, and the thruster was deselected by the redundancy management (RM). A GMEM was applied which lowered the oxidizer leak detection temperature of the vernier thrusters to 0 °F, with the fuel leak detection temperature remaining at 130 °F. Data analysis showed that the data signature was typical of a sensor or wiring problem, most likely between the sensor and the dedicated signal conditioner (DSC). The thruster continued to function nominally. KSC: Troubleshoot to isolate the cause of the anomaly. Spare is available.
STS-68-V-03	Primary RCS Thruster L3D Failed Off	279:05:00 G.m.t. 05:17:44 MET CAR 68RF02	At 279:05:00 G.m.t. (05:17:44 MET), primary RCS thruster L3D failed off after operating successfully for numerous pulses. The RCS RM annunciated a fail-off condition when three consecutive 80 msec firings had chamber pressures of less than 10 psia. There was no indication of a leak, and the thruster remained selected for the remainder of the mission. KSC: Remove and replace thruster. The thruster will be sent to White Sands Test Facility for failure investigation. Spare is available.
STS-68-V-04	Master Timing Unit (MTU) Accumulator 3 Element Bypass	279:13:05 G.m.t. 06:01:49 MET IPR 67V-0008 CAR 68RF09	A BCE STRG 3 MTU message was annunciated at 279:13:05 G.m.t. (06:01:49 MET). An input/output (I/O) reset and string 3 port mode were performed in an unsuccessful attempt to clear the problem. The MTU BITE word did not indicate any MTU problems. A BITE test and BSR read of MDM FF3 did not indicate a problem. KSC: Troubleshooting isolated the problem to the MTU. MTU will be replaced with available spare.

TABLE II.- ORBITER PROBLEM TRACKING LIST

STS-68-V-05	FES Accumulator/Hi-Load Feedline A Heater 2 Erratic Operation Level III Closure	278:15:15 G.m.t. 05:03:59 MET CAR 68Rf10	After the FES feedline heater reconfiguration to heater system 2 at 278:15:15 G.m.t. (05:03:59 MET), the FES feedline A high-load line temperature went off-scale high (> 250 °F) for nearly eight hours. The FES feedline A accumulator line temperature measurement has been experiencing erratic cycling during the off-scale high periods and has maintained temperatures above the nominal thermostat control band. The crew switched back to heater system 1 at 280:04:14 G.m.t. (06:16:58 MET) and all temperature conditions became nominal. KSC: Troubleshoot to determine cause of erratic cycling. Vehicle ferried with heater system 1 activated.
STS-68-V-06	Water Spray Boiler System 2 GN_2 Regulator Leak	272:22:39 G.m.t. Prelaunch HYD-5-08-0186 CAR 68RF03	The water spray boiler (WSB) system 2 GN_2 regulator had two internal out-of-specification leakages when the isolation valves were opened during the prelaunch time-frame. The first regulator leakage was about 42 sccm (redline limit is 10 sccm) over a 26-minute period following the first isolation valve opening. The second leakage was 73 sccm over a 28-minute period just prior to launch. On-orbit, the isolation valves were closed in accordance with nominal procedures to decrease the sensitivity of the GN_2 tanks to internal regulator leakage. A 22-sccm leak rate was observed when the GN_2 isolation valve was opened for entry. KSC: Remove and replace the regulator.
STS-68-V-07	Water Spray Boiler 1 GN_2 Regulator Pressure Decay	273:14:35 G.m.t. 00:03:19 MET HYD-5-08-0185 CAR 68RF04	The WSB 1 GN_2 regulator pressure began to decay following WSB deactivation after ascent. The slow decay in pressure continued throughout the mission and by entry day the pressure had decayed to 16.8 psia. The pressure decay is believed to be due to GN_2 leakage through the regulator relief valve. KSC: Removed and replaced the regulator.
STS-68-V-08	Degraded Tracks on Payload Recorder Level III Closure	283:16:31 G.m.t. 10.05.15 MET	Dunng playbacks of the Applied Physics Laboratory (APL) data on the payload recorder, degraded data quality was experienced from the 68-percent to the 100-percent tape position of track 2, from the 29-percent to 68-percent on track 3, and 84-percent ot 100-percent on track 4. The APL data were on Ku-band channel 2 and SRL high-rate data were on Ku-band channel 3 during parts of these dumps. In-flight troubleshooting was performed using different tape directions (forward and reverse) and dump ratios (1 to 1 and 16 to 1). Tracks 2, 3, and 4 were not used the remainder of the mission. Tracks 1 and 5-14 were still available. KSC: Troubleshoot payload recorder.

TABLE II.- ORBITER PROBLEM TRACKING LIST

STS-68-V-09	Ku-band Range Rate/Azimuth Display Tens Digit Failed Level III Closure	283:16:31 G.m.t. 10:05:15 MET CAR 68RF05	At approximately 283:16:31 G.m.t. (10:05:15 MET), the crew reported that on panel A2, the tens digit of the Ku-band range rate/azimuth display was malfunctioning. Only the upper left LED was illuminated. When the lamp test was performed, all LEDs illuminated. The fault lamp is on all the time (even during the lamp test). The cr ew used Spec 21 for Ku-band stowing. KSC: Troubleshooting repeated the problem (additional digits failed). Additional troubleshooting planned. Potential digital display replacement with available spare.
STS-68-V-10	WSB System 3 Leak	Postlanding IPR 67V-0006 HYD-5-08-0187 CAR 68RF06	Shortly after APU 3 shutdown after landing, WSB 3 regulator outlet pressure started a rapid decay in pressure. The pressure dropped from approximately 38.1 psia to 19.8 psia in just over one hour. This WSB system was stable throughout the entire mission. A water leak was observed coming from the ET umbilical doors and centerline hinge while the Orbiter was still on the runway. It has been verified that the water came from WSB 3. The WSB was inspected at Dryden Flight Research Center and the source of the leak was found to be a crack on the lube oil spray valve inlet stem between the valve body and B-nut.
STS-68-V-11	Slow Pressure Increase During Rudder Channel 3 Secondary Actuator Check	283:12:10 G.m.t. 10:00:54 MET IPR 67V-0010 CAR 68RF07	At 283:12:10 G.m.t. (10:00:54 MET), the rudder channel 3 secondary differential pressure required approximately 1.96 seconds to increase to the failure detection level during the positive stimulus portion of the secondary actuator check in the FCS checkout procedure. The channel bypassed nominally during the negative stimulus portion of the test. A delay of 1.44 seconds was noted on OV-105s previous flight (STS-59). Data review also shows that the delay occurred on STS-57 (less than 1 second), STS-54 (less than 0.25 second) and STS-49 (less than 0.15 second. There were no delays apparent on STS-47 and STS-61. KSC: Troubleshooting and data review indicate channel 3 sluggish. The rudder speedbrake PDU will be replaced with available spare.
STS-68-V-12	Operations (OPS) Recorder 2 Track 8 Failed to Dump Level III Closure	Postlanding CAR 68RF11	During postlanding OPS recorder dump operations, OPS 2 track 8 would not dump in either the forward or reverse directions. The site indication was a carrier signal with no modulation. All other tracks dumped (4 through 7 and 9 and 10). KSC: Troubleshooting verified a bad track 8. OPS recorder will be removed and replaced.

TABLE III.- GOVERNMENT FURNISHED EQUIPMENT PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-68-F-01	Smudge on Camera B Lens	274:01:27 G.m.t. 000:14:11 MET	During downlink of camera B, a smudge was noted in the lower right quadrant of the video image.
STS-68-F-02	Linhof Camera Magazine (s/n 1006) Failure	275:01:00 G.m.t. 001:13:44 MET	The crew reported that a Linhof camera had failed. The camera fuse was replaced, but normal camera operation was not restored. Subsequently, the magazine was replaced, and normal camera operation was regained. The inoperative magazine (S/N 1006) was marked and stowed.
STS-68-F-03	Linhof Camera Magazine (s/n 1005) Counter Inoperative	276:21:13 G.m.t. 003:09:57 MET	The crew stated that the counter on a Linhoff camera magazine (S/N 1005) had stopped working; however, the camera and magazine appeared to be operating nominally because ht supply reel of the magazine spins with the snapshots.
STS-68-F-04	Hasselblad Camera Failure	277:15:24 G.m.t. 004:04:08 MET	At 277:15:24 G.m.t. (04:04:08 MET), the crew reported that the Hasselblad camera (S/N 1035) failed to operate. The crew performed malfunction procedure 3.1a from the Photo/TV checklist and camera operation was recovered by replacing a failed fuse in the camera body. The camera continued to operate nominally.
STS-68-F-05	CCTV Camera C Horizontal Lines in Video	277:15:50 G.m.t. 004:04:34 MET	At 277:15:50 G.m.t. (04:04:34 MET), CCTV camera C had horizontal lines in the video. The image was a dark view of the Earth and payload baya. When the payload bay came into light, the lines disappeared.

TABLE III.- GOVERNMENT FURNISHED EQUIPMENT PROBLEM TRACKING LIST

STS-68-F-06	CTVC D Foggy Area in Image	278:01:29 G.m.t. 004:14:13 MET	A "foggy " area was noted in the CTVC D video. The area is a disk located in the center of the video image and gives the appearance of looking through fog.
STS-68-F-07	Linhof Camera Magazine (S/N 1009) Blown Fuses	277:03:03 G.m.t. 003:15:47 MET	The crew stated that the Linhof camera magazine (S/N 1009) blew a fuse at 277:03:03 G.m.t. (03:15:47 MET), and that the bad fuse light was illuminated. The fuse was replaced and the magazine functioned nominally. At 278:19:35 G.m.t. (05:08:19 MET), the crew reported another blown fuse in the magazine. The fuse was replace and the magazine functioned normally.
STS-68-F-08	Stereo Headset Intermittent Problem	283:16:59 G.m.t. 010:05:43 MET	The crew reported that multiple headsets (the number was not specified) suffered from an intermittent short while in use with the Discman.
STS-68-F-09	Linhof Camera Power Cable Problem	283:16:59 G.m.t. 010:05:43 MET	The crew reported that a Linhof camera power cable was providing power intermittently to the camera.
STS-68-F-10	Nikon F4 Diopter Failures	283:16:59 G.m.t. 010:05:43 MET	The crew reported the following problems with two Nikon cameras. S/N 1004 has a diopter that is no longer adjustable. S/N 1008 has a diopter that encounters resistance at some point during rotation.

TABLE IV.- MSFC PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-68-E-01	Main Engine 3 Exceeded High Pressure Oxidizer Turbine Discharge Temperature LCC	Launch Abort	Main engine 3 exceeding the high pressure oxidizer turbine discharge temperature was the cause of the pad abort.
STS-68-E-02	Cracked Sheet in Turnaround Duct in Turbine Discharge of High Pressure Fuel Turbopump (U/N 4113R2)	Launch Abort Inspection	The pad-abort inspection revealed a crack in the turbine discharge sheet metal turnaround duct. This crack was 4.6 inches long with cracks running 90 degrees to the long crack making a flap. The flap was resting on the coolant liner.-

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.

ADTA	air data transducer assembly
APL	Applied Physics Laboratory
APU	auxiliary power unit
ARS	atmospheric revitalization system
ATCS	active thermal control system
BFS	backup flight system
BITE	built-in test equipment
BRIC	Biological Research in Canisters
BSR	BITE status read
CCTV	closed circuit television
CEI	Contract End item
CHROMEX	Chromosome and Plant Cell Division in Space
CPCG	Commercial Protein Crystal Growth
CREAM	Cosmic Radiation Effects and Activation Monitor
CRIM	Commercial Refrigerator/Incubator Module
CRT	cathode ray tube
DEEM	digital elevation map
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
ΔV	differential velocity
ECLSS	Environmental control and life support system
EGT	exhaust gas temperature
EPDC	electrical power distribution and control subsystem
ESC	engine start command
ET	External Tank
EVA	extravehicular activity
FCE	flight crew equipment
FCL	Freon coolant loop
FCP	fuel cell powerplant
FCS	flight control system
FDA	fault detection and annunciation
FES	flash evaporator system
FF	flight critical forward
FID	Failure Identification
FRSI	flexible reusable surface insulation
ft/sec	feet per second
GAS	Getaway Special
GFE	Government furnished equipment
GMEM	general purpose computer memory
G.m.t.	Greenwich mean time
GN_2	gaseous nitrogen
GO_2	gaseous oxygen
GPC	general purpose computer

GUCP	ground umbilical carrier plate
HAINS	high accuracy inertial navigation system
HPFTP	high pressure fuel turbopump
HPOT	high pressure oxidizer turbine
HPOTP	high pressure oxidizer turbopump
IMU	inertial measurement unit
I/O	input/output
Isp	specific impulse
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt hour
LCC	Launch Commit Criteria
LED	light emitting diode
LESC	Lockheed Engineering and Science Company
LH_2	liquid hydrogen
LO_2	liquid oxygen
MAPS	Measurement of Air Pollution from Satellite
MAST	Military Application of Ship Tracks Experiment
MCC	Mission Control Center/main combustion chamber
MDM	multiplexer/demultiplexer
MECO	main engine cutoff
MET	mission elapsed time
MILA	Merit Island Launch Area
MMT	Mission Management Team
MPS	main propulsion system
MSBLS	microwave scanning beam landing system
MSFC	Marshall Space Flight Center
MTU	master timing unit
NASA	National Aeronautics and Space Administration
NGT	NASA Ground Terminal
NLGD	nose landing gear door
nmi.	nautical mile
NPSP	net positive suction pressure
NSLD	NASA Shuttle Logistics Depot
NSTS	National Space Transportation System (i.e., Space Shuttle Program)
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OPS	operations
PAL	protuberance air load
PASS	primary avionics software system
PCA	power control assembly
PGSC	payload and ground support computer
PHRR	Payload High Rate Recorder
PLBD	payload bay door
PMBT	propellant mean bulk temperature
PRSD	power reactant storage and distribution
PTI	programmed test input

RCS	reaction control subsystem
RM	redundancy management
RMS	remote manipulator system
RSRM	Redesigned Solid Rocket Motor
RSS	range safety system
S&A	safe and arm
SAR	Synthetic Aperture Radar
SIP	strain isolation pad
SIR-C	Spaceborne Imaging Radar
S/N	serial number
SORG	Shuttle Orbiter Repackaged Galley
SRB	Solid Rocket Booster
SRL-2	Space Radar Laboratory-2
SRSS	Shuttle range safety system
SSME	Space Shuttle main engine
TACAN	Tactical Air Navigation
TB's	thermal barriers
TDRS	Tracking and Data Relay Satellite
TPS	thermal protection subsystem
TUFI	toughened unipiece surface insulation
VAB`	Vehicle Assembly Building
WCS	Waste collection system
WOW	weight on wheels
WSB	water spray boiler
WSGT	White Sands Ground Terminal
X-SAR	X-band Synthetic Aperture Radar

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