NSTS-37402

N/1 A
IN-16

STS-69 SPACE SHUTTLE MISSION REPORT

December 1995

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

NOTE

The STS-69 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.

Bobbie Gail Swan, JSC 713-483-2528	Orbiter and subsystems
George Harsh, MSFC 205-544-4827	MSFC Elements (SRB, RSRM, SSME, ET, SRSS, and MPS)
A. Y. Ong, JSC 713-483-1143	Payloads/Experiments
M. Albjerg, JSC 713-483-4878	DTOs and DSOs
F. T. Burns, Jr., JSC 713-483-1262	FCE and GFE

NSTS 37402

STS-69

SPACE SHUTTLE

MISSION REPORT

Prepared by

Robert W. Fricke, Jr.
LMES/Flight Engineering and Vehicle Management Office

Approved by

Bobbie Gail Swan
STS-69 Lead Mission Evaluation Room Manager

David W. Camp
Manager, Flight Engineering and Vehicle Management Office

Jay H. Greene
Manager, Orbiter Project

Tommy W. Holloway
Space Shuttle Program Manager

Prepared by
Lockheed Martin Engineering and Sciences
for
Flight Engineering and Vehicle Management Office

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

December 1995

STS-69 Table of Contents

Title	Page

STS-69 Table of Contents

Title | Page

List of Tables

Appendixes

INTRODUCTION

The STS-69 Space Shuttle Program Mission Report summarizes the Payload activities as well as the Orbiter, External Tank (ET), Solid Rocket Booster (SRB), Reusable Solid Rocket Motor (RSRM), and the Space Shuttle main engine (SSME) systems performance during the seventy-first flight of the Space Shuttle Program, the forty-sixth flight since the return-to-flight, and the ninth flight of the Orbiter Endeavour (OV-105). In addition to the Orbiter, the flight vehicle consisted of an ET that was designated ET-72; three SSMEs that were designated as serial numbers 2035, 2109, and 2029 in positions 1, 2, and 3, respectively; and two SRBs that were designated BI-074. The RSRMs, designated RSRM-44, were installed in each SRB and the individual RSRMs were designated as 360L048A for the left SRB, and 360W048B for the right SRB.

The STS-69 Space Shuttle Program Mission Report fulfills the Space Shuttle Program requirement as documented in NSTS 07700, Volume VII, Appendix E. The requirement stated in that document is that each organizational element supporting the Program will report the results of their hardware (and software) evaluation and mission performance plus identify all related in-flight anomalies.

The primary objectives of this flight were to perform the operations necessary to fulfill the requirements of Wake Shield Facility (WSF), and SPARTAN-201. The secondary objectives of this flight were to perform the operation of the International Extreme Ultraviolet Hitchhiker (IEH-1), the Capillary Pumped Loop-2/GAS Bridge Assembly (CAPL-2/GBA), Thermal Energy Storage (TES), Auroral Photography Experiment-B (APE-B) and the Extravehicular Activity (EVA) Development Flight Test 02 (EDFT-02), the Biological Research in Canister (BRIC) payload, the Commercial Generic Bioprocessing Apparatus (CGBA) payload, the Electrolysis Performance Improvement Concept Study (EPICS) payload, the Space Tissue Loss/National Institutes of Health-Cells (STL/NIH-C) payload, and the Commercial Middeck Instrumentation Technology Associates Experiment (CMIX).

The STS-69 mission was planned as an 11-day flight plus 2 contingency days, which were available for weather avoidance or Orbiter contingency operations. The sequence of events for the STS-69 mission is shown in Table I, and the Orbiter Project Office Problem Tracking List is shown in Table II. The Government Furnished Equipment/Flight Crew Equipment (GFE/FCE) Problem Tracking List is shown in Table III. Appendix A lists the sources of data, both formal and informal, that were used to prepare this report. Appendix B provides the definition of acronyms and abbreviations used throughout the report. All times during the flight are given in Greenwich mean time (G.m.t.) and mission elapsed time (MET).

The five-person crew for STS-69 consisted of David M. Walker, Capt., U. S. Navy, Commander; Kenneth D. Cockrell, Civilian, Pilot; James S. Voss, Col. (Selectee) U. S. Army, Mission Specialist 1; Jim Newman, Ph.D., Civilian, Mission Specialist 2; and Michael L. Gernhardt, Ph. D., Civilian, Mission Specialist 3. STS-69 was the fourth space flight for the Commander, the third space flight for Mission Specialist 1, the second space flight for the Pilot and Mission Specialist 2, and the first space flight for Mission Specialist 3.

MISSION SUMMARY

The initial attempt to launch the STS-69 mission was scheduled for August 3, 1995, but it was rescheduled to repair the SRB nozzle. The second attempt to launch STS-69 was scrubbed on August 31, 1995, during the 6-hour hold prior to propellant loading because of a fuel cell 2 anomaly. The condenser exit temperature for fuel cell 2 continued to increase above the set point during start-up. The fuel cell was shut down and restarted, but it exhibited the same anomaly. Consequently, the launch was scrubbed, and fuel cell 2 was replaced. This resulted in a one-week delay of the launch.

The flight of STS-69 began with an on-time liftoff from KSC Launch Complex 39 Pad A at 250:15:08:59.995 G.m.t. (September 7, 1995). The ascent phase vehicle operations were nominal as was the trajectory and all other aspects of ascent.

Performance of the SSMEs, ET, and main propulsion system (MPS) was normal. 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 successfully recovered.

Following the S-band system handover from the Bermuda ground station to the Tracking and Data Relay Satellite (TDRS) East after main engine cutoff (MECO), the S-band forward-link signal strength was weaker than normal (Flight Problem STS-69-V-03). This resulted in frequent forward-link dropouts which continued through several antenna changes as well as when TDRS West was used. The S-band system was operating on string 2 at the time of the dropouts. S-band preamplilfier 1 was selected and the signal strength increased. This configuration was used for the remainder of the mission except when S-band tests with string 2 were being performed.

Ascent WSB performance was nominal, with no overcools or undercools on any of the three WSB systems. This is the first flight in which the WSB electric-heater modification has been connected. The heater modification, along with the Portable Data Acquisition Package (PDAP), was connected on system 3. All three WSB core preloads were 3.75 lb.

At approximately 250:18:36 G.m.t. (00:03:27 MET), the crew reported that CRT 1 was so dim that it was hard to read and was unusable in sunlight, and the condition had existed since the prelaunch timeframe (Flight Problem STS-69-V-02). All inputs made through the CRT functioned nominally. The

CRT was powered off. Troubleshooting tests performed on flight day 3 were unsuccessful in brightening the screen.

At 251:00:56 G.m.t. (000:09:47 MET), a Ku-Band bus control element (BCE) bypass fault occurred (Flight Problem STS-69-V-01). The fault signifies that the antenna management software did not receive a response from the Ku-Band system on two consecutive pollings. Another I/O reset was performed, and the Ku-Band system began functioning normally. This signature did not repeat throughout the remainder of the mission.

The RMS was powered up at 251:14:39:27 G.m.t. (00:23:30:27 MET) in preparation for the SPARTAN deployment. The RMS grappled and unberthed the payload, and the SPARTAN was successfully released at 251:15:42:58 G.m.t. (01:00:33:59 MET).

The RMS successfully captured the SPARTAN 201 at 253:15:02:22 G.m.t. (02:23:52:22 MET). Berthing of SPARTAN 201 was completed at 253:15:21:17 G.m.t. (03:00:13:17 MET). At 253:20:13:03 G.m.t. (03:05:04:03 MET), the RMS grappled the Wake Shield Facility (WSF) in the payload bay. The RMS remained grappled to the WSF until the WSF was released at approximately 254:11:25:06 G.m.t. (03:20:16:06 MET).

The Mission Management Team decided to delay the rendezvous and retrieval of the WSF approximately 24 hours to allow additional time to perform the associated WSF experiments.

At 257:16:29 G.m.t. (07:01:20 MET), the cabin pressure was lowered from 14.6 psia to 10.5 psia in support of the EVA on flight day 10. The depressurization was accomplished in 22 minutes. The cabin pressure was allowed to decrease over the next six hours to the desired pressure of 10.2 psia.

The rendezvous with the WSF was completed satisfactorily, and the WSF was captured at 257:13:59:11 G.m.t. (06:22:50:11 MET). The RMS operated satisfactorily throughout the WSF grappling and berthing activities, which were completed at 257:15:16:28 G.m.t (07:00:07:28 MET). The WSF was grappled and unberthed at 258:07:17 G.m.t. (07:16:08 MET), and the payload was placed in the Charge Hazards and Wake Studies (CHAWS) position. While the WSF was on the RMS, a number of experiments were completed, after which the WSF was berthed in the payload bay.

A simultaneous supply/waste dump was initiated at 258:16:49 G.m.t. (08:01:40 MET). The supply water dump was terminated at 258:18:00 G.m.t. (08:02:51 MET) reducing the supply quantity from 515 lb to 353 lb. The waste water dump was started at 258:16:59 G.m.t. (08:01:50 MET). At 258:17:12 G.m.t. (08:02:03 MET), the crew was instructed to terminate the waste dump because the flow rate decreased from 2.0 percent/minute to 0.11 percent/minute (Flight Problem STS-69-V-04). The waste nozzles were reheated to 250 °F, and a second attempt to dump waste was begun at 258:17:24 G.m.t. (08:02:15 MET). About 3 minutes later, the second attempt was terminated because of an upcoming loss of signal (LOS). At 258:17:56 G.m.t. (08:02:47 MET), the third attempt to continue the dump was started but was terminated about 5 minutes into the dump when it was observed that the dump rate was only 0.29 percent/minute. The total waste water dumped for the three attempts was 28.6 lb leaving the waste tank quantity at 62.8 percent. A purge of the nozzle was performed at 260:05:35 G.m.t. (09:14:26 MET) using the free-fluid wand connected to the cross-tie quick disconnect (QD), and this confirmed that the nozzle was not blocked. At 260:12:53 G.m.t. (09:21:44 MET), an in-flight maintenance (IFM) procedure was performed to bypass the urine solids filter with hoses connected to a backup urine solids filter; however, the waste water dump was terminated after 5 minutes because the waste water flow had stopped. The crew was asked to perform another IFM to transfer waste water to a contingency water container (CWC), and this was successful.

At approximately 258:23:45 G.m.t. (08:08:36 MET), a loss of Ku-band forward link was detected (Flight Problem STS-69-V-05). The forward link was showing signal strength but the data were not being demodulated. The problem is believed to be within electronics assembly (EA) -1. Two attempts were made to regain the Ku-Band uplink. Since neither attempt was successful, the Ku-Band uplink capability was declared lost for the remainder of the mission. Ku-band downlink capability remained operational.

The extravehicular activity (EVA) was successfully completed with a total time of 6 hours and 46 minutes. Both crewmen, EV-1 and EV-2, performed thermal evaluations while being exposed to a simulated worst case International Space Station cold environmental conditions. The extravehicular mobility unit (EMU) modifications of the liquid cooling garment bypass and heated gloves that were designed to aid in warming the EV crewmembers performed as designed. Both crewmembers commented that their thermal comfort was maintained throughout the EVA.

Airlock repressurization after the EVA began at 259:15:03 G.m.t. (08:23:54 MET) and was completed at 259:15:22 G.m.t. (09:00:13 MET). Cabin repressurization to 14.7 psia began at 259:15:54 G.m.t. (09:00:45 MET) and was completed at 259:16:10 G.m.t. (09:01:01 MET).

Auxiliary power unit (APU) 1 was started at 260:07:20:33.6 G.m.t. (09:16:11:33.6 MET) for the flight control system (FCS) checkout. The APU ran for about 5 minutes 11.4 seconds, and consumed 11 lb of fuel. Due to the short run time of the APU (5 minutes, 11.4 seconds), no water spray boiler (WSB) cooling was observed. All the parameters were nominal. Data review shows that the guidance, navigation and control (GNC) portion of FCS checkout was performed without incident. The RCS hot-fire was performed starting at 260:08:21 G.m.t. (09:17:12 MET); all thrusters fired nominally.

All entry stowage and deorbit preparations were completed in preparation for entry on the nominal end-of-mission landing day. The payload bay doors were successfully closed and latched at 261:07:59:24 G.m.t. (10:16:51:24 MET).

After the APU prestart at 261:09:58 G.m.t. (10:18:49 MET), the hydraulic main pump system 3 main pump depressurization solenoid did not activate when switched to low pressure (Flight Problem STS-69-V-06). Subsequently, both remote power ocntrollers tripped off. The crew cycled the APU low/norm switch four times in an attempt to take the system to low pressure. Nominal operation was achieved on the fourth switch cycle.

The deorbit maneuver for the first landing opportunity at the Shuttle Landing Facility (SLF) at Kennedy Space Center (KSC) was performed on orbit 170 at 261:10:35:13.1 G.m.t. (10:19:26:13.1 MET), and the maneuver was 216.9 seconds in duration with a ΔV of 374 ft/sec.

Entry was completed satisfactorily, and main landing gear touchdown occurred on SLF concrete runway 33 at 261:11:37:56 G.m.t. (10:20:28:56 MET) on September 18, 1995. The Orbiter drag chute was deployed at 261:11:38:03.2 G.m.t. and the nose gear touchdown occurred 4.8 seconds later. The drag chute was jettisoned at 261:11:39:35.6 G.m.t. with wheels stop occurring at 261:11:38:56 G.m.t. The rollout was normal in all respects. The flight duration was 10 days 20 hours 28 minutes and 56 seconds. The APUs were shut down 14 minutes 8 seconds after landing.

PAYLOADS

A variety of scientific objectives dealing with technology, life science, astronomy, crystal growth, and solar physics were completed during the mission. Significant firsts accomplished during the mission included the first gravity gradient deployment, the first flight where two payloads were deployed and retrieved, and the first extensive use of ground-commanded Orbiter maneuvers during crew sleep.

SPARTAN 201

The SPARTAN 201-03 mission was one of scientific research aimed at investigating the interaction between the Sun and its outflowing wind of charged particles. The primary objective of the SPARTAN 201 was to understand the physical circumstances of the corona of the Sun during the time of the passage of the Ulysses spacecraft over the north pole of the Sun. The two scientific instruments on SPARTAN 201 were the Ultraviolet Coronal Spectrometer (UVCS) and the White Light Coronagraph (WLC).

The SPARTAN 201 was unberthed and deployed successfully by the RMS on time at 251:15:42:58 G.m.t. (01:00:33:58 MET). The spacecraft successfully completed the required pirouette maneuver indicating the systems were functioning properly.

During rendezvous operations on flight day 4 upon visual acquisition, the SPARTAN 201 attitude was not as expected or planned. The spacecraft appeared to be in the Minimum Reserve Shutdown (MRS) configuration under Magnetic Attitude Control System (ACS) control. The crew performed a fly-around maneuver to get into a position to grapple the spacecraft. After a free flight of approximately 47 hours, the SPARTAN spacecraft was successfully grappled at 253:15:02:22 G.m.t. (02:23:53:22 MET).

The initial assessment of the data available upon berthing the spacecraft in the payload bay indicated that at least a major portion of the science mission was completed before the spacecraft entered the MRS condition. Conclusive diagnosis will be made after the spacecraft is returned to the ground and the recorded data examined.

WAKE SHIELD FACILITY

The Wake Shield Facility (WSF) is a 12-foot diameter, stainless steel disk that is designed to generate an "ultra-vacuum" environment in space within which to grow thin films for next generation advanced electronics. This mission is the second of four planned WSF missions.

The principle objectives of this second flight of the WSF include performance of the WSF as a free-flyer that will attain a separation distance from the Orbiter that is great enough to achieve and characterize for the first time an uncontaminated "ultra-vacuum" in low Earth orbit; and demonstrate the feasibility of epitaxial growth of high-quality compound semiconductor thin films and heterostructures required for future advanced electronic and optoelectronic devices as part of the four-flight WSF proof-of-concept program.

The WSF hardware consisted of the Shuttle cross-bay carrier mounting equipment and the Free Flyer. The carrier remains in the Shuttle payload bay and has a latch system which holds the Free Flyer. The RMS was used to deploy the Free Flyer. The Free Flyer separated from the Orbiter and remained at a stationkeeping distance of 20 to 30 nmi.

The Free Flyer is a fully equipped spacecraft with cold gas propulsion for separation from the Shuttle and a momentum bias attitude control system. A total of 60 kW of electrical energy, stored in silver-zinc batteries, powered the thin-film furnaces, substrate heaters, process controllers, and a sophisticated array of vacuum characterization devices, including mass spectrometers and total pressure gauges.

The WSF was successfully deployed using the RMS at 254:11:25:06 G.m.t. (03:20:16:06 MET), one revolution later than planned because of a WSF radio frequency (RF) interference communications problem. During the first 24 hours of free-flight operations, the WSF successfully completed three thin-film growth runs, and in the process it overcame periodic RF interference. In addition, the attitude determination and control system (ADACS) experienced several attitude excursions when crossing orbital noons; however, only one of the excursions was of significance. This problem was controlled by configuring the ADACS to the safe-hold mode during subsequent orbital noon crossings. Additionally, thermal problems were encountered that appeared to affect the ADACS. A plan to control the thermal excursions was initiated, and the free-flight time was extended by one day to allow completion of additional thin-film growths. One additional run was completed for a total of four of the seven preflight scheduled thin-film growth runs.

During rendezvous, an Orbiter plume experiment was conducted using the WSF to measure the plume impingement loads imparted on the Free Flyer from Orbiter primary RCS firings at 300 and 200 feet. Due to the uncertainty over ADACS performance and the Orbiter reaching minimum propellant levels, only the highest priority thruster firings (14 of 55 preflight planned) were performed. The WSF Free Flyer was successfully grappled by the RMS at 257:13:59:11 G.m.t. (06:22:50:11 MET) and berthed in the payload bay at 257:15:16:28 G.m.t.

(07:00:07:28 MET). The total power-on time for the WSF was 3 days 14 hours and 36 minutes with the WSF in free flight for 3 days 2 hours and 34 minutes.

On flight day 9, the WSF Free Flyer was unberthed to perform Charge Hazards and Wake Studies (CHAWS) and the Atomic Oxygen Processing Experiment (AOPROC) objectives while attached to the RMS. Both experiments successfully gathered data and obtained a wider range of parameters than on the first WSF mission. Final berthing and latching of the WSF in the payload bay occurred at 258:12:26 G.m.t. (07:21:17 MET).

INTERNATIONAL EXTREME ULTRAVIOLET HITCHHIKER

The International Extreme Ultraviolet Hitchhiker (IEH-1) measured and monitored long-term variations in the magnitude of absolute extreme ultraviolet (EUV) flux coming from the Sun, and studies EUV emissions from the plasma torus system around Jupiter originating from its moon Io. These observations were accomplished by the two complementary experiments that comprise IEH, the Solar Extreme Ultraviolet Hitchhiker (SEH), and he Ultraviolet Spectrograph Telescope for Astronomical Research (UVSTAR).

Solar Extreme Ultraviolet Hitchhiker

The sponsor of the payload reported that all expectations were satisfied and even exceeded. The experiment achieved its primary goals as well as obtaining excellent Earth atmosphere occultation data. These data will be analyzed in collaboration with the UVSTAR team who have obtained complementary Earth airglow data.

The SEH obtained the absolute solar EUV flux required to interpret the EUV emissions from the Jovian system as well as other solar system atmospheres measured by the companion experiment UVSTAR. The SEH was allocated sixteen 15-minute solar observations during Orbiter solar noon, and one complete solar observation that included a set of dawn-to-dusk measurements. The only anomaly encountered occurred on flight day 1 when the filter wheel within the solar EUV spectrometer was found frozen in an incorrect position allowing only partial operations. After allowing the filter wheel to be heated by the power driving it for two days, the a rocking movement was commanded and the wheel released and was placed in the full-open position for the remainder of the mission. The solar EUV spectrometer operated perfectly for the remainder of its planned operational period.

As a result of the STS-69 launch being delayed, near simultaneous observations with those obtained by a University of Southern California sounding rocket mission on September 12, were made possible. Three minutes of SEH solar EUV flux data were collected before and after the sounding rocket launch, and together these data will provide the scientific community with high quality solar flux data.

UV Spectrograph Telescope for Astronomical Research

The UVSTAR measured the EUV (500-850 angstroms) and Far Ultraviolet (FUV) (800-1250 angstroms) emissions of the Jovian system using a pair of telescopes with imaging spectrographs that are sensitive to these two regions.

The UVSTAR payload's objectives were to obtain spectra of the following as well as coverage of the EUV and FUV regions and at varied sprectral resolution:

a. Extended cosmic sources;
b. Jupiter;
c. The Io torus; and
d. "Hot" ultraviolet stars.

The UVSTAR mirrors, detectors and gratings performed quite well and have demonstrated that the instrument has higher-than-expected sensitivity. Two major failures hindered the UVSTAR mission:

a. An elevation-drive failure; and.
b. A star-finder failure.

The failure in the mechanical elevation drive resulted in the inability of the instrument to track a target. However, using Orbiter's fine-pointing capabilities, computing the pointing direction of the spectrograph slits and waiting for a UV star to cross the field of view, allowed scientific data to be collected. The star finder anomaly made it more difficult to identify the pointing direction and to co-align the star finder and tracker with the spectrograph slits. A failure of the spectrograph ion pumps also occurred.

The instrument acquired targets in a passive mode, obtaining high resolution spectra of "hot" UV stars, both planned targets as well as targets of opportunity. A thorough postflight review of the data will be performed to confirm the acquisition of spectra from extended cosmic sources, Jupiter, and the Io torus.

SHUTTLE GLOW EXPERIMENT

The investigation of the mysterious shroud of luminosity, called the glow phenomenon, observed by astronauts on previous Shuttle missions, was continued on the STS-69 mission. Theories suggest that the glow may be due to atmospheric gases on the windward- or ram-side surface of the vehicle colliding and interacting with gaseous engine effluents and contaminate outgassing molecules. The glow investigation covered only a short period of time after which the instruments were used to studying the Earth atmosphere.

The glow payload acquired spectral data from the atmosphere continuously through 40 orbits of the mission. The data will define the atmospheric composition, vertical structure, thermal conditions, and associated chemical reactions. The data can be used in a pathfinder mode to validate the observational experiments planned for a later mission. In addition, all of the glow dedicated experiments planned for the spacecraft interactions program appeared to have been successful.

CAPILLARY PUMPED LOOP/GET AWAY SPECIAL BRIDGE ASSEMBLY

The Capillary Pumped Loop/Get Away Special Bridge Assembly (CAPL-02/GBA) payload consisted of the CAPL-2 Hitchhiker payload, the Thermal Energy Storage -2 (TES-2) payload, and four Get Away Special (GAS) payloads on a single cross-bay structure called the GBA.

Capillary Pumped Loop Demonstration

The capillary pumped loop (CAPL-2) provided an on-orbit demonstration of the full-scale capillary pumped loop system planned for the Earth Observing System (EOS) Program. The CAPL-2 verified the heat transport requirements of the thermal control system that is being designed for the EOS Program. This experiment used an evaporator plate with a capillary pump that vaporized a liquid ammonia working-fluid using heaters.

The CAPL-2 Hitchhiker payload operated very satisfactorily throughout the mission. The CAPL-2 experiment successfully completed 100 percent of its preplanned objectives and activities. The objective of validating the design of the planned thermal control system for the EOS Program was achieved. The additional objective of characterizing the on-orbit performance of this thermal control system technology was also achieved. CAPL-2 operated approximately 102 hours, far exceeding the requirement of 72 hours. In addition, CAPL-2 was allowed to run at nominal power for 88 continuous hours during the WSF operations, thereby providing additional valuable performance data.

Thermal Energy Storage

The Thermal Energy Storage (TES-2) experiment was also a part of the CAPL-2/GBA payload. The TES-2 payload was to provide data for use in understanding the long-duration behavior of thermal energy storage fluoride salts that undergo repeated melting and freezing in microgravity. The science objective of the TES-2 payload was to evaluate the migration of a void in thermal energy salts under microgravity conditions, and to validate the ground-based model on this behavior. However, a failure occurred in the GAS control circuit, and the TES-2 payload was unable to be activated on this flight. A postflight anomaly investigation will be performed.

Get Away Specials

Four GAS payloads were flown on the STS-69 mission. Each GAS payload was contained in a five cubic foot canister that was attached to the GBA. Although one of the non-GAS payloads in one of the canisters could not be activated because of a control circuit failure, this condition did not affect any of the GAS payloads. The four GAS payloads were as follows:

a. G-515 - Control Flexibility Interaction Experiment - This experiment studied active damping control loops using a flexible plate and two piezo (pressure) actuators. The GAS payload was activated successfully by the crew early in the mission and deactivated at the appropriate time. The GAS payload data were recorded autonomously inside the canister. The results of this experiment may be obtained from the sponsor, which is the European Space Agency, Noordwijk, The Netherlands.

b. G-645 - Structural Damping Evaluation of Electrorheological (ER) Fluid-Filled Beams in Space - The experiment consisted of two instrumented aluminum beams filled with ER fluid. This GAS payload was activated as planned by the crew early in the mission, and deactivated as planned later in the mission. The data from this experiment were recorded inside the GAS canister. The results of the experiment may be obtained from the sponsor, which is the Millcreek Township School District, Erie PA.

c. G-702 - Microgravity Smoldering Combustion Experiment - The experiment studied the effects of smoldering combustion in a long-term microgravity environment using polyurethane foam. The GAS payload was activated as planned and deactivated as scheduled later in the mission. The GAS payload data were recorded inside the GAS canister. The results of this experiment may be obtained from the Lewis Research Center, Cleveland, OH.

d. G-726 - Joint Damping Experiment - The experiment studied the non-linear, gravity-dependent behavior of a pin-jointed truss. This GAS payload was activated automatically and was performed during the first crew sleep period when vehicle accelerations were minimal. The GAS payload data were recorded in the GAS canister. The results of this experiment may be obtained from the NASA Langley Research Center, Hampton, VA.

SPACE TISSUE LOSS/NATIONAL INSTITUTES OF HEALTH - CELLS

Weightlessness results in bone loss. This fact is well understood, but the cause of the loss is not totally clear. This experiment was performed to obtain more data in the quest of understanding this condition. Throughout the mission, the Space Tissue Loss (STL) rail temperatures were maintained well within the required 35 to 39 °C. The flight hardware appears to have performed exactly as planned with 100 percent of the on-orbit objectives accomplished.

COMMERCIAL GENERIC BIOPROCESSING APPARATUS

STS-69 marked the seventh flight of the Commercial Generic Bioprocessing Apparatus (CGBA). The apparatus is composed of fluid processing apparatuses (FPAs), which are multi-chambered syringes that upon activation permit fluids to be mixed. Five separate investigations were conducted during this flight, and the CGBA payload performed flawlessly with 100 percent of the science return from the flight samples expected. Only one problem was encountered that involved the ground coordination of the time of termination of Group Activator Pack 7 and that affected the simultaneous termination of the associated ground control experiment.

BIOLOGICAL RESEARCH IN CANISTER

STS-69 was the sixth flight of the Biological Research in Canister (BRIC) payload, which studied the effects of microgravity on plants, small animals, and cell cultures. The samples were contained in 36 petri dishes that were stacked inside three aluminum canisters for stowage in the middeck area. The BRIC payload was successfully activated at 251:12:47 G.m.t. (00:21:38 MET) by placing the sample canister in the gaseous nitrogen freezer. Based on the problem encountered on a previous flight of this payload, the locker foam was removed while on-orbit to minimize possible out-gassing contaminants. The foam was reinstalled for entry at about 251:06:09 G.m.t. (10:15:00 MET).

ELECTROLYSIS PERFORMANCE IMPROVEMENT CONCEPT STUDY

The requirements for oxygen and hydrogen in future long-duration space missions can be realized by electrolyzing water in space. The onboard generation of oxygen is expected to reduce the annual resupply weight for the Space Station by approximately 12,000 lb. The Static Feed Electrolyzer (SFE) has been developed for Space Station and the objective of the Electrolysis Performance Improvement Concept Study (EPICS) study was to demonstrate and validate the SFE electrochemical process in microgravity, as well as investigate performance improvements projected possible in a microgravity environment.

Shortly after the EPICS was activated on flight day 1, the Integrated Electrolysis Unit (IEU) shut down. Late in flight day 2, the crew noted that IEU 2 and 3 had also shut down. A number of out-of-limit parameters could have caused the automatic shut down of the three units. This condition was not recoverable and the experiment was powered down for the remainder of the mission.

COMMERCIAL MATERIALS DISPERSION APPARATUS INSTRUMENTATION TECHNOLOGY ASSOCIATES EXPERIMENT

The STS-69 flight was the fourth of five planned flights of the Commercial Materials Dispersion Apparatus Instrumentation Technology Associates Equipment (CMIX) experiment, which performs biological research. The CMIX middeck payload was flown to process about 400 biological samples in the microgravity environment of Earth orbit. All data available during the mission indicates that the hardware performed as planned and that all crew activities were successfully accomplished in a timely manner. The only unexpected event occurred during deactivation when an indicator showed that a unit was not closed to the entry position. Although a visual inspection by the crew showed that the unit was probably acceptable, a contingency procedure was performed that successfully completed the deactivation.

RISK MITIGATION EXPERIMENT

Risk Mitigation Experiment (RME) 1311 - Relative Global Positioning System - Operation of the Relative Global Positioning System (RGPS) under RME 1311 involved testing RGPS navigation filter, and recording data during the WSF separation and the first day of WSF free-flight. These data will be replayed postflight for analysis. Also, real-time GPS orbit determination for the Orbiter was performed using the GPS navigation filter in single vehicle mode. It was compared with GPS receiver and Orbiter onboard solutions in real-time and in near real-time on the ground. The GPS receiver on the WSF did not operate during the rendezvous. No data were received and indications were that no additional data were being recorded on the free flyer. Power-cycle commands failed to restore data from the GPS, which in turn also reduced the amount of data that were obtained by the experiment. In addition to the data collected, many lessons were learned about handling simultaneous data from multiple GPS receivers and Orbiter systems, as well as about software design features that will be valuable for future GPS relative navigation application.

VEHICLE PERFORMANCE

The performance of the SRBs, RSRMs, ET, SSMEs, MPS, and the Orbiter subsystems was nominal. No in-flight anomalies were identified for the SRBs, RSRMs, ET, SSMEs, and MPS, and only three were identified for the Orbiter subsystems. A discussion of the performance of the various elements and subsystems is contained in the following paragraphs.

SOLID ROCKET BOOSTERS

All Solid Rocket Boosters (SRBs) systems performed as expected. The SRB prelaunch countdown was normal, and no SRB Launch Commit Criteria (LCC) or Operational Maintenance Requirements and Specification Document (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 LCC ranges. At T-15 minutes, the purge was changed to high pressure to inert the SRB aft skirt.

During the launch attempt on August 31, 1995, the right-hand SRB bus B voltage exceeded the upper Operational and Maintenance Requirements and Specification Document (OMRSD) limits of 31.3 volts as measured by the multiplexer/demultiplexer (MDM) and 32.0 volts as measured by the ground measurement. Data showed that the voltage exceeded the OMRSD MDM measured value for 62 seconds with a peak reading of 31.68 Vdc and the ground measured value with a peak reading of 32.04 Vdc for 23 seconds. The condition was waived for the second and following launch attempts.

No OMRSD or LCC violations were noted during the final countdown prior to launch. The ascent performance of the SRBs was satisfactory, and both SRBs were successfully separated from the ET at approximately 122.4 seconds.

Reports from the recovery area, based on visual sightings, indicate that the deceleration subsystems performed as designed. Both SRBs were observed during descent, and were recovered and returned the KSC for disassembly and refurbishment.

REUSABLE SOLID ROCKET MOTORS

The Reusable Solid Rocket Motors (RSRM) performed satisfactorily during the ascent phase. This RSRM set (48) was the first set made from propellant processed through the new M-314 propellant premix facility. The RSRM prelaunch countdown was normal and no LCC or OMRSD violations noted.

Power up and operation of all igniter and field-joint heaters was accomplished routinely. All RSRM temperatures were maintained within acceptable limits throughout the countdown.

The RSRM motor performance parameters for this flight were within the contract end item (CEI) specification limits. Reconstructed propulsion performance parameters based on the 81 °F propellant mean bulk temperature (PMBT) are shown in the following table.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 81 °F		Right motor, 81 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10^6 lbf-sec	66.45	66.62	66.49	66.86
I-60, 10^6 lbf-sec	176.80	177.60	176.88	177.95
I-AT, 10^6 lbf-sec	297.23	296.83	297.11	296.60
Vacuum Isp, lbf-sec/lbm	268.6	268.3	268.6	268.2
Burn rate, in/sec @ 60 °F at 625 psia	0.3683	0.3704	0.3686	0.3713
Burn rate, in/sec @ 81 °F at 625 psia	0.3739	0.3760	0.3742	0.3769
Event times, seconds[a]				
Ignition interval	0.232	N/A	0.232	N/A
Web time[b]	108.5	107.6	108.4	107.4
50 psia cue time	118.2	117.4	118.1	117.0
Action time[b]	120.3	119.3	120.2	119.1
Separation command	123.1	122.3	123.0	122.3
PMBT, °F	81	81	81	81
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	2.7	2.8	2.9
Tailoff Imbalance Impulse differential, Klbf-sec	Predicted		Actual	
	N/A		514.8	

Impulse Imbalance = Integral of the absolute value of the left motor thrust minus right motor thrust from web time to action time.
[a] All times are referenced to ignition command time except where noted by a [b].
[b] Referenced to liftoff time (ignition interval).

The right-hand motor of this flight set experienced an out-of-family burn rate of 0.3713 inch/second (ips); however, the burn rate did not exceed the control limit. This condition did not impact the ascent phase performance .

Data indicate that the flight performance of both RSRMs was well within the allowable performance envelopes and was typical of the performance observed on previous flights. The postflight disassembly of the RSRMs showed that all field and igniter joints performed as designed. The repaired joints 3 and 4 were in good condition with no gas paths. The other nozzle internal joints and bondlines showed nominal performance.

EXTERNAL TANK

The ET loading and flight performance was excellent, and no in-flight anomalies were identified. All flight objectives and requirements associated with the ET propellant loading and flight operations 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 were identified.

Typical ice/frost formations were observed on the ET during the countdown. There was no observed ice or frost on the acreage areas of the ET. Normal quantities of ice or frost were present on the LO_2 and LH_2 feed-lines and on the pressurization line brackets, and some frost was present along the LH_2 protuberance airload (PAL) ramps. A frost ball was reported on the +Y intertank flange adjacent to the jackpad close-out. These observations were acceptable per NSTS 08303. The Ice/Frost "Red Team" reported that there were no anomalous TPS conditions.

The ET pressurization system functioned properly throughout engine start and flight. The minimum LO_2 ullage pressure experienced during the ullage pressure slump was 14.1 psid.

ET separation occurred on time, and the predicted ET intact impact point was approximately 62 nmi. up-range of the preflight prediction.

SPACE SHUTTLE MAIN ENGINE

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

Flight data indicate that SSME performance during mainstage, throttling, shutdown, and propellant dumping operations was normal. The high pressure oxidizer turbopump (HPOTP) and the high pressure fuel turbopump (HPFTP) temperatures appeared to be well within specification throughout engine operation. The specific impulse (Isp) was rated as 452.62 seconds based on trajectory data. Space Shuttle main engine cutoff (MECO) occurred at engine start plus 510.728 seconds. There were no in-flight anomalies nor significant SSME problems identified.

SHUTTLE RANGE SAFETY SYSTEM

The Shuttle Range Safety System (SRSS) closed-loop testing was completed as scheduled during the launch countdown. All SRSS safe and arm (S&A) devices were armed and system inhibits turned off at the appropriate times. All SRSS measurements indicated that the system operated as expected, with one exception, throughout the countdown and flight.

As planned, the SRB S&A devices were safed; however, the right-hand SRB range safety system (RSS) S&A device failed to attain a "safed on" sustained indication prior to SRB separation. The arm indication did properly show "armed off" and had rotated to the safe position. This S&A device had the same problem during prelaunch testing. The problem was determined to be the adjustment of the "safe" position indication switch assemblies of this particular lot.

SRB system power was turned off prior to SRB separation, and the ET system remained active until ET separation from the Oribiter.

ORBITER SUBSYSTEMS PERFORMANCE

Main Propulsion System

The overall performance of the main propulsion system (MPS) was nominal. LO_2 and LH_2 loading were performed as planned with no stop-flows or reverts, and there were no OMRSD or LCC violations.

Throughout the period of preflight operations, no significant hazardous gas concentrations were detected. The maximum hydrogen concentration level in the Orbiter aft compartment (which occurred shortly after the start of fast-fill) was approximately 135 ppm, which compares favorably with previous data from this vehicle.

A comparison of the calculated propellant loads at the end of replenish with the inventory (planned) loads results in a loading accuracy of 0.03 percent for LH_2, and 0.04 percent for LO_2.

Ascent MPS performance was completely normal. Data indicate that the LH_2 and LO_2 pressurization systems performed as planned, and the minimum LO_2 ullage pressure experienced during the period of ullage pressure slump was 14.1 psid. All net positive suction pressure (NPSP) requirements were met throughout the flight.

The gaseous oxygen (GO_2) fixed orifice pressurization system performed as predicted. Reconstructed data from engine and MPS parameters closely matched the actual ET ullage pressure measurements.

The gaseous hydrogen (GH_2) flow control valves also performed nominally. All three valves were refurbished prior to this flight, and STS-69 was also the first flight of the re-oriented manifold assembly. No valve sluggishness was noted during the flight.

On-orbit decay of the SSME and pneumatic helium systems was nominal. Helium consumption during entry was 61.5 lbm, which is within the historical fleet limits.

Reaction Control Subsystem

The RCS performed satisfactorily throughout the mission. The primary RCS thrusters were used for 14 maneuvers during the mission. The RCS thrusters performed nominally during the RCS hot-fire prior to entry as well as throughout the mission. The erratic vernier thruster L5D oxidizer injector temperature which had been a problem during the two previous flights of this pod performed nominally. Propellant consumption by the RCS was 4872.0 lbm from the RCS tanks and 3484.8 lbm (26.91 percent) from the OMS tanks.

During the postlanding redundant circuit verification valve test, the left RCS manifold 3 oxidizer valve failed to gain a closed indication following cycling. The cycling was repeated with the same results; however, manifold pressure data shows that the valve did cycle. The most probable cause of the failure is the valve position indicator microswitch in the valve actuator.

Orbital Maneuvering Subsystem

The OMS performed nominally during eight firings during the mission. The total firing time of the engines was 513.8 seconds on the left OMS engine, and 515.3 seconds on the right OMS engine. A total of 23,312.0 lbm of OMS propellants were consumed during the mission. Of this total, 3484.8 lbm (26.91percent) were consumed by the RCS during interconnect operation. The gaging system performance was nominal with all oxidizer probes operating satisfactorily and all fuel probes except the left forward operative. The following table delineates the significant parameters for each OMS firing.

OMS FIRINGS

OMS firing	Engine	Ignition time, G.m.t./MET	Firing duration, seconds	ΔV, ft/sec
OMS-2	Both	250:15:50:44.5 G.m.t. 00:00:41:44.5 MET	187.7	293.9
OMS-3	Left	253:18:35:42.7 G.m.t. 03:03:26:42.7 MET	34.6	37.6
OMS-4	Right	253:19:21:35.3 G.m.t. 03:04:12:35.3 MET	29.2	23.4
OMS-5	Left	257:07:09:18.1 G.m.t. 06:16:00:18.1 MET	10.8	8.5
OMS-6	Right	257:10:16:55.4 G.m.t. 06:19:07:55.4 MET	13.2	10.5
OMS-7	Left	257:16:47:10.1 G.m.t. 07:01:38:10.1 MET	63.8	52.2
OMS-8	Right	257:17:32:21.5 G.m.t. 07:02:23:21.5 MET	68.3	56.1
Deorbit	Both	261:10:35:13.1 G.m.t. 10:19:26:13.1 MET	216.9	374.3

A right OMS accumulator leak was detected following the OMS-8 maneuver. This leak ranged from 37 to 47 scch. The accumulator bottle was repressurized three times prior to the deorbit maneuver, and the leak rate decreased to 37 scch after the second repressurization. This behavior has been seen on previous missions with leak rates as high as 100 scch. Extensive postflight troubleshooting has not isolated the leak. The specification limit for a leak at this point is a maximum of 30 scch; however, leaks of this magnitude neither affect flight safety nor impact the mission. This condition was waived prior to flight.

Power Reactant Storage and Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem performed satisfactorily throughout the mission. The oxygen consumption for the mission was 2801 lbm, and the hydrogen consumption was 338 lbm. Included in the oxygen consumption was 121 lbm furnished to the crew module for breathing and pressurization. The mission extension capability at an average power level of 14.9 kW was 81 hours. The oxygen/hydrogen (O_2/H_2) manifold isolation valves were cycled each day to support the crew sleep periods.

Fuel Cell Powerplant Subsystem

The fuel cell powerplant subsystem performed satisfactorily throughout the mission. During the 260.5-hour mission, the fuel cells produced 3884 kWh of electrical energy at an average power level of 14.9 kW and load of 488 A. The fuel cells consumed 338 lbm of hydrogen and 2680 lbm of oxygen, and produced 3018 lbm of water. The fuel cells were purged five times during the mission. The actual fuel cell voltages at the end of the mission were 0.10 volt above the preflight predicted level for fuel cells 1 and 3, and as predicted for fuel cell 2. The overall thermal performance of the fuel cell water relief, water line and reactant purge systems was nominal.

The first launch attempt for the STS-69 mission was scrubbed when the condenser exit temperature (TCE) of fuel cell powerplant 2 increased nominally for the first 18 minutes, at which time the TCE did not stabilize at about 150 °F which it does normally. The TCE continued to increase until it reached 164 °F when the ready-to-load indication was received. About two minutes later, fuel cell 2 was connected to the main bus and the temperature had risen to 170 °F. A decision was made to shut down the fuel cell when the TCE reached 184 °F. The second attempt to start fuel cell 2 was made after fuel cell 3 was satisfactorily started. Again the temperature continued rising and when it reached 175 °F, the fuel cell was again shut down. The fuel cell was replaced with a spare, and after a one-week delay, the launch of STS-69 was satisfactorily completed. The replacement fuel cell operated satisfactorily during the STS-69 mission.

Fuel cell 2 (S/N 118) was sent to the vendor for testing to determine the cause of the anomaly. Initial tests did not duplicate the anomaly; however, it was determined that a QD may have been mated improperly when the fuel cell was installed on the vehicle. Tests were run with the coolant discharge line disconnected and the temperature signature was the same as seen on the vehicle. Further analysis showed that the coolant discharge quick disconnects could be joined in a cocked manner that would appear to be mated and not easily pulled apart, yet prevent coolant flow. This indicated that coolant flow blockage was responsible for the high temperatures.

Data showed that the hydrogen flowmeter on fuel cell 1 indicated accurately during the first half of the mission, then began drifting high for the remainder of the mission. This flowmeter has been erratic for several missions. Tests isolated the problem to the measurement rather than any fuel cell component.

Auxiliary Power Unit Subsystem

The auxiliary power unit (APU) subsystem performed satisfactorily throughout the mission, with no in-flight problems or anomalies identified. The APUs were shut down following ascent in the order required (3, 1, and 2) by Development Test Objective (DTO) 414 (Sequence A). The following table presents significant APU operational parameters.

APU RUN-TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (S/N 203)		APU 2 (S/N 308)		APU 3 (S/N 304)	
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	19:12	46	19:27	50	18:50	46
FCS checkout	05:11	11				
Entry[a]	58:01	104	58:10	126	87:20	162
Total	82:24	161	77:37	176	106:10	208

[a] The APUs were shut down approximately 14 minutes 8 seconds after main gear touchdown.

Hydraulics/Water Spray Boiler Subsystem

The hydraulics/water spray boiler subsystem performed nominally during the STS-69 mission. One in-flight anomaly was identified and it is discussed later in this subsystem section.

During prelaunch operations at T-20 minutes, low water spray boiler (WSB) regulator 2 outlet pressure (below 39 psia) was observed upon opening the isolation valve. An unintentional off-loading of water from this same WSB (2) occurred prior to STS-67, and troubleshooting to resolve that problem revealed that the pressure transducer had a negative bias of approximately 1.2 to 1.5 psi. This bias explains the indicated 0.3-psi under-pressure on the WSB 2 nitrogen (N2) regulator that occurred.

The hydraulics/water spray boiler subsystem operated properly during ascent with no over-cooling or under-cooling conditions observed. An electric heater was added to water spray boiler (WSB) 3 for this mission. The heater was activated and operated satisfactorily with no anomalous behavior noted. Following MECO, the APUs were shut down in the order required by DTO 414, and no back-driving of the power drive unit (PDU) was observed in the data.

The hydraulics/WSB subsystem performed satisfactorily during the flight control system (FCS) checkout. No WSB cooling was required because of the short operating time of the APU.

WSB 3 experienced an over-cooling condition during entry. The lubrication oil temperature dropped from 250 °F to 193 °F. The temperature then rose back to 250 °F. The cause of this temperature change is still being evaluated.

Electrical Power Distribution and Control Subsystem

The electrical power display and control (EPD&C) subsystem performed in acceptable manner throughout the mission.

During deorbit preparations at APU prestart, the hydraulic main pump system 3 depressurization solenoid remote power controller (RPC) tripped because of an overload condition. Shortly after the low pressure toggle switch command was issued, a 4 ampere current increase was present for about 2.5 seconds on each of the two main buses feeding the RPCs (Flight Problem STS-69-V-06). This condition is evidence of a short circuit to ground of the wiring feeding the solenoid or a failure within the solenoid itself. The overload or short circuit condition was cleared after the switch was cycled four times. Successful circuit operation was then achieved allowing nominal operation of APU 3. Postflight failure analysis of the hydraulic pump 3 depressurization solenoid revealed damaged wiring near the solenoid, and that is the most probable cause of this anomaly.

Environmental Control and Life Support System

The active thermal control system (ATCS) performed satisfactorily throughout the mission. There were no actively cooled payloads in the payload bay, consequently, both Freon loops remained in the interchanger position for the entire mission.

A flash evaporator system (FES) shut down occurred at 250:17:04 G.m.t. (000:01:55 MET), on the primary A controller after the high-load evaporator was switched off in accordance with the post-insertion checklist. About 2.5 minutes later, the crew cycled the switch and the FES was successfully restarted on the primary A controller, and the FES operated satisfactorily for the remainder of the mission. Review of the data has indicated that the high-load evaporator was still operating when it was disabled by the crew, and this subjected the topping evaporator to an unexpected thermal transient which could not be overcome; consequently an over-temperature shut down occurred.

The radiator cold-soak provided cooling during entry through touchdown plus 15 minutes when ammonia system B was activated using the secondary controller at 261:11:52 G.m.t.(10:20:43 MET). Ammonia system B operated 32 minutes when it was turned off because ground cooling was connected.

At 250:16:35 G.m.t. (00:01:26 MET), the crew reported that the regenerative carbon dioxide removal system (RCRS) ON light did not illuminate when the RCRS was powered. The crew checked the RCRS circuit breaker on panel ML86B and reported that the "CO_2 System 1 Controller" circuit breaker was open. The crew closed the breaker and reran the RCRS startup procedures, and the RCRS operated normally for the remainder of the mission.

The supply water system performed nominally and was managed through the use of the overboard dump system and flash evaporator system (FES). Six overboard dumps were performed at an average dump rate of 1.57 percent/minute (2.6 lb/min). The supply water dump line temperature was maintained between 70 and 92 °F throughout the mission with the operation of the line heater.

The waste management system experienced a problem with degraded dumps overboard late in the mission. The first waste water dump appeared normal with a flow rate of 1.97 percent/minute (3.25 lb/min), which duplicates the last flight conditions. A simultaneous supply/waste dump was initiated at 258:16:49 G.m.t. (08:01:40 MET), and it was terminated at 258:18:00 G.m.t. (08:02:51 MET) reducing the supply quantity from 515 lb to 353 lb. The waste water dump was started at 258:16:59 G.m.t. (08:01:50 MET). At 258:17:12 G.m.t. (08:02:03 MET), the crew was instructed to terminate the waste dump because the flow rate had decreased from 2.0 percent/minute to 0.11 percent/minute. The waste nozzles were reheated to 250 °F, and a second attempt to dump waste was begun at 258:17:24 G.m.t. (08:02:15 MET). About 3 minutes later, the second attempt was terminated because of an upcoming loss of signal (LOS). At 258:17:56 G.m.t. (08:02:47 MET), the third attempt to continue the dump was started but was terminated about 5 minutes into the dump when it was observed that the dump rate was only 0.29 percent/minute. The total waste water dumped for the three attempts was 28.6 lb leaving the waste tank quantity at 62.8 percent.

A purge of the nozzle was performed using the free-fluid wand connected to the cross-tie quick disconnect (QD), and this confirmed that the nozzle was not blocked. Subsequently, the crew attempted to continue dumping by bypassing the high capacity urine solids filter and using the contingency waste water dump filter connected to the cross-tie QD and the waste collection system (WCS) urine outlet QD. This appeared initially to operate satisfactorily, however, only 7.5 percent (12.4 lb) was dumped before this path also became blocked. Using the highest waste tank fill rates observed for this flight, it was estimated that there was enough waste tank ullage to last until the early hours of flight day 10. The crew was asked to perform another IFM to transfer waste water to a contingency water container (CWC), and this was successful. The ullage after the dump was sufficient to complete the mission. This vehicle had been flushed with citric acid, and the urine solids filter had been replaced with a clean filter prior to flight. Extensive postflight troubleshooting revealed no blockage of the filters, waste lines, or nozzle. The cause of this anomaly is unexplained.

The waste water dump line temperature was maintained between 54 and 90 °F throughout the mission, The 90 °F is slightly higher than expected, however, this was prior to the first dump when the lines were not filled with water. After the first dump, this measurement came into limits. The vacuum vent line temperature was maintained between 58 and 82 °F, while the nozzle was maintained between 114 and 162 °F.

The waste collection system performed adequately throughout the mission.

The atmospheric revitalization pressure control system performed normally throughout the mission. During the redundant component check, the pressure control configuration was switched to the alternate system. Both systems exhibited nominal operation. At 258:01:29 G.m.t. (07:10:20 MET), the cabin was depressurized to 10.2 psia in preparation for the extravehicular activity (EVA).

Following the completion of the EVA, the cabin was repressurized to 14.7 psia.

Airlock Support System

The airlock support system performed satisfactorily throughout the mission. The airlock depressurization valve was used to depressurize the cabin from 14.7 psia to 10.2 psia, and the airlock from 10.2 psia to vacuum to support the scheduled EVA. The active system monitor parameters indicated normal output throughout the duration of the flight.

Smoke Detection and Fire Suppression.

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

Avionics and Software Support System

The integrated guidance, navigation and control performance was nominal during the mission. The system was exercised heavily with two rendezvous trajectories flown as well as participating in the payload deployment activities.

The flight control system performed satisfactorily during the mission.

The inertial measurement unit performance was very nominal. Only one gyro and one accelerometer compensation were required during the mission.

Star tracker performance was normal throughout the mission.

Prior to the RMS releasing the SPARTAN, the Orbiter was tracking a celestial target that was specified by a right ascension (RA) and declination (DEC) on the Universal Pointing (UP) display. The crew was attempting to load a future maneuver to an inertial attitude (roll, pitch, and yaw) when the RA was inadvertently over-written with the roll component of the future attitude, and an unwanted maneuver occurred.

The normal procedure for using UP is to load the desired option (maneuver, track, or rotate), and then perform the item entry to start the maneuver to the desired attitude. In the case of the described scenario, the functional requirements were not consistent. The RA and DEC are used to compute the desired line-of-sight unit vector that is stored on the star table. This vector and the current body vector are used to compute the desired attitude. If the RA or DEC are changed, then the unit vector is changed which automatically updates the desired attitude, and if the digital autopilot (DAP) is in Auto, then a maneuver is commanded.

The data processing system hardware and software performed nominally with one in-flight anomaly identified. At approximately 250:18:36 G.m.t. (00:03:27 MET), the crew reported that CRT 1 was so dim that it was hard to read and was unusable in sunlight, and the condition had existed since the prelaunch timeframe (Flight Problem STS-69-V-02). All inputs made through the CRT functioned nominally. The CRT was powered off. Troubleshooting tests performed on flight day 3 were unsuccessful in brightening the screen. The CRT was powered up at approximately landing minus 5 hours and was used for entry. CRT dimness is a characteristic of old CRTs (this one is 12 years old), and with no other error annunciations present, the age of the CRT is most probably the cause of the dimness.

At 251:17:48:56 G.m.t. (01:02:39:56 MET) an "I/O ERR CRT 2" fault summary message was annunicated, and an error was logged. The crew reported that CRT 2 appeared nominal. This signature did not repeat throughout the remainder of the mission.

Displays and Controls Subsystem

The displays and controls subsystem performed all necessary functions to support and complete the mission.

At 258:11:35 G.m.t. (07:20:26 MET), during payload bay floodlight operation, currents on the mid main B bus showed evidence of arcing and an RPC trip. The midport, forward starboard, and forward bulkhead floodlights are powered by main B bus. At 259:08:01 G.m.t. (08:16:52 MET), the crew powered on all but the forward starboard and forward bulkhead floodlights, and there was no evidence in the data of the midport floodlight coming on. At 259:08:31 G.m.t.

(08:17:22 MET), the crew turned on the forward starboard floodlight, and currents showed a start-up but no indication of the light reaching full illumination. Three minutes later, the forward bulkhead light was turned on and it operated nominally. Another seven minutes later, the crew reported that the forward starboard and forward port floodlights were dimly flickering purple. At 259:09:40 G.m.t. (08:18:32 MET), the crew reported that both forward floodlights were still not working, and they were turned off. These three floodlights were not available for the remainder of the mission.

Communications and Tracking Subsystems

The communications and tracking subsystems operated nominally providing satisfactory communications and tracking throughout the mission, although a number of problems were noted.

Shortly after the release of the SPARTAN payload, the Ku-band radar indicated approximately a 200-foot difference in range when compared with the hand-held Laser Range Finder and ground-based tracking. After dropping lock and reacquiring the SPARTAN, the Ku-band range then agreed with the Laser Range Finder and the ground-based tracking. The Ku-band radar performed nominally for the remainder of the SPARTAN deployment and retrieval activities and the WSF deployment and retrieval activities. The cause of this discrepancy is believed to be the tracking of a small piece of debris.

Following the S-band system handover from the Bermuda ground station to the Tracking and Data Relay Satellite (TDRS) East after main engine cutoff (MECO), the S-band forward link signal strength was weaker than normal. This resulted in frequent forward-link dropouts which continued through several antenna changes as well as when TDRS West was used. The S-band system was configured on string 2 at the time of the dropouts. S-band preamplilfier 1 (string 1) was selected and the signal strength increased. This configuration was used for the remainder of the mission except when S-band tests with string 2 were being performed. Additional testing was performed for 1 hour and 24 minutes beginning at 260:08:06 G.m.t. (09:16:57 MET). Although the preamplifier 2 signal strength was about 3-4 dB lower than preamplifier 1, the frame synchronizer remained locked and communications were not affected. Postflight troubleshooting verified that preamplifier 2 was operating 3 dB below the specified output power.

At 251:00:56 G.m.t. (000:09:47 MET), a Ku-Band BCE bypass fault occurred (Flight Problem STS-69-V-01). The fault signifies that the antenna management software did not receive a response from the Ku-Band system on two consecutive pollings. An input/output (I/O) reset was performed at 251:01:03 G.m.t. (000:09:54 MET) to resume antenna management polling of Ku-Band via the payload forward 1(PF1) multiplexer/demultiplexer (MDM) and recovered the Ku-Band operation. Another BCE bypass occurred at 251:01:19 G.m.t. (00:10:10 MET). The system was placed in standby until a recovery plan was developed. After the crew was awakened, the Ku-band was powered off, the circuit breakers cycled, and the Ku-Band repowered at 251:07:20 G.m.t. (00:16:11 MET). Another I/O reset was performed, and the Ku-Band system began functioning normally. This signature did not repeat throughout the remainder of the mission. Extensive postflight troubleshooting could not reproduce the problem.

At approximately 258:23:45 G.m.t. (08:08:36 MET), a loss of Ku-band forward link was detected. The forward link was showing signal strength but the data were not being demodulated. The problem was believed to be within electronics assembly (EA) -1. The S-Band forward link remained operational throughout the mission. Two attempts were made to regain the Ku-Band uplink. The first procedure involved a change from spread spectrum to unspread spectrum. The second procedure recycled Ku-Band power. Since neither attempt was successful, the Ku-Band uplink capability was declared lost for the remainder of the mission. Ku-band downlink capability remained operational. Postflight troubleshooting confirmed the failure was within EA-1, and the EA-1 unit was replaced.

Operational Instrumentation/Modular Auxiliary Data System

The operational instrumentation and the modular auxiliary data system (MADS) operated nominally throughout the mission. The master timing unit (MTU) did cause an intermittent "frequency difference" bite. This condition did not operationally impact the mission. Postflight tests verified that the frequencies were within specification, and no anomalous condition existed.

Structures and Mechanical Subsystems

The structures and mechanical subsystems performed nominally during the mission. The drag chute performance was nominal. The postflight inspection revealed that the tires and brakes were in satisfactory condition, and the landing and braking data are shown in the table on the following page.

Approximately one hour prior to launch, the side hatch was closed and the seal leak check was performed in accordance with prescribed procedures. Using the ground support equipment (GSE) pressure-supply system, the cavity between the two hatch/Orbiter seals was pressurized. The requirement is to pressurize to 15.0 psig ± 1.0 psig, and verify that the pressure decrease was no more than 1 psig per minute. Since the pressure decrease was at the maximum allowable rate, the decision was made to open the hatch and inspect the seals.

Landing and Braking Parameters

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	1981	211.4	~ 4.4	N/A
Nose gear touchdown	6333	154.8	N/A	~5.6

Brake initiation speed	118.0 knots
Brake-on time	36.6 seconds
Rollout distance	10,246 feet
Rollout time	59.9 seconds
Runway	33 (Concrete) SLF @ KSC
Winds	5 knots steady from 220 deg true (4.7 lft to rght, 1.7 tail)
Orbiter weight at landing	219,377 lb

Brake sensor location	Peak pressure, psia	Brake assembly	Energy, million ft-lb
Left-hand inboard 1	936	Left-hand outboard	11.09
Left-hand inboard 3	840	Left-hand inboard	12.81
Left-hand outboard 2	876	Right-hand inboard	12.92
Left-hand outboard 4	888	Right-hand outboard	10.82
Right-hand inboard 1	1020		
Right-hand inboard 3	900		
Right-hand outboard 2	840		
Right-hand outboard 4	876		

No debris or seal discontinuities were found and the seals were wiped down with isopropyl alcohol. The hatch was then closed and the final leak check was within specification, and a go for launch was given.

The ET/Orbiter separation devices (EO-1, EO-2, and EO-3) functioned normally. All Orbiter umbilical separation ordnance retention shutters were closed properly, and no debris was found on the runway beneath the umbilicals.

Integrated Aerodynamics, Heating and Thermal Interfaces

The prelaunch thermal interface purges were nominal. Likewise, the ascent aerodynamics and plume heating was nominal. Entry aerodynamic heating and aerodynamics were nominal.

Data evaluation showed that the integrated heating was nominal during ascent and entry. Thermal interface temperatures were nominal.

Thermal Control System

The performance of the thermal control system (TCS) was nominal during all phases of the mission. All subsystem temperatures were maintained within acceptable limits.

Aerothermodynamics

Aerothermodynamics were nominal during entry with acreage heating as well as local heating being well within the expected ranges. Boundary layer transition was likewise normal.

Thermal Protection System

The prelaunch closeout crew reported that a filler bar under a crew-hatch carrier panel appeared to be missing. Based on the description from the closeout crew, it is believed that the location of the missing filler bar was under the upper (-Z side of the hatch window) carrier panel adjacent to the window carrier panel tiles. The closeout crew verified that the advanced flexible reusable surface insulation (AFRSI) blanket on the carrier panel had a butt fit to the adjacent thermal protection subsystem (TPS) and the decision was made to fly as-is. The filler bar protects the structure from gap heating. The butt fit protects the structure and temperatures in this area would not cause significant damage if a gap existed.

The thermal protection system (TPS) performed satisfactorily. Based on structural temperature response data (temperature rise), the entry heating was nominal. Boundary layer transition from laminar to turbulent flow was symmetric, occurring at 1295 seconds after entry interface at the forward centerline of the vehicle and the aft centerline of the vehicle.

Based on data from the debris team inspection, overall debris damage was above average when compared with 55 previous missions of similar configuration. Postlanding inspection data showed that the Orbiter TPS had 198 hits of which 27 had a major dimension of 1 inch or greater. This total does not include the numerous hits on the base heat shield attributed to flame arrestment sparkler system.

A total of 175 impacts were counted on the lower surface of the vehicle (average = 91). The number of impacts on the lower surface with a major dimension of one inch or greater was 22, which is also above the average of 14. The majority of the lower surface damage sites (116 total with 13 greater than one inch) were concentrated in an area just aft of the left-hand ET door. This damage was most likely caused by a combination of impacts from ice and shredded pieces of umbilical purge barrier material flapping in the airstream.

Many tile damage sites were located to the right of the centerline on the lower surface along a line from the nose to tail, and these hits are generally caused by ice impacts from the ET liquid oxygen feedline bellows and support brackets.

A total of 16 hits were noted on the upper surface with three having a major dimension of one inch or greater; one hit on the right side; no hits on the left side; three hits on the right OMS pod with one hit having a major dimension of one inch or greater; and three hits on the left OMS pod with one hit having a major dimension of 1inch or greater. None of the tile damage was attributed to micrometeorites or on-orbit debris.

All three dome-mounted heat shield (DMHS) closeout blankets were in excellent condition with no tears or missing material. Tiles on the vertical stabilizer stinger area and around the drag chute door were intact and undamaged. A piece of tile, 2.25 inches long by 2 inches wide by 5/8 inch thick was missing on the base heat shield outboard of SSME 2 with the filler bar exposed. No thermal degradation was apparent.

Orbiter windows 3 and 4 exhibited moderate hazing and streaking. A light haze was present on the other windows. Tile damage on the window perimeter was concentrated above window 3. The 11 tile damage sites in this window 3 and 5 area were probably caused by impacts from forward RCS paper cover pieces or room temperature vulcanizing (RTV) material.

REMOTE MANIPULATOR SYSTEM

The Remote Manipulator System (RMS) performed in an excellent manner throughout the mission on this the tenth flight of this RMS arm (S/N 303). The primary activities performed were the deployment and retrieval of the SPARTAN-201, the deployment and retrieval of the WSF, and the support provided during the EVA.

The RMS was selected at 250:19:32:20 G.m.t. (00:04:26:25 MET) in preparation for the RMS checkout which was performed with no anomalies. A payload bay survey was performed immediately after the checkout, and the RMS was deselected and cradled at 250:22:23 G.m.t. (00:07:14 MET).

The RMS was powered up at 251:14:39:27 G.m.t. (00:23:30:27 MET) in preparation for the SPARTAN deployment. The RMS grappled and unberthed the payload, and the SPARTAN was successfully released at 251:15:42:58 G.m.t. (01:00:34 MET). Following the SPARTAN-201 release, the RMS was placed in the unloaded extended park position for the crew sleep period.

On flight day 3, the RMS was used to support the activities of the Orbiter Space Vision System (OSVS) video taping (DTO-700-10), and the Manipulator Position Display (MPD) Evaluation (DTO 831). RMS cameras were used to view OSVS targets mounted on the ram side of the WSF, and the MPD was evaluated while the arm was maneuvered through a series of predefined positions. Time constraints caused the MPD activities to be terminated after six of the 14 tasks were completed.

The RMS successfully captured the SPARTAN 201 at 253:15:02:22 G.m.t. (02:23:52:22 MET). Berthing of SPARTAN 201 was completed at 253:15:21:17 G.m.t. (03:00:12:17 MET). At 253:20:13:03 G.m.t. (03:05:04:03 MET), the RMS grappled the WSF in the payload bay. The RMS remained grappled to the WSF until the WSF was released at approximately 254:11:25:06 G.m.t. (03:20:16:06 MET).

The rendezvous with the WSF was completed satisfactorily, and the WSF was grappled at 257:13:59:11 G.m.t. (06:22:50:11 MET). The RMS operated satisfactorily throughout the WSF grappling and berthing activities. The WSF was grappled and unberthed at 258:07:17 G.m.t. (07:16:08 MET), and the payload was placed in the charge hazards and wake studies (CHAWS) position. While the WSF was on the RMS, a number of experiments were completed, after which the WSF was berthed in the payload bay at 258:12:26 G.m.t. (07:21:17 MET).

The RMS, with the portable foot restraint (PFR) attached to the RMS wrist, was used during a 6.5-hour EVA that was performed to evaluate assembly and maintenance tasks for the International Space Station (ISS). The RMS positioned the EVA crewmembers at a task board located on the starboard side of the payload bay, as well as positioning the crewmembers approximately 30 feet above the payload bay to test new thermal modifications made to the spacesuit. Following the EVA, the arm was returned to the extended park position from where it was moved to the cradle position and powered down the following day.

EXTRAVEHICULAR ACTIVITY

The STS-69 EVA was the thirtieth EVA and the second EVA Development Flight Test (EDFT-02) of the Program. The EVA was performed very satisfactorily. The results of the thermal evaluations were excellent. The results of other evaluations indicated that additional testing is required in some areas. The extravehicular activity (EVA) was successfully completed with a total time of 6 hours and 46 minutes. Both crewmen, EV-1 (Voss) and EV-2 (Gernhardt), performed thermal evaluations while being exposed to a simulated worst case International Space Station cold environmental conditions. The extravehicular mobility unit (EMU) modifications of the liquid cooling garment bypass and heated gloves that were designed to aid in warming the EV crewmembers performed as designed. Both crewmembers commented that their thermal comfort was maintained throughout the EVA. Detailed results of the EVA are available from the EVA Spacesuit and System personnel at Johnson Space Center (JSC).

The extravehicular mobility unit (EMU) checkout was performed over a 2-hour 26-minute period beginning at 256:07:59 G.m.t. (05:16:50 MET). Both EMUs performed as expected during the checkout and were ready to support the extravehicular activity (EVA) on flight day 10.

The EVA preparations were nominal with the 40-minute prebreathe beginning 11 minutes behind the timeline. During the course of the prebreathe, the intravehicular crewmembers were also preparing for their participation in the EVA. The prebreathe was completed at 259:08:00 G.m.t. (08:16:51 MET), at which point the airlock depressurization began. The two crewmembers egressed the airlock at 259:08:32 G.m.t. (08:17:23 MET).

The first planned activity of translation adaptation was quickly completed, and the task of payload bay set-up was initiated. As part of the set-up, EV2 installed one thermal cube on the portable foot restraint (PFR), which had been mounted on the RMS. This would enable temperature measurements during the cold-soak thermal conditioning exercise that was performed by both crewmembers.

Following completion of EV2's tasks with the RMS, EV2 was translated by the RMS to the EVA task board where a second thermal cube was installed to measure payload bay temperatures.

The Task Board Evaluation involved evaluation of tasks that could not be adequately tested in one-g, or in the Weightless Environment Training Facility (WETF), or the zero-gravity aircraft. Each crewmember performed the same tasks, and as each crewmember performed each task, a rating was given as to the acceptability or non-acceptability of each task. The tasks in addition to the

EVA Task Board included a EMU thermal evaluation including the heated gloves, a placard and lighting evaluation, and an on-going evaluation of the electronic cuff checklist throughout the EVA.

After completion of the various tasks, the payload bay was cleaned up in preparation for ingressing the airlock. The crew ingressed the airlock, and airlock repressurization was initiated at 259:15:03 G.m.t. (08:23:54 MET). The EVA was 6 hours 46 minutes in length. Cabin repressurization to 14.7 psia began at 259:15:54 G.m.t. (09:00:45 MET) and was completed at 259:16:10 G.m.t. (09:01:01 MET).

FLIGHT CREW EQUIPMENT/GOVERNMENT FURNISHED EQUIPMENT

At 250:16:34 G.m.t. (00:01:25 MET), the crew reported that the middeck audio terminal unit (ATU) had failed, resulting in the loss of the middeck speaker unit (Flight Problem STS-69-F-01). The crew noted that circuit breaker 5 on panel R15, which powers the ATU, was open. This same failure occurred on the previous flight of OV-105 (STS-67). The crew believes that the circuit breaker popped following the first attempt to communicate using a hand-held microphone (HHM) (S/N 1014), which was not the same HHM used during STS-67 (HHM S/N 1020). Data were reviewed and a current spike was not identified. At 251:14:33 G.m.t. (00:23:24 MET), the Mission Specialist (MS) ATU circuit breaker on panel R14 row A abruptly opened when the crew plugged in the same HHM (S/N 1014) and extension cable that opened the circuit breaker on the middeck ATU. The crew reset the flight deck circuit breaker and continued normal operations using the flight deck HHM (S/N 1019).

At approximately 251:17:45 G.m.t. (01:02:36 MET), the crew closed the middeck ATU circuit breaker (5). Circuit breaker 5 remained closed and communications were nominally received through the middeck speaker. This suspect hardware was stowed and was not used for the remainder of the mission. At 252:11:00 G.m.t. (01:19:51 MET), the crew plugged in HHM (S/N 1020) on the middeck, and a good communications check was performed with the ground using this unit. No anomalous current traces were seen and the middeck ATU circuit breaker 5 did not open. Postflight troubleshooting and testing of the middeck communications extension cable (S/N 5011) and HHM (S/N 1014) revealed that a hard short existed in the HHM cable near the strain relief on the microphone.

At 253:17:17 G.m.t. (03:02:08 MET), the crew reported that camcorder (L1) would not eject the tape. Troubleshooting was not successful in correcting the problem (Flight Problem STS-69-F-02). However, later in the mission, the crew reported that the tape cassette had been extracted from the camcorder, and the tape was shredded. A new tape was installed and the camcorder operated for the remainder of the mission, but exhibited distortion in the lower portion of the image.

At 256:11:10 G.m.t. (05:20:01 MET), the crew reported that the Arriflex camera was running slow (Flight Problem STS-69-F-04). Although the camera battery light was green, indicating that the battery was satisfactory, the crew changed the battery. Normal camera operation was regained after the battery replacement.

At 257:18:29 G.m.t. (07:03:20 MET), the crew reported that the rower cord would not retract when pulled out (Flight Problem STS-69-F-05). Apparently, a power spring failure occurred and the rower was not used for the remainder of the mission.

At approximately 258:07:10 G.m.t. (07:16:01 MET), closed circuit television (CCTV) monitor 2 emitted a loud "crack" and the screen went blank (Flight Problem STS-69-F-06). The crew turned the unit off and checked the circuit breaker, which was found closed. Review of the data did not reveal any power spikes associated with the event. The crew cleaned the filter on CCTV monitors 1 and 2, and repowered monitor 2 verifying its proper operation. CCTV monitor 2 performance was nominal for the remainder of the mission. Postflight, the crew reported that the monitor had gone blank on two other occasions. The monitor was removed and sent to the vendor for troubleshooting and analysis.

At 256:01:55 G.m.t. (05:10:46 MET), the video downlink from camera D (color television camera) was lost. The ground cycled the camera power, and normal operation was restored.

CARGO INTEGRATION

The integration hardware performance was nominal throughout the mission with no anomalies identified.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

A total of 21 development test objectives (DTOs) and 16 detailed supplementary objectives were assigned to the STS-69 mission. Each DTO is listed and where preliminary results are available, these are provided.

DEVELOPMENT TEST OBJECTIVES

DTO 301D - Ascent Structural Capability Evaluation - This DTO was a data-only DTO and the data were recorded on the MADS recorder, which cannot be dumped during the flight. The data have been given to the sponsor for evaluation. The results will be published in separate documentation.

DTO 305D - Ascent Compartment Venting Evaluation - This DTO was a data-only DTO and the data were recorded on the MADS recorder, which cannot be dumped during the flight. The data have been given to the sponsor for evaluation. The results will be published in separate documentation.

DTO 306D - Descent Compartment Venting Evaluation - This DTO was a data-only DTO and the data were recorded on the MADS recorder, which cannot be dumped during the flight. The data have been given to the sponsor for evaluation. The results will be published in separate documentation.

DTO 307D - Entry Structural Capability - This DTO was a data-only DTO and the data were recorded on the MADS recorder, which cannot be dumped during the flight. The data have been given to the sponsor for evaluation. The results will be published in separate documentation.

DTO 312 - ET TPS Performance (Method 1 and 3 Only) No Planned Maneuvers - The hand-held photography portion of this DTO was not performed because the vehicle was, as planned, not maneuvered to an attitude where the ET would be visible.

Three rolls of umbilical well photography film, one 35 mm and two 16 mm, were reviewed. The only item of significance was a thin, circular object with a circular hole in the center that was seen near the electrical cable tray, and the object tumbled away from the Shuttle. No damage was observed in the film from the object. All other observations have been seen from previous launches and were not of any significance.

DTO 414 - APU Shutdown Test (Sequence A) - The APUs were shut down in the order required by the DTO (3, 1, and 2). The data analysis revealed no back-driving of the power drive unit (PDU).

DTO 415 - Water Spray Boiler Electrical Heater Capability - The heater on WSB 3 was activated along with the portable data acquisition package (PDAP) during ascent. No anomalous behavior was noted in the data. The results of the evaluation of the data from this DTO will be published in separate documentation.

DTO 653 - Evaluation of the MK-1 Rowing Machine-1 Locker - Exercise was accomplished on the rowing machine until late in flight day 8 when the crew reported a failure of the rower spring which provides the needed resistance. Results of the evaluation and a discussion of the failure will be reported in separate documentation.

DTO 656 - PGSC Single Event Upset Monitoring (Configuration 2 Only) - Data collected by the crew using the payload general support computers (PGSCs) were provided to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DTO 667 - Portable In-Flight Landing Operations - The Portable In-Flight Landing Operations Trainer (PILOT) was exercised by the crew on flight day 10. The crew evaluation of the PILOT has been given to the sponsor, and the results of that evaluation will be reported in separate documentation.

DTO 671 - EVA Hardware for Future Scheduled EVA Missions, Test 10 - This DTO was a part of the EVA Development Flight Test -02 (EDFT-02) that required a 10.2 psia protocol and a minimum 6-hour EVA. The test protocol for this DTO was successfully completed. The data for this DTO was given to the sponsor, and the results of the sponsor evaluation will be reported in separate documentation.

DTO 672 - EMU Electronic Cuff Checklist - This DTO protocol was successfully performed during the EVA. The results have been given to the sponsor for evaluation, and the results of that evaluation will be published in separate documentation.

DTO 679 - Ku-band Communications Adapter Demonstration - The Ku-band Communications Adapter (KCA) performed flawlessly throughout the mission and all DTO objectives were accomplished. In addition, the KCA was used to transfer messages between the crew and ground and successfully transfer large amounts of experiment data for DTO 700-8 (GPS) and Risk Mitigation Experiment 1311 (Relative GPS). The results of the sponsors evaluation of this experiment will be published in separate documentation.

DTO 700-8 - Global Positioning System Development Flight Test - The Global Positioning System (GPS) Development Flight Test was completed satisfactorily. Early data analysis indicates that fewer system reinitializations were required than on previous flights. Approximately 350 megabytes of GPS data were downlinked for evaluation by the sponsor, and the results of that evaluation will be published in separate documentation.

DTO 700-10 - Orbiter Space Vision System Flight Video Taping - Data were collected for this DTO on flight day 3. The RMS cameras provided views of the various WSF areas.

DTO 805 - Crosswind Landing Performance -This DTO was not performed because insufficient crosswinds were present at the time of landing.

DTO 831 - Manipulator Position Display as an Aid to RMS Operators - Activities in support of this DTO were performed from 252:17:53 G.m.t. (02:02:44 MET) to 252:18:57 G.m.t. (02:03:48 MET). Because of time constraints, only 6 of the 14 planned tasks were performed. The data from this evaluation has been given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

DTO 833 - EMU Thermal Comfort Evaluations (10.2-psia Prebreathe Protocol) - The tests required in support of this DTO were successfully completed. The crew reported that the heated gloves and the EMU modifications (Liquid Cooling and Ventilation Garment bypass capability) worked very well. The data have been given to the sponsor for evaluation, and the results will be published in separate documentation.

DTO 914 - Space Linear Acceleration Mass Measurement Device Evaluation (SLAMMD) - The crew reported finishing the flight day 3 activities for this DTO. Other activities later in the flight were also accomplished. The data have been given to the sponsor for evaluation, and the results will be published in separate documentation.

DTO 1210 - EVA Operations Procedures/Training (10.2-psia Prebreathe Protocol) - All required activities in support of this DTO were accomplished during the EVA. The data have been given to the sponsor for evaluation, and the results will be published in separate documentation.

DETAILED SUPPLEMENTARY OBJECTIVES

The results of the DSOs require a significant amount of time to evaluate and present the results. Data were collected for each of the DSOs and these data have been given to the sponsor for evaluation. The release or publication of the results is the responsibility of the sponsor. The DSOs performed on the STS-69 mission are as follows:

1. DSO 482 - Cardiac Rhythm Disturbances during Extravehicular Activity;
2. DSO 483 - Back Pain Pattern in Microgravity;
3. DSO 485 - Inter MARS TEPC (ITEPC) (1 located in bay 5, port side, and the second is located in bay 5 starboard side);
4. DSO 487 - Immunological Assessment of Crewmembers (Preflight and Postflight Only);
5. DSO 489 - EVA Dosimetry Evaluation;
6. DSO 491 - Characterization of Microbial Transfer Among Crewmembers During Spaceflight (Pre and Postflight Only);
7. DSO 492B - In-Flight Evaluation of a Portable Clinical Blood Analyzer;
8. DSO 494 - Influence of Microgravity and Extravehicular Activities on Pulmonary Oxygen Exchange;
9. DSO 604 - O1-3B Visual-Vestibular Integration as a Function of Adaptation (Pre and Postflight Only);
10. DSO 605 - Postural Equilibrium Control During Landing/Egress (Pre and Postflight Only);
11. DSO 608 - Effects of Space Flight on Aerobic and Anaerobic Metabolism During Exercise;
12. DSO 610 - In-Flight Assessment of Renal Stone Risk;
13. DSO 624 - Pre and Postflight Measurement of Cardiorespiratory Responses to Submaximal Exercise;
14. DSO 901 - Documentary Television;
15. DSO 902 - Documentary Motion Picture Photography; and
16. DSO 903 - Documentary Still Photography.

PHOTOGRAPHY AND TELEVISION ANALYSIS

LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS

A total of 24 videos of launch were screened for anomalous conditions. In addition, 51 films of launch activities were also screened. No potential anomalies were identified in the screening activity.

Post-separation photographs of the ET were taken with the umbilical well mounted 35 mm camera and two 16 mm cameras. Analysis of the photography showed less than usual number of small "popcorn"-type divots in the aft LH_2 tank acreage, and normal minor erosion on the LO_2 feedline flange and thrust strut flange closeouts. In addition, no divots were visible in the +Z area of the intertank-to-LH_2 tank flange closeout, and the redesigned jack pad closeouts performed satisfactorily.

ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS

No requirements were expressed for any screening of on-orbit film, because no anomalous activities documented with film.

LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSIS

A total of 10 films and 10 videos of landing were screened for anomalous conditions, and no potential anomalous conditions were identified.

TABLE I.- STS-69 MISSION EVENTS

Event	Description	Actual time, G.m.t.
APU Activation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	250:15:04:11.093 250:15:04:13.029 250:15:04:14.868
SRB HPU Activation[a]	LH HPU System A start command LH HPU System B start command RH HPU System A start command RH HPU System B start command	250:15:08:32.115 250:15:08:32.275 250:15:08.32.435 250:15:08:32.595
Main Propulsion System Start[a]	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	250:15:08:53.443 250:15:08:53.568 250:15:08:53.681
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	250:15:08:59.995
Throttle up to 104 Percent Thrust[a]	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	250:15:09:03.682 250:15:09:03.684 250:15:09:03.689
Throttle down to 67 Percent Thrust[a]	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	250:15:09:29.922 250:15:09:29.924 250:15:09:29.929
Maximum Dynamic Pressure (q)	Derived ascent dynamic pressure	250:15:09:50
Throttle up to 104 Percent[a]	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	250:15:10:00:163 250:15:10:00.165 250:15:10:00.169
Both SRM's Chamber Pressure at 50 psi[a]	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	250:15:10:56.955 250:15:10:57.155
End SRM [a] Action[a]	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	250:15:10:59.325 250:15:10:59.505
SRB Physical Separation[a]	LH rate APU turbine speed - LOS RH rate APU turbine speed - LOS	250:15:11:02.435 250:15:11:02.435
SRB Separation Command	SRB separation command flag	250:15:11:03
Throttle Down for 3g Acceleration[a]	ME-1 command accepted ME-3 command accepted ME-2 command accepted	250:15:16:32.970 250:15:16:32.973 250:15:16:32.976
3g Acceleration	Total load factor	250:15:16:34.9
Throttle Down to 67 Percent Thrust[a]	ME-1 command accepted ME-3 command accepted ME-2 command accepted	250:15:17:23.531 250:15:17:23.534 250:15:17:23.537
SSME Shutdown[a]	ME-1 command accepted ME-3 command accepted ME-2 command accepted	250:15:17:30.171 250:15:17:30.174 250:15:17:30.177
MECO	MECO command flag MECO confirm flag	250:15:17:31 250:15:17:31
ET Separation	ET separation command flag	250:15:17:50

[a]MSFC supplied data

TABLE I.- STS-69 MISSION EVENTS (Continued)

Event	Description	Actual time, G.m.t.
APU Deactivation	APU-3 GG chamber pressure APU 1 GG chamber pressure APU 2 GG chamber pressure	250:15:23:05.064 250:15:23:23.026 250:15:23:40.029
OMS-1 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Not performed - direct insertion trajectory flown
OMS-1 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	
OMS-2 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	250:15:50:44.5 250:15:50:44.6
OMS-2 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	250:15:53:52.1 250:15:53:52.2
Payload Bay Doors (PLBDs) Open	PLBD right open 1 PLBD left open 1	250:16:51:47 250:16:51:53.06
SPARTAN-201 Unberth	PLD SEL 1 latch 3A ready-to-latch	251:15:12:46
SPARTAN-201 Deploy	PLD captured	251:15:42:58
SPARTAN-201 Capture	PLD captured	253:15:02:22
SPARTAN-201 Berth	PLD SEL 1 latch 3A ready-to-latch	253:15:21:17
SPARTAN-201 Latached	PLD SEL 1 latch 3A latch	253:15:22:24
OMS-3 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	253:18:35:42.7 Not applicable
OMS-3 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	253:18:36:17.3 Not applicable
OMS-4 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Not applicable 253:19:21:35.3
OMS-4 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	Not applicable 253:19:22:04.5
WSF Unberth	PLD SEL 2 latch 1A ready-to-latch	254:05:50:53
WSF Deploy	PLD captured	254:11:25:06
OMS-5 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	257:07:09:18.1 Not applicable
OMS-5 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	257:07:09:28.9 Not applicable
OMS-6 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Not applicable 257:10:16:55.4
OMS-6 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	Not applicable 257:10:17:08.6
WSF Capture	PLD captured	257:13:59:11
WSF Berth	PLD SEL 3 latch 1A ready-to-latch	257:15:16:28
WSF Latched	PLD SEL 2 latch 1A latch	257:15:18:59
OMS-7 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	257:16:47:10.1 Not applicable
OMS-7 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	257:16:48:13.9 Not applicable
OMS-8 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Not applicable 257:17:32:21.5
OMS-8 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	Not applicable 257:17:33:29.8

[a]MSFC supplied data

TABLE I.- STS-69 MISSION EVENTS (Continued)

Event	Description	Actual time, G.m.t.
Flight Control System Checkout		
APU Start	APU-1 GG chamber pressure	260:07:20:33.659
APU Stop	APU-1 GG chamber pressure	260:07:25.45.065
Payload Bay Doors Close	PLBD left close 1 PLBD right close 1	261:07:56:53 261:07:59:24
APU Activation for Entry	APU-3 GG chamber pressure APU-2 GG chamber pressure APU-1 GG chamber pressure	261:10:24:45.325 261:10:53:53.550 261:10:54:02.373
Deorbit Burn Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	261:10:35:13.1 261:10:35:13.1
Deorbit Burn Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	261:10:38:50.0 261:10:38:50:0
Entry Interface (400K feet)	Current orbital altitude above	261:11:06:23
Blackout end	Data locked (high sample rate)	No blackout
Terminal Area Energy Mgmt.	Major mode change (305)	261:11:31:30
Main Landing Gear Contact	LH main landing gear tire pressure 1 RH main landing gear tire pressure 2	261:11:37:56 261:11:37:56
Main Landing Gear Weight on Wheels	LH main landing gear weight on wheels RH main landing gear weight on wheels	261:11:37:56 261:11:37:56
Drag Chute Deployment	Drag chute deploy 1 CP Volts	261:11:38:03.2
Nose Landing Gear Contact	NLG LH tire pressure 1	261:11:38:08
Nose Landing Gear Weight On Wheels	NLG weight on wheels 1	261:11:38:09
Drag Chute Jettison	Drag chute jettison 1 CP Volts	261:11:39:35.6
Wheel Stop	Velocity with respect to runway	261:11:38:56
APU Deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	261:11:52:02.346 261:11:52:03.770 261:11:52:04.353

TABLE II.- ORBITER PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-69-V-01	Ku-Band BCE Bypass	251:00:56 G.m.t. 00:09:47 MET CAR 69RF02	At 251:00:56 G.m.t.(00:09:47 MET), a Ku-band BCE bypass fault occurred. An input/output (I/O) Reset was performed at 251:01:03 G.m.t. (00:09:54 MET) by the crew and Ku-band operation was recovered. Another BCE bypass occurred at 251:01:19 G.m.t. (00:10:10 MET). The system was placed in standby until a recovery plan was developed. After the crew was awake, the crew powered off the Ku-band, cycled the circuit breakers, and repowered the Ku-band at 251:07:20 G.m.t. (00:16:11 MET). Another I/O reset was performed, and the Ku-band system began functioning nominally. KSC: Troubleshooting was performed to isolate the problem. An under-voltage condition is suspected.
STS-69-V-02	CRT 1 Dim Display Level III Closure	250:18:36 G.m.t. 00:03:27 MET CAR 69RF03	At 250:18:36 G.m.t. (00:03:27 MET), the crew reported that the display on CRT 1 (S/N 25) was so dim that it was hard to read. The crew reported that the condition had existed since the prelaunch time frame and that CRT 1 was dim constantly from prelaunch until the time it was powered off (not degrading). Troubleshooting did not change the brightness level of the display. The crew used CRT 1 for entry, and no IFM was performed. KSC: CRT 1 (S/N 25) will be removed and replaced.
STS-69-V-03	Low Signal Strength on S-band Preamplifier 2 Level III Closure	250:15:40 G.m.t. 00:00:31 MET IPR-72V-0013	S-band preamplifier 2 data showed 3-7dB less uplink signal strength than preamplifier 1. The decrease was noted to be independent of which transponder, frequency, antenna, or TDRS being used. KSC: Troubleshooting (including retest not performed during last flow) will be performed.
STS-69-V-04	Waste Dump Blockage Level III Closure	258:17:12 G.m.t. 08:02:03 MET CAR 69RF05 IPR 72V-0011	At the indicated time, the crew was instructed to terminate the waste dump because the waste tank quantity ceased to decrease. A subsequent dump attempt was terminated due to low flow. An IFM revealed that the dump line from the contingency cross tie to the nozzle was clear. The crew then bypassed the urine solids filter with hoses and the backup urine solids filter. Waste dump using the bypass started nominally, but flow stopped after about 5 minutes, indicating the backup filter was clogged. Crew off-loaded excess waste water into a contingency water container. KSC: Postflight analysis of filters is complete, and this does not appear to be the cause of the blockage. Nozzle flow checks were also clean, and no anomalies were noted. Line heater wrap inspections and nozzle tube X-rays will be performed.
STS-69-V-05	Ku-Band EA-1 Failure	258:23:45 G.m.t. 08:08:36 MET CAR 69RF06 IPR 72V-0007	The Ku-band forward link was lost at the noted time. Return link had also been lost but was regained by going to the Designate mode. Forward link showed signal strength but no demodulation. Neither sending an unspread signal or power cycling the Ku-band system regained the forward link. KSC: Troubleshooting repeated failure. More troubleshooting to confirm EA-1 as source of problem. Probable EA-1 removal and replacement.

TABLE II.- ORBITER PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-69-V-06	Hydraulic System 3 Main Pump Low Pressure Anomaly	261:09:58 G.m.t. 10:18:49 MET IPR 72V-0008	After the APU prestart at 261:09:58 G.m.t. (10:18:49 MET) for entry, there were no remote power controller (RPC) indications on hydraulic main pump system 3 depressurization. The crew cycled the APU low/norm switch four times in an attempt to take the system to low pressure. Nominal operation was achieved on the fourth switch cycle. KSC: Non-intrusive troubleshooting (wiring Hi-Pot, resistance checks, wire harness) completed and nothing anomalous was found. Wire replacements are in work.

TABLE III.- GOVERNMENT FURNISHED EQUIPMENT PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-69-F-01	Loss of Middeck Audio	250:16:34 G.m.t. 00:01:25 MET IPR 72V-0002	At 250:16:34 G.m.t. (00:01:25 MET), the crew reported that the middeck audio terminal unit (ATU) had failed, resulting in the loss of the middeck speaker unit. The crew noted that the circuit breaker powering the middeck ATU was open. At 251:14:33 G.m.t. (00:23:24 MET), a Mission Specialist (MS) ATU circuit breaker popped on the flight deck when the crew plugged in the same hand-held microphone (HHM) and extension cable that had been in use on the middeck prior to the loss of the middeck audio. The crew reset the flight deck circuit breaker and later the middeck circuit breaker. The suspect HHM and extension cable were stowed, and nominal communications operations were restored on the middeck and flight deck.
STS-69-F-02	Camcorder (L1) Eject Failure	253:17:17 G.m.t. 03:02:08 MET	At the noted time, the crew reported that the camcorder (L1) would not eject the tape. Troubleshooting effort did not recover the camcorder until later in the mission when the crew was able to remove the tape. The camcorder was usable the remainder of the mission.
STS-69-F-03	Camera D Loss of Downlink	256:01:55 G.m.t. 05:10:46 MET	At the noted time, the video downlink from camera D (a CTVC camera) was lost. The ground cycled the power to the camera via uplink command and normal operation was recovered.
STS-69-F-04	Arriflex Camera Battery Problems	256:11:10 G.m.t. 05:20:01 MET	The crew reported that the Arriflex camera was running slow. The crew changed the battery and nominal camera operation was restored.
STS-69-F-05	Rower Failure	257:19:34 G.m.t. 07:04:25 MET	At the noted time, the crew reported that the rower cord would not retract when pulled out for use. This is believed to be a spring failure.
STS-69-F-06	CCTV Monitor 2 Transient Failure	258:07:20 G.m.t. 07:16:11 MET	CCTV Monitor 2 made a "crack" sound and went blank. The crew powered off the monitor, cleaned the filter, and successfully repowered the monitor, which functioned nominally for the remainder of the mission.

TABLE III.- GOVERNMENT FURNISHED EQUIPMENT PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-69-F-07	Lack of Power to EMU EV Communicator	259:05:27 G.m.t. 08:14:18 MET	When EMU 1 went to the comm mode A, telemetry showed that the EVC was not being powered by the airlock power supply. The crew reported BATT AMPS were 0. EMU 1 was cycled from SCU to BATT and back, and the EVC was powered up nominally
STS-69-F-08	EMU 2 "Set PWR SCU" Message	259:08:14 G.m.t. 08:17:05 MET	During prebreathe, EV2 received "Set PWR SCUP" message. Vehicle airlock power supply downlink showed that EMU 2 was powered by SCU. Message cleared and was apparently intermittent during prebreathe and depressurization.
STS-69-F-09	Power Tool Failure	259:12:47 G.m.t. 08:21:38 MET	During task board operations, EV2 reported problems with power tool S/N 1002. The battery was swapped, but power tool was reported not working 27 minutes later. Crew reported power tool worked after ingress.
STS-69-F-10	Portable Foot Restraint Fit	259:10:03 G.m.t. 08:18:54 MET	Both EV crewmembers reported that they had problems egressing the PFR. This PFR was the one stowed on the WSF carrier.
STS-69-F-11	Safety Tether Velcro Strap On Camera A Mount		During ingress, EV2 reported that the safety tether Velcro strap on the port forward camera mount was not sticking.

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.

ACS	attitude control system
ADACS	Attitude Determination and Control System
AFRSI	advanced flexible reusable surface insulation
AOPROC	Atomic Oxygen Processing Experiment
APE-B	Auroral Photographic Experiment (B)
APU	auxiliary power unit
ATCS	active thermal control system
AT	audio terminal unit
BCE	bus control element
BRIC	Biological Research in Canisters
CAPL-2/GBA	Capillary Pumped Loop-2/Getaway Special Bridge Assembly
CCTV	closed circuit television
CGBA	Commercial Generic Bioprocessing Apparatus
CHAWS	Charge Hazard and Wake Studies
CMIX	Commercial Middeck Instrumentation Technology Associates Experiment
CRT	cathode ray tube
CWC	contingency water container
DAP	digital autopilot
dB	decibel
DEC	declination
DMHS	dome-mounted heat shield
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
ΔV	differential velocity
EA	electronics assembly
EDFT-02	Extravehicular Activity Development Flight Test-02
EMU	extravehicular mobility unit
EPDC	electrical power distribution and control subsystem
EPICS	Electrolysis Performance Improvement Concept Study
ER	Electrorheological
ET	External Tank
EUV	extreme ultraviolet
EVA	extravehicular activity
FCE	flight crew equipment
FCS	flight control system
FES	flash evaporator system
FUV	far ultraviolet
ft/sec	feet per second
GAS	getaway special
GBA	GAS Bridge Assembly
GFE	Government furnished equipment
G.m.t.	Greenwich mean time
GNC	guidance, navigation and control

GSE	ground support equipment
HHM	hand-held microphone
HPFTP	high pressure fuel turbopump
HPOTP	high pressure oxidizer turbopump
IEH-1	International Extreme Ultraviolet Hitchhiker
IEU	integrated electronics unit
IFM	in-flight maintenance (procedure)
I/O	input/output
ISS	International Space Station
KCA	Ku-band communications adapter
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt/hour
lbm	pound mass
LCC	Launch Commit Criteria
LH_2	liquid hydrogen
LMES	Lockheed Martin Engineering and Science
LO_2	liquid oxygen
LOS	loss of signal
MADS	modular auxiliary data system
MDM	multiplexer/demultiplexer
MECO	main engine cutoff
MET	mission elapsed time
MPS	main propulsion system
MPD	Manipulator Position Display
MRS	minimum reserve shutdown
MS	Mission Specialist
MTU	master timing unit
N_2	nitrogen
NASA	National Aeronautics and Space Administration
nmi.	nautical mile
NPSP	net positive suction pressure
NSTS	National Space Transportation System (i.e., Space Shuttle Program)
O_2	oxygen
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OSVS	Orbiter Space Vision system
PAD	portable foot restraint
PAL	protuberance air load
PDAP	portable data acquisition package
PDU	power drive unit
PFI	
PGSC	payload general support computer
PILOT	Portable In-flight Landing Operations Trainer
PMBT	propellant mean bulk temperature
ppm	parts per million
PRSD	power reactant storage and distribution
psi	pound per square inch
psia	pound per square inch absolute

psig	pound per square inch gravity
QD	quick disconnect
RA	right ascension
RCRS	Regenerative Carbon Dioxide Removal System
RCS	reaction control subsystem
RFI	radio frequency interference
RGPS	relative global positioning system
RME	Risk Mitigation Experiment
RMS	Remote Manipulator System
RPC	remote power controller
RSRM	Reusable Solid Rocket Motor
RSS	Range Safety System
RTV	room temperature vulcanizing (material)
S&A	safe and arm
SEH	Solar Extreme Ultraviolet HItchhiker
SFE	Static Feed Electrolyzer
SLF	Shuttle Landing Facility
SLAMMD	Space Linear Acceleration Mass Measurement Device
S/N	serial number
SPARTAN 201	Shuttle Pointed Autonomous Research Tool for Astronomy
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSME	Space Shuttle main engine
STL-NIH-C	Space Tissue Loss-National Institutes of Health-Cells
TCE	condenser exit temperature
TCS	thermal control system
TDRS	Tracking and Data Relay Satellite
TES-2	Thermal Energy Storage-2
TI	terminal phase initiation
TPS	thermal protection subsystem
UP	
UVCS	ultraviolet coronal spectrometer
UVSTAR	ultraviolet spectrograph telescope for astronomical research
WCS	waste collection system
WLC	White Light Coronagraph
WSB	water spray boiler
WSF	Wake Shield Facility