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STS-78 SPACE SHUTTLE MISSION REPORT

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National Aeronautics and
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Lyndon B. Johnson Space Center
Houston, Texas

NOTE

The STS-78 Space Shuttle Mission Report was prepared from inputs received from the Space Shuttle Vehicle Engineering Office as well as other organizations. The following personnel may be contacted should questions arise concerning the technical content of this document.

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STS-78

SPACE SHUTTLE

MISSION REPORT

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INTRODUCTION

The STS-78 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-eighth flight of the Space Shuttle Program, the fifty-third flight since the return-to-flight, and the twentieth flight of the Orbiter Columbia (OV-102). In addition to the Orbiter, the flight vehicle consisted of an ET that was designated ET-79; three SSMEs that were designated as serial numbers 2041, 2039, and 2036 in positions 1, 2, and 3, respectively; and two SRBs that were designated BI-081. The RSRMs, designated RSRM-55, were installed in each SRB and the individual RSRMs were designated as 360L055A for the left SRB, and 360L055B for the right SRB.

The STS-78 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 objective of this flight was to successfully perform the planned operations of the Life and Microgravity Spacelab experiments. The secondary objectives of this flight were to complete the operations of the Orbital Acceleration Research Experiment (OARE), Biological Research in Canister Unit-Block II (BRIC), and the Shuttle Amateur Radio Experiment II-Configuration C (SAREX-II).

The STS-78 mission was planned as a 16-day, plus one day flight plus two contingency days, which were available for weather avoidance or Orbiter contingency operations. The sequence of events for the STS-78 mission is shown in Table I, and the Space Shuttle Vehicle Management 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. The Marshall Space Flight Center (MSFC) Problem Tracking List is shown in Table IV. 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 seven-person crew for STS-78 consisted of Terence T. Hendricks, Col., U. S. Air Force, Commander; Kevin R. Kregel, Civilian, Pilot; Richard M. Linnehan, Civilian, DVM, Mission Specialist 1; Susan J. Helms, Lt. Col., U. S. Air Force, Payload Commander, Flight Engineer, and Mission Specialist 2; Charles E. Brady, Jr., CDR, U. S. Navy, Mission Specialist 3; Jean-Jacques Favier, Civilian, Ph. D., (French Space Agency,) Payload Specialist 1; and Robert Brent Thirsk, Civilian, M. D., (Canadian Space Agency,) Payload Specialist 2. STS-78 was the fourth flight for the Commander; the third space flight for Mission Specialist 2; the second space flight for the Pilot; and the first space flight for Mission Specialist 1, Mission Specialist 3, Payload Specialist 1, and Payload Specialist 2.

MISSION SUMMARY

The STS-78 countdown proceeded nominally with no unplanned holds, and the vehicle was launched on-time at 172:14:49:00.019 G.m.t. (9:49 a.m. c.d.t.) on June 20, 1996. No Orbiter problems were noted during the countdown. The ascent phase was nominal, and the vehicle was inserted into the planned orbit having an inclination of 39 degrees.

A determination of vehicle performance was made using vehicle acceleration and preflight propulsion prediction data. From these data, the average flight-derived engine specific impulse (Isp) determined for the period between SRB separation and start of 3-g throttling was 453.57 seconds as compared to an SSME tag value of 453.05 seconds. All SSME and RSRM start sequences occurred as planned; however, SSME 3 (S/N 2036) violated the thrust buildup rate during the engine-start sequence (Flight Problem STS-78-E-01). The SSME anomaly did not impact the ascent phase, and the ascent phase performance was satisfactory. First stage ascent performance was nominal with SRB separation, entry, deceleration, and water impact occurring as expected. Performance of the SSMEs, ET and main propulsion systems was nominal.

Both SRBs were recovered and returned to KSC for disassembly and refurbishment. During the disassembly activities, it was noted that all six field joints exhibited some degree of sooting in the J-leg insulation region. Heavy sooting and heat effects (discoloration and charring) were observed on the J-leg insulation interfaces in the center (left-hand and right-hand) and aft (left-hand and right-hand) field joints (Flight Problem STS-78-M-01).

Postflight reconstruction indicated that there was less LH_2 and more LO_2 remaining than predicted preflight. The data indicate a potential mixture-ratio problem (Flight Problem STS-78-I-01). A review of the mixture ratio from the previous 11 flights shows the trend to be biased low with the STS-78 mixture ratio being 3σ low.

At approximately 172:14:54 G.m.t. (00:00:05 MET), a built-in test equipment (BITE) bit was set on multiplexer-demultiplexer (MDM) flight critical aft (FA) 1 card 14. This bit is indicative of a problem in the analog-to-digital (A/D) converter in the sequence control unit (SCU) or a problem in card 14. However, simultaneous with this BITE, the SSME 1 liquid hydrogen (LH_2) inlet pressure failed off-scale high (OSH). This pressure measurement is channelized through card 14 (channel 16). Analysis of the BITE logic indicates that an OSH voltage from this sensor will cause the BITE indication on MDM FA 1. Thus, this BITE is an explained condition. Postflight testing confirmed that the LH_2 inlet pressure transducer had failed. The transducer was removed and replaced.

During ascent, the flash evaporator system (FES) high-load duct temperatures were erratic and lower than normal (Flight Problem STS-78-V-02). The inboard duct temperature dropped to approximately 119 °F (normally remains above

190 °F) by 172:15:02 G.m.t. (13 minutes MET). The heaters were reconfigured from system-A-only to systems A and B at approximately 13.5 minutes MET, and the temperatures eventually recovered. Throughout the occurrence, the evaporator outlet temperatures were stable. No further problems with the FES were noted during ascent. To verify the performance of the high-load-duct system A heater, the heater was powered up at 173:16:14 G.m.t. (01:01:25 MET), and temperatures were monitored for approximately 2 hours and 45 minutes. A nominal temperature signature was observed.

At 172:15:18:30 G.m.t. (00:00:29:30 MET), the general purpose computer (GPC) 5 input/output (I/O) terminate B discrete began behaving erratically (Flight Problem STS-78-V-01). The backup flight system (BFS) software was contained in GPC 5. At 172:21:18 G.m.t. (00:06:29 MET), a hardware-initiated stand-alone memory (HISAM) dump of the BFS software contained in GPC 5 memory was performed to support troubleshooting the erratic I/O terminate B discrete condition. An analysis of the dump of the BFS software was performed, and no problems were found with the software. The BFS software was successfully loaded into GPC 2 at approximately 176:20:05 G.m.t. (04:05:16 MET). A dump-and-compare of the GPC 2 software confirmed a nominal software load. During the same time frame, GPC 5 was loaded with primary avionics software system (PASS) G2 software and placed in a redundant set with GPC 1. This configuration was maintained for the remainder of the on-orbit period and no anomalous GPC 5 behavior was observed. GPC 5 ran the PASS G3 software in the redundant set (commanding string 4) during entry and its performance was nominal.

During deorbit preparations at 189:09:19 G.m.t. (16:18:30 MET), the BFS, resident in GPC 2, registered an error code 41 (illegal engage) similar to the error that was logged during ascent when the BFS was in GPC 5. This occurrence was coincident with the GPC 4 output switch being taken from terminate to normal, which explained the error code.

Extensive postflight troubleshooting has been performed, and the problem has not recurred. However, the I/O terminate B wiring was removed and replaced, and damage was found in one of the connectors. Failure analysis will attempt to determine if the damage is the source of the problem.

The orbital maneuvering subsystem (OMS) 1 maneuver was not required as a direct ascent trajectory was flown. The OMS 2 maneuver was performed at 172:15:30:28.5 G.m.t. (00:00:41:28.5 MET). The maneuver was 117.5 seconds in duration, and the differential velocity (ΔV) was 185.5 ft/sec. The resulting orbit was 153.6 by 146.7 nmi. Following the OMS 2 maneuver, the payload bay doors were opened at 172:16:09 G.m.t. (00:01:20 MET).

As expected, the APU 1 fuel pump inlet pressure decayed after ascent following closure of the fuel isolation valve (FIV) as a result of fuel-pump carbon-seal leakage into the seal cavity drain (Flight Problem STS-78-V-05). This is the same APU that was flown in this position on the previous flight of OV-102 (STS-75), when a similar decay was observed. The fuel inlet pressure dropped to approximately 40 psia indicated (24 psia corrected) which was just above the indicated seal-cavity drain-line pressure of 22 to 23 psia. The pressure decayed at a higher rate this mission than during STS-75, indicating that the leak was becoming worse (the inlet pressure did not crack the FIV relief valve as is typically seen). Opening the FIV with a fuel pump inlet pressure above 15 psia was not a concern and dynamic seal leakage was not noted on this APU. Therefore, this leak did not pose a flight impact. APU 1 fuel pump seal performance was nominal during the entry run. During postflight operations, a total of 365 cc of hydrazine was drained from the APU 1 catch bottle.

At 189:11:51 G.m.t. (16:21:02 MET) when APU 1 was started for its entry run, the down-listed turbine speed sensor operation was erratic (Flight Problem STS-78-V-06). The erratic behavior continued for the first four minutes of the APU run. This is one of three turbine speed sensors in the APU and did not affect APU performance. Because of this condition as well as the APU 1 fuel pump seal leakage, the decision was made to remove and replace APU 1.

At approximately 174:15:50 G.m.t. (02:01:01 MET), while in the topping mode and on the primary A controller, the FES shut down (Flight Problem STS-78-V-03). A restart attempt on the A controller was unsuccessful, and was followed by an unsuccessful restart attempt on the B controller. Data from the shutdown and subsequent unsuccessful restarts indicated icing in the FES core. A FES core-flush initiated at 174:17:12 G.m.t. (02:02:23 MET) successfully removed the ice from the core. To reduce the heat load to the FES, at 174:18:13 G.m.t. (02:03:24 MET), the port radiator was deployed. The deployed radiator provided additional cooling capacity for the active thermal control system, and nominal FES operation was observed on the B controller in the supplemental cooling mode.

At approximately 180:08:19 G.m.t. (07:17:30 MET), a water dump through the FES using the B controller was initiated to troubleshoot the shutdown that occurred previously on the A controller. The FES subsequently shut down at approximately 180:10:08 G.m.t. (07:19:19 MET). The crew successfully performed the FES core-flush procedure to remove any ice that may have formed and caused the shutdown.

During deorbit preparations at approximately 189:10:04 G.m.t. (16:19:15 MET), the FES shut down after almost an hour and a half operating in the full-up mode on the primary B controller. The high-load core was flushed, and the data indicate ice was exiting through the high-load ducts. A flush was performed on the topping core followed by a second high-load core flush, but no additional ice was noted. The remainder of the mission was performed using the primary A controller with no further anomalies.

Postflight troubleshooting has lead to the removal of the system A and B high-load spray valves and flushing of the feedlines between the spray valves and the accumulators. An adjustment may be made to the Freon coolant loop (FCL) 1 flowrate to reduce the difference between its flowrate and that of FCL 2.

The quantities of hydrogen (H_2) tanks 4 and 5 began diverging at approximately 176:12:00 G.m.t. (03:21:11 MET) while fuel cell H_2 was being supplied by tanks 4 and 5 (Flight Problem STS-78-V-04). On OV-102, the H_2 tank 4 and 5 heaters share a heater controller and as such the heaters cycle on and off simultaneously. Troubleshooting, during which H_2 tanks 4 and 5 were operated for several hours on only the A-heaters followed by several hours on only the B-heaters, confirmed that the B heater on H_2 tank 4 had failed. The H_2 tank 4 and 5 heaters were then reconfigured for heater-A-only operation. This condition did not impact H_2 tanks 4 and 5 usage, and the cryogen's were used to tank depletion. KSC troubleshooting isolated the failure to a mechanically failed fuse in the B heater control circuit. A similar failure occurred on the last flight of OV-102 (STS-75) and was isolated to a fuse failure in the A heater control circuit. The fuse was replaced during the STS-78 flow. The STS-75 fuse failure was mechanical and caused by thermal stress cycles, not by an anomalous over-current condition.

At 185:17:04 G.m.t. (13:02:15 MET), the starboard radiator was deployed to provide additional cooling for the vehicle.

The RCS hot-fire was successfully performed at 188:08:34 G.m.t. (15:17:45 MET). All RCS thrusters functioned properly during the hot-fire.

The flight control systems (FCS) checkout was successfully performed, and nominal performance on all subsystems exercised during the checkout was observed. As planned, APU 2 was used for FCS checkout. The APU was started at 188:08:49:56 G.m.t. (15:18:00:56 MET), ran for 5 minutes and 4 seconds, and consumed 16 lb of fuel.

All three parts of Development Test Objective (DTO) 837 - Vernier RCS Reboost - were performed satisfactorily. Vernier thruster operation was nominal during the DTO performance. Data from the DTO will be analyzed postflight.

All 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 189:09:00:26 G.m.t. (16:18:11:26 MET).

During deorbit preparations, the rudder channel 3 position feedback became erratic (Flight Problem STS-78-V-07). Prior to entry interface (EI), the rudder is at +5 degrees so that a failure of this type can be detected. The problem was also seen in the servovalve current as well as the secondary differential pressure (ΔP) measurements following APU 2 start. After EI, the rudder channel 3 was manually commanded to bypass. The bypass command left the rudder operating on channels 1, 2, and 4 and was thus tolerant of a second failure. During the latter part of entry when the rudder was used for steering, the rudder position was apparently healed and operated properly. Postflight troubleshooting has not yet repeated or isolated the problem.

The deorbit maneuver for the first landing opportunity at the Shuttle Landing Facility (SLF) was performed on orbit 271 at 189:11:36:36 G.m.t.

(16:20:47:36 MET), and the maneuver was 162.16 seconds in duration with a ΔV of 271.4 ft/sec.

Entry was completed satisfactorily, and main landing gear touchdown occurred on SLF concrete runway 33 at 189:12:36:36 G.m.t. (16:21:47:36 MET) on July 7, 1996. The Orbiter drag chute was deployed at 189:12:36:40 G.m.t. and the nose gear touchdown occurred 8 seconds later. The drag chute was jettisoned at 189:12:37:12 G.m.t. with wheels stop occurring at 189:12:37:31 G.m.t. The rollout was normal in all respects. The flight duration was 16 days 21 hours 47 minutes and 36 seconds, which is a new endurance record for a Space Shuttle flight. The APUs were shut down 14 minutes 53 seconds after landing.

PAYLOADS

The Life and Microgravity Sciences (LMS) payload was carried in the Spacelab module, and the two main areas of concentration were life science studies and microgravity experiments. The Life Sciences general performance was outstanding, with nearly 100 percent of the planned data and science collected. Some problems arose, but all systems were restored to operational service through IFM procedures.

The life science studies probed the responses of living organisms to the low-gravity environment with the primary concentration in musculoskeletal physiology. The microgravity experiments, which were also very successful, focused on understanding the subtle influences that are at work during processing of various samples. In addition, all secondary payload operations were successfully conducted.

LIFE AND MICROGRAVITY SCIENCES

Human Physiology Experiments

The human physiology experiments were divided into two fields: human physiology and space biology. The human physiology field was further divided into five areas which were as follows:

a. Musculoskeletal;
b. Metabolic;
c. Pulmonary;
d. Human behavior and performance; and
e. Neuroscience.

The musculoskeletal experiments group were completed satisfactorily with data collected as required. This group consisted of the following experiments:

a. Effects of Weightlessness on Human Single Muscle Fiber Function;

b. Relationship of Long-Term Electromyographic Activity and Hormonal Function to Muscle Atrophy and Performance;

c. Effects of Microgravity on Skeletal Muscle Contractile Properties;

d. Effects of Microgravity on the Biomechanical and Bioenergetic Characteristics of Human Skeletal Muscle;

e. Magnetic Resonance Imaging After Exposure to Microgravity (Ground Study); and

f. An Approach to Counteract Impairment of Musculoskeletal Function in Space (Ground Study).

The Regulatory Function Metabolic Experiments were completed satisfactorily and all experiments runs were successful. This group consisted of the following experiments:

a. Direct Measurement of the Initial Bone Response to Space Flight; and

b. Measurement of Energy Expenditure During Space Flight With The Doubly Labeled Water Method.

The Lung Function Pulmonary Experiment, which was entitled Extended Studies of Pulmonary Function in Weightlessness, was completed satisfactorily and all experiment runs were successful. A problem developed with the oxygen tank, but an IFM was performed to obtain oxygen from the flight deck. Data were also collected prior to the flight as well as after the flight for this experiment.

The Sleep, Schedule and Skills Human Behavior and Performance Experiments were conducted satisfactorily with all desired data collected. The two experiments that make up this group of human behavior and performance experiments were:

a. Human Sleep, Circadian Rhythms and Performance in Space; and

b. Microgravity Effects on Standardized Cognitive Performance Measures using the Performance Assessment Workstation.

The Adapting to Space Neuroscience Experiments were conducted satisfactorily with all desired data collected. No problems or in-flight anomalies occurred in the experiment group, which consisted of the following experiments:

a. Torso Rotation Experiment; and

b. Canal and Otolith Interaction Studies.

Space Biology Experiments

The three space biology experiments studied the growth of pine saplings, development of fish embryos, and bone changes in laboratory rats. All of these experiments were completed nominally with no in-flight anomalies or significant problems noted. The experiments in this grouping were:

a. Lignin Formation and the Effects of Microgravity - A New Approach;

b. Development of the Fish Medaka in Microgravity; and

c. Role of Corticosteriods in Bone Loss During Space Flight.

Microgravity Science Experiments

The STS-78 microgravity science experiments involved basic fluid physics investigations, advanced semiconductor and metal-alloy materials processing, and medical research in protein crystal growth. The goal of the microgravity science research is to improve both production methods and final products of Earth-based industries. The on-orbit experiments were conducted primarily by scientists on the ground remotely commanding (telescience) the experiments. Data were collected as required to fulfill the requirements of these experiments with all experiment runs being completed. The Microgravity Sciences group of experiment categories are discussed in the following paragraphs.

Bubble, Drop and Particle Unit - Fluid Physics Research: The fluid physics research in the Bubble, Drop and Particle Unit (BDPU) collected data that may advance materials processed on Earth. All test containers were processed; however, the -15V power failed and this may have affected several test containers. This problem was repaired by the crew and normal operations were achieved. Also, a problem developed with retracting the needle, and this condition was also corrected with an IFM. A listing of the experiments in this area of fluid physics research follows:

a. Bubble and Drops Interaction with Solidification Fronts Experiment;

b. Evaporation and Condensation Kinetics at a Liquid Vapor Interface; and Efficient Cooling of High-Powered Small Electronic Devices by Boiling Under Microgravity Experiments;

c. The Electrohydrodynamics of Liquid Bridges;

d. Nonlinear Surface Tension Driven Bubble Migration; and

e. Oscillatory Marangoni Instability.

Advanced Gradient Heating Facility - Materials Processing: This materials processing experiment provided data for additional understanding of the conditions at which freezing materials change from solidifying with a flat boundary or transition surface (edge) to solidifying with cellular and dendrite (tree-like) transition shapes.

All cartridges were processed. However, some problems were noted and corrected during the flight. Initially, the crew was unable to attach the primary cable and used a backup cable on the first cartridge. The crew discovered that a loose electromagnetic Interference (EMI) ring was hindering the cable connection. The primary cable was attached and used for the remainder of the flight. Two IFMs were performed to correct electrical problems.

The experiments performed using the Advanced Gradient Heating Facility are as follows:

a. Comparative Study of Cells and Dendrites During Directional Solidification of a Binary Aluminum Alloy at 1-g and Under Microgravity;

b. Coupled Growth in Hypermonotectics;

c. Effects of Convection on Interface Curvature during Growth of Concentrated Ternary Compounds;

d. Equiaxed Solidification of Aluminum Alloy;

e. Interactive Response of Advancing Phase Boundaries to Particles; and

f. Particle Engulfment and Pushing by Solidifying Interfaces.

Advanced Protein Crystallization Facility - Medical Research: The Advanced Protein Crystallization Facility - Medical Research were completed satisfactorily and all experiments runs were successful. This group consisted of the following experiments:

a. Advanced Protein Crystallization Facility on the Life and Microgravity Sciences Mission;

b. Crystallization of EGFR-EGF;

c. Crystallization of Crustacyanin Subunits;

d. Crystallization of Engineered 5S rRNA Molecules;

e. Crystallization of Thermus Thermophilus AspRS;

f. Monitoring of Lysozyme Protein Crystal Growth in Microgravity via a Mach-Zehnder Interferometer and Comparison with Earth Control Data;

g. Crystallization of the Nucleosome Core Particle in Space;

h. Enhanced Resolution Through Improved Crystal Quality in the Crystal Structure Analysis of Photosystem I;

i. Mechanism of Membrane Protein Crystal Growth: Bacteriorhodopsin -- Mixed Micelle Packing at the Consolution Boundary, Stabilized in Microgravity;

j. Crystallization in a Microgravity Environment on CcdB, a Protein Involved in the Control of Cell Death;

k. Crystallization of Sulfolobus Solfataricus Alcohol Dehydrogenase; and

l. Growth of Lysozyme Crystals at Low Nucleation Density.

SECONDARY PAYLOADS

Biological Research in Canister

The Biological Research in Canister (BRIC) payload consisted of nine small canisters of day-lily plant cells. A study was conducted postflight to investigate the somatic embryogenisis of day lily cells after 17 days of microgravity.

Shuttle Amateur Radio Experiment

The Shuttle Amateur Radio Experiment (SAREX) equipment was set up on flight day 2, and supported the planned 11 school contacts and 7 personal contacts. The international school contacts involved a total of 271 students. The locations included Grenoble, France; Nova Scotia, Canada; Australia and United States. Numerous random contacts (100+) included Robert Thirsk's father and operators aboard the USS Essex.

Accelerometers for Characterizing the Microgravity Environment

Space Acceleration Measurement System: The Space Acceleration Measurement System (SAMS) measured high-frequency accelerations such as Orbiter thruster firings. Several materials and fluid science experiments were particularly sensitive to accelerations in the frequency ranges that SAMS recorded. The SAMS operated satisfactorily throughout the mission.

Orbital Acceleration Research Experiment: The Orbital Acceleration Research Experiment (OARE) provided extremely accurate measurements of low-frequency changes in accelerations and vibrations experienced during on-orbit operations. OARE operation was nominal throughout the mission.

Microgravity Measurement Assembly: The Microgravity Measurement Assembly (MMA) provided data for determining both high- and low-frequency disturbances. The MMA collected data from a network of sensors at selected locations within the Spacelab module. The data from these sensors as well as the equipment-dedicated and remote sensors is integrated into a unified data set. The MMA operated nominally, but minor problems were noted and corrected.

VEHICLE PERFORMANCE

SOLID ROCKET BOOSTERS

Analysis of the flight data and assessment of the postflight condition of the recovered hardware indicates that all Solid Rocket Booster (SRB) systems performed nominally. The SRB prelaunch countdown was normal with no unplanned holds, and no SRB Launch Commit Criteria (LCC) or Operational Maintenance Requirements and Specification Document (OMRSD) violations occurred. Likewise, no SRB in-flight anomalies were identified from the data and inspection.

For this flight, the low-pressure heated ground purge in the SRB aft skirt was used to maintain the case/nozzle joint temperatures within the required LCC ranges. At T-15 minutes, the purge was changed to high pressure to inert the SRB aft skirt.

Both SRBs were satisfactorily separated from the External Tank (ET) at 123.7 seconds after liftoff. The SRBs were recovered and returned to KSC for disassembly and refurbishment.

REUSABLE SOLID ROCKET MOTORS

The Reusable Solid Rocket Motors (RSRMs) flight performance was well within the allowable performance envelopes and was typical of the performance observed on previous flights. No LCC or OMRSD violations occurred during the countdown, and all RSRM temperatures were maintained within acceptable limits during the countdown. The RSRM propellant mean bulk temperature was 76 °F at liftoff.

Motor performance parameters for this flight were within contract end item (CEI) specification limits. Propulsion performance data are shown in the table on the following page. The maximum trace shape variation of pressure versus time was calculated to be 0.90 percent at 80 seconds for the left motor, and 0.95 percent at 80 seconds for the right motor. These values were well within the 3.2 percent allowable limits.

Field joint heaters operated for 10 hours 48 minutes during the countdown. Power was applied to the igniter heating elements 33 percent of the time to maintain the igniter-joint temperatures in the normal operating range.

During the postflight disassembly and inspection of the RSRMs, sooting was observed on all six field-joint J-leg insulation interfaces (Flight Problem STS-78-M-01). Heavy sooting and heat effects (discoloration and charring) were observed on the J-leg insulation interfaces in the center and aft field joints. No heating effects were noted to the capture feature-to-clevis metal interfaces or the capture feature O-rings, and no gas had penetrated past the capture feature

O-rings. The sooting/charring patterns were most extensive in the center joints, then the aft joints followed by the forward joints which exhibited the least sooting/charring effects with only slight soot penetration at localized points. All engineering and CEI specifications were met; however, this was the first occurrence of heat effected insulation within the field joint J-leg region.

The detailed inspection revealed that the left-hand center field joint exhibited nine locations with soot to the capture feature O-ring and seal surfaces. Slight discoloration was noted at some locations; however, no charring was evident on the left-hand center joint. The right-hand center field joint exhibited three locations with light soot slightly past the J-leg radius with no charring or discoloration present after cleaning. The aft and forward field joints did not exhibit any soot patterns past the radius. At the writing of this report, an investigation into the cause or causes of the STS-78 anomaly is continuing.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 76 °F		Right motor, 76 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10^6 lbf-sec	65.42	66.35	65.47	66.25
I-60, 10^6 lbf-sec	174.48	176.75	174.59	177.05
I-AT, 10^6 lbf-sec	296.79	297.40	296.92	297.58
Vacuum Isp, lbf-sec/lbm	268.6	269.1	268.6	269.2
Burn rate, in/sec @ 60 °F at 625 psia	0.3665	0.3691	0.3665	0.3693
Burn rate, in/sec @ 77 °F at 625 psia	0.3707	0.3733	0.3707	0.3735
Event times, seconds[a]				
Ignition interval	0.232	N/A	0.232	N/A
Web time[b]	110.0	108.5	110.0	108.3
50 psia cue time	119.8	118.8	119.8	118.5
Action time[b]	121.9	120.7	121.9	120.2
Separation command	124.7	123.7	124.7	123.4
PMBT, °F	76	76	76	76
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	2.5
Tailoff Imbalance Impulse differential, Klbf-sec	Predicted		Actual	
	N/A		239.4	

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).

EXTERNAL TANK

The ET loading and flight performance was excellent, and no in-flight anomalies occurred. All ET electrical and instrumentation equipment performed satisfactorily, and all ET purges and heaters operated properly. No ET LCC or OMRSD violations were identified. All flight objectives were satisfied.

There was no ice observed on the ET acreage, and the Red Team reported no unacceptable ice/frost formations. Normal quantities of ice or frost were present on the LO_2 and LH_2 feedlines, the pressurization brackets and along the LH_2 protuberance air load (PAL) ramps. All observations were acceptable as determined from the NSTS 08303 document. The Ice/Frost Red Team reported that no anomalous thermal protection subsystem (TPS) conditions existed, and the foam crack that typically develops on the -Y vertical strut did not occur.

The ET pressurization system functioned properly throughout the engine start and flight. The minimum LO_2 ullage pressure experienced during the ullage pressure slump was 14.6 psid.

ET separation occurred as planned, and the ET intact impact point was approximately 13 nmi. uprange of the preflight prediction.

SPACE SHUTTLE MAIN ENGINE

All Space Shuttle main engine (SSME) parameters were normal throughout the prelaunch countdown and were typical of the prelaunch parameters observed on previous flights. Engine ready was achieved at the proper time; all LCC were met; and engine start and thrust buildup on SSME 1 and 3 was normal. Thrust build-up of SSME 2 (S/N 2036) violated the thrust build-up rate specification during engine start (Flight Problem STS-78-E-01). The requirement specifies that the thrust build-up will not exceed 14,000 lb thrust change for any two consecutive 20-ms time intervals above 15 percent of rated power level. Three total data points violated the specification with two of the data points being consecutive in time. This requirement is the result of an aft compartment acoustic over-pressure concern for the block 1 engine. This was the first occurrence of this limit violation. The start transient requirements are being reassessed.

Data review indicated that all four of the LH_2 low-level engine cut-off (ECO) sensors indicated dry approximately 2.3 seconds after MECO. The ECO sensors are located at the bottom of the LH_2 tank and are positioned so that approximately 1867 lbm of LH_2 remained within the total system (ET, Orbiter, and SSMEs). Postflight reconstruction of the propellant usage indicates 2799 lbm of LH_2 remaining at MECO, and that was 790 lbm less than the preflight prediction. This amount of propellant remaining was the least measured since the return to flight (STS-26). Nominally, 3,000 to 5,000 lbm of LH_2 is remaining at MECO. Calculations of the residual LH_2 level, based on flight performance, indicates no vehicle anomalies in the ECO system.

The evaluation of the LO_2 residual quantity indicated 3899 lbm of excess LO_2. In combination with the findings of the previous paragraph (low LH_2 residual) and the high LO_2 residual, a potential mixture ratio problem is indicated (Flight Problem STS-78-I-01). A review of the mixture ratio from the previous 11 flights shows a trend to be biased low with the STS-78 mixture ratio being 3-sigma low. Postflight calculations also revealed that approximately 3200 lb less LO_2 was consumed than predicted. This was the first time in the Shuttle Program that insufficient LH_2 remained to burn all of the available LO_2.

Flight data indicate that the SSME performance during mainstage, throttling, shutdown, and propellant dumping operations was normal. The high pressure oxidizer turbopump (HPOTP) and high pressure fuel turbopump (HPFTP) temperatures were well within specification limits throughout engine operation. Main engine cutoff (MECO) occurred at T + 509.28 seconds. No failures or significant SSME problems were noted.

SHUTTLE RANGE SAFETY SYSTEM

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

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

ORBITER SUBSYSTEM PERFORMANCE

Main Propulsion System

The overall performance of the main propulsion system (MPS) was nominal. The LO_2 and LH_2 loading was performed as planned with no stop-flows or reverts; however, the initiation of tanking was delayed approximately 20 minutes to correct a ground electrical problem. No LCC or OMRSD violations occurred.

No significant hazardous gas concentrations were detected during preflight operations. The maximum hydrogen concentration level in the Orbiter aft compartment, which occurs after the start of fast-fill, was approximately 140 ppm (corrected), and this compares favorably with previous data for this vehicle.

The LH_2 loading operations were normal. Based on an analysis of loading system data, the LH_2 load at the end of replenish was 231,866 lbm. Compared to the inventory (predicted) load of 231,832 lbm, this assessment yields a difference of +0.04 percent, which is well within the required loading accuracy of ±0.37 percent.

The LO_2 loading operations were normal. Based on an analysis of the loading system data, the LO_2 load at the end of replenish was 1,388,872 lbm. Compared to the inventory (predicted) load of 1,388,277 lbm, this assessment yields a difference of + 0.02 percent, which is well within the MPS loading accuracy of ± 0.43 percent.

The ascent MPS performance was satisfactory. Data show that both pressurization subsystems performed as planned, and that all net positive suction pressure (NPSP) requirements were met throughout the flight. The liquid oxygen ullage pressure of 28.3 psia was the highest ever measured. The minimum LO_2 ullage pressure experienced during the period of the ullage pressure slump was 14.5 psid.

A review of the MPS manifold pressure data indicated that the LH_2 manifold repressurization after the second vacuum inert was not performed. Further review of the data indicated that the LH_2 pressurization line vent valve was opened for eight seconds instead of the LH_2 manifold repressurization valve. The switches for both valves are located on panel R4. Consideration was given to performing the repressurization later in the flight to fulfill the OMRSD File IX (In-Flight Checkout) requirement associated with this procedure; however, the decision was made not to pursue an on-orbit repressurization of the LH_2 system. The gaseous hydrogen (GH_2) flow control valves and filter elements are scheduled to be removed and replaced during the STS-80 flow (next flight of this vehicle), and KSC will perform the leak check after that system reconfiguration.

The SSME 1 LH_2 inlet pressure measurement failed off-scale high (OSH) at 172:14:53:56 G.m.t. Coincident with the transducer failure, a BITE bit was set on MDM FA 1 card 14. This bit is indicative of a problem in the A/D converter in the SCU or a problem in card 14. The SSME LH_2 inlet pressure measurement as well as three other SSME pressure measurements, which functioned nominally, are channelized through card 14. Analysis of the BITE logic indicates that an OSH voltage from the LH_2 sensor will cause the BITE indication on MDM FA 1. Thus, this BITE is an explained condition. A similar failure was observed on STS-51 (SSME 2 LO_2 inlet pressure) that resulted in the same BITE indication on MDM FA2. Postflight testing confirmed that the LH_2 inlet pressure transducer had failed. The transducer was removed and replaced.

The gaseous oxygen (GO_2) fixed orifice pressurization system performed as predicted. The GH_2 pressurization system also performed nominally. All tank and engine requirements were met by both systems.

STS-78 was the first flight of OV-102 with all of the GH_2 pressurization systems modifications incorporated and with filters installed in all engine legs plus the pre-pressurization leg. All flow control valve (FCV) cycles were evaluated for slow valve response, and no slow responses were found.

Reaction Control Subsystem

The reaction control system (RCS) performed satisfactorily throughout the mission with no in-flight anomalies identified. Propellant consumption during the mission was 4,204.8 lbm from the RCS tanks, and 325.3 lbm from the OMS tanks during interconnect operations.

At 172:19:19 G.m.t. (00:04:30 MET), a RCS retrograde trim maneuver was performed. This maneuver lasted 52 seconds and imparted a 12-ft/sec ΔV to the vehicle. Subsystem performance was nominal.

When establishing a left OMS interconnect at 173:10:18 G.m.t. (00:19:29 MET), the right RCS tanks and the left OMS tanks were inadvertently interconnected. The maximum ΔP during the interconnect period was 4.7 psid, well within the Shuttle Operational Data Book (SODB) limit of 50 psid, and there was no impact to the mission from this inadvertent operation. During the interconnect period, approximately 12 lbm of oxidizer and 4 lbm of fuel were transferred from the left OMS tanks to the right RCS tanks.

The RCS vernier thruster F5L oxidizer and fuel injector temperature data suggested that the heater on this thruster may have been failed-on. Starting at approximately 172:20:19 G.m.t. (00:05:30 MET), the fuel injector temperature remained 10 °F warmer than the oxidizer injector temperature. This signature was indicative of a heater that was continuously on. There were several occasions, following the F5L thruster firings, when the thruster appeared to be warm enough for a sufficient length of time to turn the heater off; however, the evaluation was not conclusive. The thruster heater eventually cycled off at approximately 187:05:10 G.m.t. (14:14:21 MET) while the injector temperatures were off-scale high due to thruster firings. When the injector temperatures returned to scale at 187:05:30 G.m.t. (14:14:41 MET), the heater had switched off as indicated by the injector temperatures tracking closely. Later in the mission, the heater again cycled properly indicating satisfactory performance.

The RCS hot-fire was successfully performed at 188:08:34 G.m.t. (15:17:45 MET). All RCS thrusters functioned properly during the hot-fire.

Orbital Maneuvering Subsystem

The orbital maneuvering subsystem (OMS) performed nominally throughout the flight and no in-flight anomalies were noted. A total of 11,080 lbm of OMS propellants were consumed during the mission. The RCS used 325.3 lbm of that total during interconnect operations. The table on the following page presents pertinent data from the two OMS maneuvers. The OMS 1 maneuver was not required as a direct ascent trajectory was flown. The OMS 2 maneuver was performed at 172:15:30:28.5 G.m.t. (00:00:41:28.5 MET). The resulting orbit was 153.6 by 146.7 nmi. The deorbit maneuver for the first landing opportunity at the SLF was performed on orbit 271 at 189:11:36:36 G.m.t. (16:20:47:36 MET).

OMS FIRINGS

OMS firing	Engine	Ignition time, G.m.t./MET	Firing duration, seconds	ΔV, ft/sec
OMS-2	Both	172:15:30:28.5 G.m.t. 00:00:41:28.5 MET	117	185
Deorbit	Both	189:11:36:36 G.m.t. 16:20:47:36 MET	162	271

The inlet pressures, chamber pressure and regeneration jacket temperature for both engines was as expected. The OMS firing times and propellant consumption were consistent with predictions, and this also verified proper performance. The GN_2 regulator outlet pressure was in the normal operating band during the OMS engine starts and during postfiring purges. During the deorbit firing, the pressure jumped from a steady-state value of 315 psia to 320 psia during the start of the firing, indicating some slight stickiness may be present in the valve. However, the bipropellant valve opening times were within specification limits, so the regulator performance (slight stickiness) had no noticeable affect. Also the regulator set pressure during the postflight GN_2 bottle dumps was nominal.

Power Reactant Storage and Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem performed nominally on this the eighth flight of the extended duration Orbiter (EDO) pallet. The PRSD subsystem supplied 5320 lbm of oxygen and 670 lbm of hydrogen to the fuel cells for the production of electricity. In addition, the PRSD supplied 220 lbm of oxygen to the environmental control and life support system (ECLSS) for crew breathing and cabin pressurization. At the end of the mission, a 68-hour mission extension capability at average mission power levels of 18.9 kW was possible with the remaining reactants. This extension capability was 97 hours at the extension-day average power level of 13.5 kW. Since this was only a single-shift mission for the crew, one set of the manifold isolation valves were closed for each sleep period, and this satisfied the in-flight checkout requirement.

During the fuel cell high-load test and the PRSD system integrity check, subsequent to fuel cell start-up, the hazardous gas detection system (HGDS) detected a 10 ppm increasing trend in the oxygen concentration in the midfuselage. The requirement is that no increase in concentration will occur above the background level. This increase began at 172:06:26 G.m.t. and lasted for almost 10 minutes. The gas supply valves were closed for 5.5 minutes. The integrity check, in which the gas supply valves are closed and the fuel cells operate on internal reactants, was repeated at 172:11:32 G.m.t. The gas supply valves were closed for 14 minutes, and the HGDS detected no increase in the oxygen concentration this time. HGDS data from the previous Extended Duration

Orbiter (EDO) flight (STS-75) was reviewed, and the signature was identical. For this flight, the relative humidity of the payload bay purge during the first check was 2 percent, compared with a humidity of 0 percent during the second check. The 10 ppm oxygen concentration increase may be attributed to the 2 percent relative humidity. The Orbiter purge is switched from air to gaseous nitrogen (GN_2) just prior to the first integrity check. Residual moisture from the air purge remains in the system for three to four hours after the air-to-GN_2 changeover.

The quantities of H_2 tanks 4 and 5 began diverging at approximately 176:11:57 G.m.t. (03:21:08 MET) while fuel cell H_2 was being supplied by tanks 4 and 5 (Flight Problem STS-78-V-04). On OV-102, the H_2 tank 4 and 5 A and B heaters each have a common controller and as such the heaters cycle on and off simultaneously. On-orbit troubleshooting, during which H_2 tanks 4 and 5 were operated for several hours on only the A-heaters followed by several hours on only the B-heaters, confirmed that the B heater on H_2 tank 4 had failed. The H_2 tank 4 and 5 heaters were then reconfigured for heater-A-only operation. A similar failure occurred on the last flight of OV-102 and was isolated to a fuse failure in the A heater control circuit. The fuse was replaced during the STS-78 flow. Failure of the tank 4 heater did not significantly impact H_2 tank use, and tanks 4 and 5 were depleted using the A heaters only. KSC troubleshooting isolated the B heater failure to a mechanically failed fuse in the B heater control circuit.

In all of the EDO flights, H_2 tanks 8 and 9 have diverged in quantity because of a higher heat leak into tank 8. This higher heat leak causes tank 8 to pressurize faster than tank 9 when the tanks are not being pressurized by their heaters. Tank 8 reaches the manifold pressure sooner, and therefore begins feeding the fuel cells before tank 9. This causes the quantity in tank 8 to decrease more quickly than tank 9. When tank 8 was at 15 percent and tank 9 was at 30 percent, the B heater in tank 8 was turned off. With both the A and B heaters cycling in tank 9 and just the B heater in tank 8, the quantities converged at 6 percent. Later on, both heaters in each tank were turned on to deplete the tanks.

Fuel Cell Powerplant Subsystem

Fuel cell flight performance was nominal. The Orbiter electrical power levels averaged 18.9 kW and the total Orbiter electrical load averaged 622 amperes. The fuel cells produced 7675 kWh of electrical energy and 5990 lb of potable water. The fuel cells consumed 5320 lbm of oxygen and 670 lbm of hydrogen during the 405.8 hour mission. Seven fuel cell purges were performed and all were nominal. The actual fuel cell voltages at the end of the mission were 0.10 volt above the predicted level for fuel cells 1 and 3, and 0.05 volt above the predicted level for fuel cell 2. No in-flight anomalies occurred in this subsystem during the mission.

Fuel cell 1 (S/N 109) continued to have a slightly high condenser exit temperature (TCE), which is a characteristic of this particular fuel cell. The TCE has been fluctuating between approximately 156 and 159 °F since STS-52 (four previous flights) when this fuel cell was refurbished as a zero-hour fuel cell. The Launch

Commit Criteria (LCC) allows steady-state operation above 160 °F provided the fuel cell inlet and outlet electrolyte concentrations remain within the 24- to 48-percent range. Since the concentration remained steady at approximately 31 percent, no concern existed for violating the LCC.

Auxiliary Power Unit Subsystem

The auxiliary power unit (APU) subsystem performed nominally with two in-flight anomalies identified, neither of which impacted the flight. The following table presents the APU serial numbers flown as well as the amount of propellants consumed and the run-time of the APUs.

APU RUN TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (S/N 204)		APU 2 (S/N 303)		APU 3 (S/N 403)	
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	21:37	54	19:44	59	21:51	56
FCS checkout			05:03	16		
Entry[a]	59:41	113	79:51	163	59:50	116
Total	81:18	167	106:38	238	81:41	172

[a] The APUs were shut down 15 minutes 15 seconds after landing.

As expected, the APU 1 fuel pump inlet pressure decayed from 340 psia to 40 psia in about two hours after ascent following closure of the FIV (Flight Problem STS-78-V-05). This decay is indicative of fuel-pump carbon-seal leakage into the seal cavity drain. This is the same APU that was flown in this position on the previous flight of OV-102 (STS-75), when a similar decay was observed. The fuel inlet pressure dropped to approximately 40 psia indicated (24 psia corrected) which was just above the indicated seal-cavity drain-line pressure of 22 to 23 psia. The pressure decayed at a higher rate this mission than during STS-75, indicating that the leak was becoming worse (the inlet pressure did not crack the FIV relief valve as is typically seen). Opening the FIV with a fuel pump inlet pressure above 15 psia was not a concern, and dynamic seal leakage was not noted on this APU; therefore, this leak did not pose a flight impact. The APU was pressurized for entry, and the pressure decayed again after landing and APU shutdown. During postflight operations, a total of 365 cc of hydrazine was drained from this APU's catch bottle.

At 189:11:51 G.m.t. (16:21:02 MET) when APU 1 was started for its entry run, the down-listed turbine speed sensor [magnetic pickup unit (MPU)] 3 initially failed off, then operated erratically for approximately four minutes, and then operated satisfactorily for the remainder of APU 1 operation (Flight Problem STS-78-V-06).

MPU 3 is one of three turbine speed sensors in each APU but is the only downlinked speed sensor from APU 1. The erratic operation did not affect overall APU 1 performance or impact the mission. This was the first occurrence of an in-flight failure of a speed sensor; however, this failure mode has been seen previously in ground operations and testing. Postflight testing at KSC confirmed that a discontinuity existed in the MPU 3 circuit. APU 1 has been removed and sent to the contractor for inspection of the fuel pump seals discussed in the previous paragraph and replacement of the speed sensor.

The FCS checkout was successfully performed, and nominal performance on all subsystems exercised during the checkout was observed. As planned, APU 2 was used for FCS checkout. The APU was started at 188:08:49:56 G.m.t. (15:18:00:56 MET), ran for 5 minutes and 3 seconds, and consumed 16 lb of fuel.

The APU heater systems were switched to the B heaters at approximately 188:10:00 G.m.t. (15:19:11 MET), shortly after completion of FCS checkout. The APU 1 lubrication oil outlet temperature decreased to approximately 41.7 °F at 188:19:29 G.m.t. (016:04:40 MET), at which time the crew was instructed to switch back to the A heaters to avoid a possible fault detection and annunciation (FDA) alarm later during the crew sleep period. The FDA alarm occurs at 41 °F. The thermal switches that control the APU 1 lubrication oil heaters are located near APU 2 and are affected by the heat generated by APU 2 usage. This phenomenon has been observed on other flights when APU 2 has been used for FCS checkout. After reviewing the data on this behavior, the decision was made to switch back to the B heaters prior to entry in an attempt to verify nominal B heater operation. A heater cycle on the B heater was not required prior to the end of the mission. KSC will verify the operation of this heater during turnaround testing.

Hydraulics/Water Spray Boiler Subsystem

The hydraulics/water spray boiler (WSB) subsystem performed nominally during the flight with one in-flight anomaly identified.

An under-cooling condition occurred during ascent of WSB 3 while operating on controller A. The APU 3 lubrication oil return temperature reached 297 °F before cooling was noted. The B controller was selected at approximately 172:15:02 G.m.t. (00:00:13 MET), shortly after spray cooling was observed on the A controller. The lubrication oil return temperature stabilized at 253 °F, while on the B controller. A switch back to the A controller was performed at approximately 172:15:04 G.m.t. (00:00:15 MET), and nominal cooling continued. There were no mission constraints on the use of WSB 3.

Just prior to or during landing, the heat exchanger mode is normally reached on all three WSBs. At 189:12:31 G.m.t. (16:21:42 MET), several minutes prior to landing, toggling of the WSB 1 ready indication was indicated (Flight Problem STS-78-V-08). Toggling of this indication is not unusual and is typically caused by the WSB hydraulic fluid bypass valve transitioning between the heat exchanger and bypass positions. However, during STS-78, bypass valve movement was not indicated. None of the other parameters that can cause a ready indication to change state (controller enabled, steam vent temperature, or GN_2 shut-off valve position) explain the toggles that were indicated. A review of previous flight data shows similar performance during the previous flight of this WSB (STS-75). Proper operation of the bypass valve and the ready indication will be verified post flight. A troubleshooting plan has been developed that will consist of cycling the bypass valve.

During landing, the reservoir quantity on hydraulic system 1 dropped 17.4 percent during landing gear deployment, and the specification for this condition is no more than 15 percent. KSC will inspect the hydraulic system for leaks during the turnaround operations.

Electrical Power Distribution and Control Subsystem

The electrical power distribution and control (EPDC) subsystem performed nominally throughout all phases of the flight. One in-flight anomaly, H_2 Tank 4 and 5 Heater Failure, is discussed in the Power Reactant Storage and Distribution Subsystem section of this report.

Environmental Control and Life Support Subsystem

The atmospheric revitalization system (ARS) functioned satisfactorily. Cabin temperature was maintained between 72.5 and 79.8 °F, with a maximum cabin humidity level of 43.58 percent. The $PPCO_2$ did not exceed 3.0 mm Hg during the flight. The maximum air temperature in avionics bays 1, 2, and 3 was 105.1, 91.78, and 87.03 °F, respectively. The maximum heat exchanger water outlet temperature for avionics bays 1, 2, and 3 was 94.6, 89.6 and 89.44 °F, respectively. The maximum cold-plate temperature for avionics bays 1, 2, and 3 was 99.1, 88.9, and 88.9 °F, respectively.

The regenerative CO_2 removal system (RCRS) operated satisfactorily throughout the mission, maintaining CO_2 within the desired range. STS-78 was the third flight of this unit, and the unit has approximately 2.2 years of life remaining.

The indicated carbon dioxide (CO_2) concentration of the RCRS shifted low and became erratic at 173:07:59 G.m.t. (00:17:10 MET). The measurement remained erratic throughout the mission. The measurement does not affect performance of the RCRS, and the indicated cabin CO_2 concentration was nominal throughout the mission.

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

The ATCS successfully supported payload cooling requirements by placing both of the Freon coolant loop (FCL) flow proportioning valves in the payload position approximately 2 hours after launch. The valves were returned to the interchanger position during the Spacelab deactivation.

During ascent, the flash evaporator system (FES) high-load duct temperatures were erratic and lower than normal. The inboard duct temperature dropped to approximately 119 °F (normally remains above 190 °F) by 172:15:02 G.m.t. (13 minutes MET). The heaters were reconfigured from system-A-only to systems A and B at approximately 13.5 minutes MET, and the temperatures eventually recovered. Throughout the occurrence, the evaporator outlet temperatures were stable. No further problems with the FES were noted during ascent. To verify the performance of the high-load duct system A heater, the heater was powered up at 173:16:14 G.m.t. (01:01:25 MET), and temperatures were monitored for approximately 2 hours and 45 minutes. A nominal temperature signature was observed.

At approximately 174:15:50 G.m.t. (02:01:01 MET), while operating in the topping mode and on the primary A controller, the FES shut down. A restart attempt on the A controller was unsuccessful, and was followed by an unsuccessful restart attempt on the B controller. Data from the shutdown and subsequent unsuccessful restarts indicated icing in the FES core. A FES core-flush initiated at 174:17:12 G.m.t. (02:02:23 MET) successfully removed the ice from the core. The heat load at the time of the first shutdown was high; therefore, to reduce the heat load to the FES, the port radiator was deployed at 174:18:13 G.m.t. (02:03:24 MET). The deployed radiator provided additional cooling capacity for the active thermal control system (ATCS), and nominal FES operation was observed on the B controller in the supplemental cooling (topping) mode.

At approximately 180:08:19 G.m.t. (07:17:30 MET), a water dump through the FES using the B controller was initiated to troubleshoot the shutdown that occurred previously on the A controller. The FES subsequently shut down at approximately 180:10:08 G.m.t. (07:19:19 MET). The crew successfully performed the FES core-flush procedure to remove any ice that may have formed and caused the shutdown. This FES had icing problems during its previous mission (STS-75) and following that mission, the topping evaporator spray valves and the accumulators were removed and replaced.

During deorbit preparations at approximately 189:10:04 G.m.t. (16:19:15 MET), the FES shut down after almost an hour and a half operating in the full-up mode on the primary B controller. The high-load core was flushed, and the data indicate ice was exiting through the high-load ducts. A flush was performed on the topping core followed by a second high-load core flush, but no additional ice was noted. The remainder of the mission was performed using the primary A controller with no further anomalies.

KSC troubleshooting consisted of internal and external visual-inspections of the high-load and topping evaporator cores, as well as leak and flowrate testing of the system A and B high-load and topping spray valves. No anomalies were noted in the visual inspections or spray valve leak tests. Initial flowrate testing of the high-load system A spray valve resulted in a flowrate of 141 lb/hr. Following several back-flushes of the valve, the flowrate decreased to 101 lb/hr. Since the change in flowrate was unexplainable, the decision was made to remove and replace the valve. The system B high-load spray valve was removed and replaced as well. No problems were noted with the topping spray valves, and therefore, the valves were not removed (these valves had been removed and replaced prior to STS-78). Additional flushing of the A and B feedwater systems was performed, and the accumulators were verified clean on the bench.

Note that the Freon coolant loop (FCL) 1 flowrate (approximately 3050 lb/hr), which is the highest flowrate of any FCL in the fleet, or the FCL 1 and 2 flowrate imbalance (approximately 275 lb/hr), may have played a role in the freeze-ups of the topping evaporator. As a result, FES testing is planned at JSC to demonstrate that theory. The results from this testing will determine what, if any, adjustment needs to be made to the FCL 1 flowrate.

The radiator coldsoak provided cooling during entry through touchdown plus 4 minutes 46 seconds when ammonia boiler system (ABS) A was activated using the secondary controller at 189:12:40 G.m.t. (16:21:51 MET). To minimize thermal stress on the long-duration crew, ammonia cooling was activated early by selecting the high-outlet temperature set point (57 °F) on both FCL radiator flow controllers when the radiator controller outlet temperatures exceeded 40 °F. This provided the necessary heat load for the ABS and avoided the increased cabin temperature and humidity transient which occurs during nominal postlanding operations between coldsoak depletion and ammonia activation. System A operated for 34 minutes until it was deactivated at 189:13:14 G.m.t. (16:22:25 MET) in preparation for ground-cooling connection.

The supply and waste water subsystem performed nominally throughout the mission, and no in-flight anomalies were identified. All in-flight checkout requirements were met prior to landing.

Supply water was managed through the use of the FES and overboard dump system. Fourteen supply water dumps were performed at an average rate of 1.49 to 1.69 percent/minute (2.46 to 2.79 lb/min). Four of the dumps were performed simultaneously with waste water dumps. The supply water dump line temperature was maintained between 77 and 106 °F throughout the mission with the operation of the line heater.

Waste water was gathered at approximately the predicted rate. Five waste water dumps were performed at an average rate of 1.93 to 2.00 percent/minute (3.18 to 3.3 lb/min). The waste water dump line temperature was maintained between 54 and 79 °F throughout the mission. The vacuum vent line temperature was maintained between 60 and 75 °F with the vacuum vent nozzle between 110 and 161 °F.

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

Airlock Support Subsystem

The airlock support system hardware was not required because no extravehicular activity was planned or performed. The active-system-monitor parameters indicated normal outputs throughout the mission.

Smoke Detection and Fire Suppression Subsystems

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

Avionics and Software Support Subsystems

At approximately 172:14:54 G.m.t. (00:00:05 MET), a built-in test equipment (BITE) bit was set on MDM FA 1 card 14. This bit is indicative of a problem in the A/D converter in the sequence control unit (SCU) or a problem in card 14. However, simultaneous with this BITE, the SSME 1 LH_2 inlet pressure failed off-scale high (OSH). This pressure measurement is channelized through card 14 (channel 16). Analysis of the BITE logic indicates that an OSH voltage from this sensor will cause the BITE indication on MDM FA 1. Thus, this BITE is an explained condition. A similar failure was observed on STS-51 (SSME 2 LO_2 inlet pressure) that resulted in the same BITE indication on MDM FA2. Postflight testing confirmed that the transducer had failed.

At 172:15:18:30 G.m.t. (00:00:29:30 MET), the GPC 5 I/O terminate B discrete began behaving erratically. The BFS software was contained in GPC 5. At 172:21:18 G.m.t. (00:06:29 MET), a HISAM dump of the BFS software contained in GPC 5 memory was performed to support troubleshooting the erratic I/O terminate B discrete condition. An analysis of the dump of the BFS software contained in GPC 5 memory was performed and no problems were found with the BFS software.

The BFS software was successfully loaded into GPC 2 at approximately 176:20:05 G.m.t. (04:05:16 MET). A dump-and-compare of the GPC 2 software confirmed a nominal software load. During the same time frame, GPC 5 was loaded with primary avionics software system (PASS) G2 software and placed in a redundant set with GPC 1. No anomalous GPC 5 behavior was observed during the remainder of the mission. The GPC 5 output switch, which had been in the terminate position since the GPC was loaded with PASS software and placed in the redundant set, was placed in the normal position as planned at 177:20:59 G.m.t. (05:06:10 MET).

To further troubleshoot the intermittent I/O terminate B problem, the GPC 4 output switch was placed in backup at 181:17:07 G.m.t. (09:02:18 MET). Had the failure repeated in this configuration, it would have indicated that the problem was between the GPC output switches and their power source, and therefore, the problem would affect whichever GPC was running the BFS software. At approximately 184:07:29 G.m.t. (11:16:40 MET), the GPC 4 output switch was moved from the backup position to the terminate position. No intermittent I/O terminate B discretes were experienced.

During deorbit preparations at 189:09:19 G.m.t. (16:18:30 MET), the BFS, resident in GPC 2, registered an error code 41 (illegal engage) similar to the error that was logged during ascent when the BFS was in GPC 5. This incident was coincident with the GPC 4 output switch being taken from terminate to normal. The break-before-make design of the switch coupled with the wiring design of the output switches resulted in the error code when the switch was moved. GPC 5 ran PASS G3 software in the redundant set (commanding string 4) during entry and its performance was nominal.

A similar failure occurred in this same slot on STS-32 (OV-102, flight 9). The backup flight controller (BFC) and the GPC were removed and replaced. The failure was not isolated in ground testing and was closed as an unexplained anomaly with a most probable cause of the BFC.

Postflight troubleshooting began with the state of the I/O terminate B discrete being monitored for approximately 80 hours. There was no recurrence of the anomaly during this time. Wire wiggle and pin-push tests were performed with no recurrence of the anomaly. A breakout box was installed at the BFC and the select, select off, and the terminate B true and complement signals were verified to be nominal. The BFC delay timer was measured and found to be within specification, suggesting that the circuit upstream of the BFC did not play into the failure. A high potential (HiPOT) of the I/O terminate B true and complement lines showed 0.2 milliamperes of leakage at 800 volts, indicating a potential short between the lines. Flexing the harness caused the reading to fluctuate. Although the reading was within OMRS limits (0.5 milliamperes), the wire runs were removed. In the process of removing the wires a split was noticed in the rubber grommet between the pins for the I/O Terminate B true and complement signals. Also the crimp on one of the wires appeared to be suspect. The wire had been stripped back farther than normal and a wire strand looked to be loose. The decision was made to replace the entire 128-pin connector. The removed hardware was sent to the malfunction laboratory for analysis.

The FCS checkout was successfully performed, and nominal performance on all subsystems exercised during the checkout was observed. As planned, APU 2 was used for FCS checkout.

Also during deorbit preparations, the rudder channel 3 position feedback became erratic. Prior to EI, the rudder is at +5 degrees so that a failure of this type can be detected. The problem was also seen in the servovalve current as well as the secondary ΔP measurements following APU 2 start. After EI, the rudder channel 3 was manually commanded to bypass. The bypass command left the rudder operating on channels 1, 2, and 4 and was thus tolerant of a second failure. During the latter part of entry when the rudder was used for steering, the rudder position was apparently healed and operated properly. The problem is believed to be caused by a discontinuity in the wiring between the power drive unit (PDU) and aerosurface actuator (ASA) 3 in avionics bay 6. KSC troubleshooting had not isolated the problem as of this writing.

Displays and Controls Subsystem

The displays and controls subsystem performed satisfactorily during the flight with no in-flight anomalies identified.

Communications and Tracking Subsystems

All communications and tracking subsystems hardware performed nominally throughout the mission. On-orbit S-band and Ku-band communications via the Tracking and Data Relay Satellite (TDRS) were satisfactory. A new item for this mission was the real-time video of entry and landing that was provided by the Pilot-Point-of-View Camera (PPOV-CAM) and the S-band frequency modulation (FM) system. Its performance was nominal.

The Ku-band communications adapter (KCA) was used many times during the mission. An excellent demonstration of its two-way video/voice capabilities was obtained when, starting at 179:22:27 G.m.t. (07:07:38 MET), uplinking of taped video and voice for the BDPU IFM troubleshooting procedures was provided to the crew. The success of this procedure demonstrated the effectiveness of this communications tool.

Operational Instrumentation/Modular Auxiliary Data System

The operational instrumentation/modular auxiliary data system (MADS) performed satisfactorily during the flight. No in-flight anomalies occurred within the system.

Structures and Mechanical Subsystems

The tires and brakes were found to be in average condition for a landing on the KSC concrete runway. The table on the following page provides the landing and braking data for this flight.

Ply under-cutting was noted on the left main landing gear inboard tire during the inspection. The under-cutting was very light on both outer ribs. This has been observed on approximately 20 percent of the landings. The specific cause is not known, but several parameters probably contribute to this type of damage. STS-78 was a heavyweight vehicle (230,000 lb), had a main gear touchdown ground speed of 214 knots (about 13 knots above average), and a light crosswind

LANDING AND BRAKING PARAMETERS

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	2435	208.0	~ 1.3	N/A
Nose gear touchdown	6537	148.9	N/A	~4.5

Brake initiation speed	116.3 knots
Brake-on time	37.4 seconds
Rollout distance	9,290 feet
Rollout time	57.1 seconds
Runway	33 (Concrete) KSC
Orbiter weight at landing	229,198 lb

Brake sensor location	Peak pressure, psia	Brake assembly	Energy, million ft-lb
Left-hand inboard 1	1032	Left-hand inboard	23.19
Left-hand inboard 3	1056	Left-hand outboard	22.03
Left-hand outboard 2	1032	Right-hand inboard	17.93
Left-hand outboard 4	1032	Right-hand outboard	19.77
Right-hand inboard 1	948		
Right-hand inboard 3	864		
Right-hand outboard 2	972		
Right-hand outboard 4	924		

(3 to 6 knots) from left to right. These parameters combined resulted in a left inboard tire brake energy of 23.2 million ft-lb (the highest of the four tires), which was 16-percent higher than average.

The ET/Orbiter separation devices EO-1, EO-2, and EO-3 functioned normally. Two clips were missing from the EO-2 "salad bowl" fitting. No ordnance fragments were found on the runway beneath the umbilical cavities. However, several pieces of purge barrier material held together with Mylar tape lay on the runway beneath the LH_2 ET/Orbiter umbilical. Debris, which appeared to be a small piece of lockwire adhering to a piece of Mylar tape, was wedged between the forward 16 mm camera lens and window. Virtually no umbilical close-out foam or white room temperature vulcanizing (RTV) dam material adhered to the umbilical plate near the LH_2 recirculation line disconnect.

Integrated Aerodynamic and Vehicle Heating and Thermal Interfaces

The prelaunch thermal interface purges were all conducted with nominal results. The ascent aerodynamic and plume heating was nominal as was the entry aerodynamic heating to the SSME nozzles.

Thermal Control Subsystem

The thermal control subsystem (TCS) performance was nominal during all phases of the mission. All subsystem temperatures were maintained within acceptable limits. No TCS failures or in-flight anomalies were noted. The beta angle ranged from -15.0 degrees at orbital insertion to +36.2 degrees at EI.

Thermal analyses were made to evaluate changes to the planned attitude timelines (ATLs). Eight revisions to the planned ATLs were analyzed and assessed based on inputs from the flight control team to provide alternate attitudes for increased water production and improved main landing gear (MLG) tire temperature margins at EI. In these analyses, the bending effects temperature (BET) was predicted to approach but not exceed the 200 °F limit during +Z solar inertial (bottom to Sun) attitudes late in the mission.

Aerothermodynamics

The acreage heating and local heating were both nominal. The boundary layer transition was also nominal.

Thermal Protection Subsystem and Windows

The TPS performed satisfactorily. Based on structural temperature response data (temperature rise), the entry heating was nominal for the vehicle. Boundary layer transition from laminar flow to turbulent flow occurred at approximately 1330 seconds after entry interface at the forward centerline of the vehicle and at the aft centerline of the vehicle. There were no measurements or other evidence to indicate that an asymmetric transition occurred.

Based on data from the debris inspection team, overall debris damage was significantly less than average. Of the total of 85 impacts, only 35 were recorded on the lower surface with only 5 having a major dimension greater than one-inch or larger. None of impacts was identified as being caused by micrometeorites or on-orbit debris. The following table delineates the number of hits by area of the Orbiter.

TPS DAMAGE SITES

Orbiter Surfaces	Hits > 1 Inch	Total Hits
Lower Surface	5	35
Upper Surface	3	34
Right Side	0	2
Left Side	3	4
Right OMS Pod	0	5
Left OMS Pod	1	5
Total	12	85

The largest lower surface tile damage site was located aft of the ET/Orbiter umbilicals and measured 3.2 inches long by 1.25 inch wide with a maximum depth of 0.5 inch. The most likely cause of the damage was an impact of ice from the umbilicals. The tile damage sites aft of the LH_2 and LO_2 ET/Orbiter umbilicals, usually caused by impacts from umbilical ice or shredded pieces of umbilical purge barrier material flapping in the air stream, were less than usual in number and size.

One lower body flap tile sustained a large damage that measured 2.0 inches by 1.5 inches by 0.2 inch deep. The upper body flap RCS vernier engine impingement area had one large damage area. Also, several main landing gear door thermal barriers were frayed and two were breached.

The SSME 1 dome mounted heat shield (DMHS) closeout blankets were frayed at the 5:00 o'clock position and torn at the 7:00 o'clock position. Severe tearing and fraying of the SSME 3 DMHS blankets occurred from the 7:00 to 12:00 o'clock position. The SSME 2 DMHS blankets were undamaged.

Tiles on the vertical stabilizer stinger were intact and undamaged. However, one tile at the +Y -Z corner of the drag chute cavity was chipped. Damage to approximately 50 percent of one tile on the trailing edge of the left rudder/speedbrake was not related to drag chute deployment. A damage cavity, or tunnel, in the X direction in the inboard side of the tile may indicate a debris impact due to exhaust plume recirculation during ascent.

No ice adhered to the payload bay door. The reddish-brown discoloration on the leading edge of the left-hand payload bay door had not changed in appearance from the previous flight. No unusual tile damage was observed on the leading edges of the vertical stabilizer and OMS pods.

An unusual finding was tile damage on the upper surface of the left wing near the leading edge but aft of the reinforced carbon carbon (RCC) panels. The damage site measured approximately 5 inches long by 0.75 inch wide by 0.125 inch deep, and the damage was oriented in the longitudinal (-X) direction.

Hazing and streaking of Orbiter windows 2, 3, and 4 was typical. Damage sites on the window perimeter tiles (five hits on window 2; five hits on window 3; and four hits on window 4) were determined to be new damage sites. Numerous other damage sites were attributed to old repair material flaking off. A tile between windows 3 and 4 had a damage site 2 inches long by 1 inch wide by 0.125 inch deep.

FLIGHT CREW EQUIPMENT/GOVERNMENT FURNISHED EQUIPMENT

The flight crew equipment/Government furnished equipment performed acceptably. At the flight crew debriefing, the crew noted that the galley dispensed some air into the first water draw each morning, but the condition was not significant and does not require corrective action. Three in-flight anomalies identified during the mission, and none impacted the mission. These are discussed in the following paragraphs.

At 175:19:27 G.m.t. (03:04:38 MET), the ground was unable to command the closed-circuit television (CCTV) camera A focus (Flight Problem STS-78-F-01). The camera was usable and produced a clear picture for a wide field of view. The camera was power cycled several times in an unsuccessful attempt to regain control of the focus. At 179:08:33 G.m.t. (06:17:44 MET), after the camera had been left on for more than eight hours and the telemetry-indicated temperature had risen to +33 °C, the focus mechanism began working properly. The camera temperature was 8 °C during the failed attempt to focus.

At 178:13:49 G.m.t. (05:23:00 MET), the crew reported that a threaded fastener that secured the ergometer to its frame was broken and that another threaded fastener was sheared (Flight Problem STS-78-F-02). The remaining two fasteners were loose. The crew replaced the broken fasteners with the two spare fasteners and tightened the two loose fasteners. The crew was told to tighten all four fasteners prior to each exercise session. A similar ergometer failure was experienced during a previous mission (STS-65).

At approximately 185:10:50 G.m.t. (12:20:01 MET), the crew reported that the wireless function of audio interface unit (AIU) E in the Spacelab was not operating on either frequency in any mode (Flight Problem STS-78-F-03). However, the hard-line function of the AIU operated nominally as did both functions of the alternate AIU in the Spacelab (AIU D) and the three AIUs in the Orbiter. The crew reported that the communication configuration in the Spacelab was acceptable.

CARGO INTEGRATION

The integration hardware performance was nominal throughout the mission, with no issues or in-flight anomalies identified.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DEVELOPMENT TEST OBJECTIVES

The Development Test Objectives individually in the following paragraphs.

DTO 301 D - Ascent Structural Capability Evaluation - This DTO was data-only, with the data being recorded on the modular auxiliary data system (MADS) recorder. The data were dumped from the recorded after landing and were given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DTO 307D - Entry Structural Capability - This DTO was data-only, with the data being recorded on the MADS recorder. The data were dumped from the recorded after landing and were given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DTO 312 - ET TPS Performance (Methods 1 and 3) - Photography of the ET after separation was acquired, following the pitch maneuver, with the Nikon 35 mm camera with a 300 mm lens and a 2X extender (method 1). A total of 38 excellent quality views of the ET were on roll 457. All aspects of the ET were imaged, and timing data were on the film. The first picture was taken approximately 14 minutes after liftoff, and the final picture was taken 9 minutes 12 seconds later. The aero-heating marks and the booster-separation motor burn scars were typical of previous missions. No ET anomalies were noted in the film. Mission Specialist 1 took the 35 mm camera pictures, and Mission Specialist 2 provided coverage using the camcorder.

Three rolls of umbilical-well camera film were exposed during ascent; two rolls from the 16 mm camera and one roll from the 35 mm camera (method 3). All of the film had good focus, and the exposures were good except for the backlighting by the Sun during the ET separation sequences. Good coverage of the left SRB, as well as good coverage of the ET separation were acquired on the 16 mm film. No anomalous conditions were noted from the 16 mm film. The 35 mm film showed that two of the five lightning contact strips were missing from the ET/Orbiter LO_2 umbilical interface plate. This condition has been observed on previous flights, as recently as STS-77. No anomalous conditions were observed on the 35 mm film.

DTO 319D - Shuttle/Payload Low Frequency Performance - This DTO was data-only, with the data being recorded on the MADS recorder. The data were dumped from the recorded after landing and were given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DTO 416 - Water Spray Boiler Quick Restart - This DTO was successfully completed and demonstrated acceptable restart capability. The detailed results of this DTO will be documented in other publications.

DTO 623 - Cabin Air Monitoring - Cabin air conditions were measured as required during the flight. These data have been given to the sponsor for evaluation. The results of the evaluation will be presented in a separate document.

DTO 667 - Portable In-Flight Landing Operations Trainer (PILOT) - The Commander and Pilot successfully used the PILOT software to maintain performance levels of training for entry and landing during the 17-day flight. All equipment and software functioned satisfactorily during the mission. The overall results of this DTO will be presented in separate documentation.

DTO 675 - Voice Control of Closed Circuit TV System - This DTO provided a voice recognition system that interfaced with the Shuttle CCTV system and enabled voice commanding of the payload bay cameras. The Commander and Pilot exercised the interface several times during the flight. The system worked excellently and was capable of adapting the complex human voice patterns into camera commands. Discussions of the results of this DTO will be published in separate documentation.

DTO 837 - Vernier RCS Reboost Demonstration/Test No. 3 - All three parts of DTO 837 - Vernier RCS Reboost - were performed satisfactorily. Vernier thruster operation was nominal during the DTO performance. This test successfully demonstrated the satisfactory use of the RCS vernier thrusters to perform a translation ΔV reboost of the Orbiter/ Hubble Space Telescope during the upcoming STS-82 mission. Data analysis is continuing to determine if this method will offer a clean separation after payload deployment/servicing. The results of the analysis will be published in separate documentation.

DTO 1126 - KCA Video Teleconferencing - This DTO provided the capability for the Mission Control Center (MCC) and personnel onboard the Orbiter to conduct video teleconferences using the Shuttle Payload and General Support Computer (PGSC). This DTO was extremely successful and was even used for uplinking a video-taped IFM procedure that was partially instrumental in the repair of the BDPU -15 volt power supply. Numerous daily video conferences were conducted. These activities included private medical conferences, personal family conferences, and management demonstrations. The small right-angle camera provided as a part of this DTO was used to provide excellent in-cabin views of the crew during launch and during landing.

DETAILED SUPPLEMENTARY OBJECTIVES

Data were collected as required for the Detailed Supplementary Objectives (DSOs). These data have been given to the sponsors for evaluation, and the results of the evaluation will be reported in separate publications. The DSOs assigned to the STS-78 mission were as follows:

a. DSO 331 - LES and Sustained Weightlessness (Commander and Pilot Only);

b. DSO 487 - Immunological Assessment of Crew;

c. DSO 491 - Microbial Transfer Among Crew;

d. DSO 493 - Latent Virus Shedding (Commander and Pilot Only);

e. DSO 802 - Educational Activities (Option 1 and 2);

f. DSO 901 - Documentary Television; and

g. DSO 903 - Documentary Still Photography.

PHOTOGRAPHY AND VIDEO DATA ANALYSIS

LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS

The launch photography and video data were screened, and no anomalous conditions were noted. A total of twenty-four 16 mm and twelve 35 mm films plus 24 videos of the launch were screened and analyzed.

ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS

No on-orbit photography or video data were analyzed as no conditions occurred that required analysis.

LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSIS

Twelve videos of landing operations were screened and no anomalous conditions were noted. In addition, a video of out-the-pilot-window conditions during entry and landing was also reviewed.

TABLE I.- STS-78 SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
APU Activation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	172:14:44:10.417 172:14:44:11.340 172:14:44:12.262
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	172:14:48:32.089 172:14:48:32.249 172:14:48.32.409 172:14:48:32.569
Main Propulsion System Start[a]	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	172:14:48:53.458 172:14:48:53.577 172:14:48:53.687
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	172:14:49:00.019
Throttle up to 104 Percent Thrust[a]	ME-2 Command accepted ME-1 Command accepted ME-3 Command accepted	172:14:49:04.128 172:14:49:04.128 172:14:49:04.149
Throttle down to 67 Percent Thrust[a]	ME-2 Command accepted ME-1 Command accepted ME-3 Command accepted	172:14:49:34.048 172:14:49:34.048 172:14:49:34.070
Maximum Dynamic Pressure (q)	Derived ascent dynamic pressure	172:14:49:49
Throttle up to 104 Percent[a]	ME-2 Command accepted ME-1 Command accepted ME-3 Command accepted	172:14:49:59.968 172:14:49:59.969 172:14:49:59.990
Both SRM's Chamber Pressure at 50 psi[a]	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	172:14:50:58.539 172:14:50:58:739
End SRM [a] Action[a]	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	172:14:51:00.499 172:14:51:00.909
SRB Physical Separation[a]	LH rate APU turbine speed - LOS RH rate APU turbine speed - LOS	172:14:51:03.699 172:14:51:03.699
SRB Separation Command	SRB separation command flag	172:14:51:04
Throttle Down for 3g Acceleration[a]	ME-2 command accepted ME-1 command accepted ME-3 command accepted	172:14:56:30.374 172:14:56:30.378 172:14:56:30.398
3g Acceleration	Total load factor	172:14:56:32.1
Throttle Down to 67 Percent Thrust[a] for Cutoff	ME-2 command accepted ME-1 command accepted ME-3 command accepted	172:14:57:22.854 172:14:57:22.859 172:14:57:22.879
SSME Shutdown[a]	ME-2 command accepted ME-1 command accepted ME-3 command accepted	172:14:57:29.334 172:14:57:29.339 172:14:57:29.359
MECO	MECO command flag MECO confirm flag	172:14:57:30 172:14:57:31
ET Separation	ET separation command flag	172:14:57:49
APU Deactivation	APU-1 GG chamber pressure APU 2 GG chamber pressure APU 3 GG chamber pressure	172:15:05:47.289 172:15:05:55.423 172:15:06:04.411

[a]MSFC supplied data

TABLE I.- STS-78 SEQUENCE OF EVENTS (Concluded)

Event	Description	Actual time, G.m.t.
OMS-1 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Not performed - direct insertion trajectory flown
OMS-1 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	
OMS-2 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	172:15:30:28.6 172:15:30:28.7
OMS-2 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	172:15:32:26.6 172:15:32:26.7
Payload Bay Doors (PLBDs) Open	PLBD right open 1 PLBD left open 1	172:16:08:07 172:16:09:28
Port Radiator Deployment	Port Radiator Deploy 2	174:18:12:53
Starboard Radiator Deployment	Starboard Radiator Deployment 1	185:17:04:20
Flight Control System Checkout APU Start APU Stop	 APU-2 GG chamber pressure APU-2 GG chamber pressure	 188:08:49:56.285 188:08:54:59.393
Starboard Radiator Stow	Starboard Radiator Latch 7-12 Latch 2	188:13:28:53
Port Radiator Stow	Port Radiator Latch 7-12 Latch 2	188:13:28:53
Payload Bay Doors Close	PLBD left close PLBD right close	189:08:58:28 189:09:00:26
APU Activation for Entry	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	189:11:31:32.530 189:11:51:38.275 189:11:51:39.875
Deorbit Burn Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	189:11:36:36.1 189:11:36:36.2
Deorbit Burn Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	189:11:39:18.5 189:11:39:18.6
Entry Interface (400K feet)	Current orbital altitude above	189:12:04:37
Blackout end	Data locked (high sample rate)	No blackout
Terminal Area Energy Mgmt.	Major mode change (305)	189:12:30:15
Main Landing Gear Contact	LH main landing gear tire pressure 1 RH main landing gear tire pressure 2	189:12:36:35 189:12:36:35
Main Landing Gear Weight on Wheels	LH main landing gear weight on wheels RH main landing gear weight on wheels	189:12:36:36 189:12:36:36
Drag Chute Deployment	Drag chute deploy 1 CP Volts	189:12:36:39.9
Nose Landing Gear Contact	NLG 1 RH tire pressure 1	189:12:36:48
Nose Landing Gear Weight on Wheels	NLG no weight on wheels	189:12:36:48
Drag Chute Jettison	Drag chute jettison 1 CP Volts	189:12:37:11.7
Wheel Stop	Velocity with respect to runway	189:12:37:31
APU Deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	189:12:51:18.778 189:12:51:23.624 189:12:51:29.046

TABLE II.- STS-78 ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-78-V-01	GPC 5 I/O Terminate B Discrete Erratic	172:15:18 G.m.t. 00:00:29 MET CAR 78RF03 IPR 80V-0003	At 172:15:18:30 G.m.t. (00:00:29:30 MET), the general purpose computer (GPC) 5 input/output (I/O) terminate B discrete began behaving erratically, toggling from high to low six times. The backup flight system (BFS) software was contained in GPC 5. The I/O terminate B discrete controls GPC I/O on the flight critical buses. The BFS software was successfully loaded into GPC 2 at approximately 176:20:05 G.m.t. (04:05:16 MET). A dump and compare of the GPC 2 software confirmed a nominal software load. During the same time frame, GPC 5 was initial program loaded (IPLed) with Primary Avionics Software System(PASS), loaded with GNC OPS 2 software, and placed in a redundant set with GPC 1(commanding no strings). The GPC 5 output switch was placed in the terminate position. This configuration was maintained with no anomalous GPC 5 behavior observed until 177:21:01 G.m.t. (approximately 25 hours), at which time the GPC 5 output switch was placed in normal. This configuration was maintained until deorbit preparations, and no further occurrences of the erratic I/O term B discrete were observed. Troubleshooting steps involving GPC 4 were taken to assist in isolating the failure. The GPC 4 output switch was placed in the backup position at 181:17:07 G.m.t. (09:02:18 MET) to provide insight into a possible failure between the essential bus (ESS) 3AB fuse powering the backup position of the GPC output switches as well as the output switches. If the GPC 4 I/O term B discrete toggled while this switch was in the backup position, the failure would affect the BFS regardless of which GPC contained the BFS software. No toggles were seen and the GPC 4 output switch was placed in terminate at 184:07:29 G.m.t. (11:16:40 MET). During deorbit preparations at 189:09:19 G.m.t. (16:18:30 MET), the BFS (in GPC 2) registered an error code 41 (illegal engage) similar to the error that was logged during ascent when the BFS was in GPC 5. This event was coincident with the GPC 4 output switch being taken from terminate to normal, thus offering an explanation for the error code. The output switches for the GPCs are "break-before-make," and as such, moving the GPC 4 output switch from terminate to normal causes a momentary break in the ESS 3AB power to the backup position of the GPC 2 output switch, in turn causing a transient in the I/O term B for GPC 2. No further occurrences of the erratic I/O term B were seen during the remainder of the mission. As a precaution, GPC 2 software (BFS) was dumped for analysis postlanding.

TABLE II.- STS-78 ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-78-V-01 (Continued)	GPC 5 I/O Terminate B Discrete Erratic	172:15:18 G.m.t. 00:00:29 MET CAR 78RF03 IPR 80V-0003	A similar failure occurred in this same slot on STS-32 (OV-102/flight 9). The backup flight controller (BFC) and the GPC were removed and replaced. The failure was not isolated in ground testing and was closed as an unexplained anomaly with a most probable cause of the BFC. KSC: During troubleshooting, the state of the I/O terminate B discrete was monitored for approximately 80 hours, with no recurrence of the anomaly. Wire wiggle and pin-push tests were performed with no recurrence of the anomaly. A breakout box was installed at the BFC and the select, select off, and the terminate B true and complement signals were verified to be nominal. The BFC delay timer was measured and found to be within specification, suggesting that the circuit upstream of the BFC did not play into the failure. A HiPOT of the I/O terminate B true and complement lines showed 0.2 milliamps of leakage at 800 volts, indicating a possible short between the lines. Flexing the harness caused the reading to fluctuate. Although the reading was within OMRS limits (0.5 milliamps), the wire runs were removed and sent to the malfunction laboratory for analysis. HiPOT of the new wires will be performed.
STS-78-V-02	FES High-Load Duct Temperatures Low During Ascent and High-Load Core Freeze-up During Deorbit Preparations	172:15:00 G.m.t. 00:00:11 MET CAR 78RF06 IPR 80V-0005	During ascent, the flash evaporator system (FES) high-load duct temperatures were erratic and lower than normal. The inboard duct temperature dropped to approximately 119 °F by 13 minutes MET (normally the temperature stays above 190 °F). The heaters were reconfigured from system A only to systems A and B at approximately 13.5 minutes MET and the temperatures eventually recovered. Throughout the occurrence, the evaporator outlet temperatures were stable. No further problems with the FES were noted during ascent. To verify the performance of the high load duct system A heater, the heater was powered at 173:16:14 G.m.t. (01:01:25 MET), and temperatures were monitored for approximately 2 hours and 45 minutes. A nominal temperature signature was observed. During deorbit preparations at approximately 189:10:04 G.m.t. (16:19:15 MET), the FES shut down after almost an hour and a half of operation in the full-up mode on the primary B controller. The high-load core was flushed, and the data indicated ice exiting through the high-load duct. A flush was also performed on the topping core followed by a second high-load core flush, but no additional ice was noted. The remainder of deorbit preparations and entry was performed using the primary A controller with no further anomalies.

TABLE II.- STS-78 ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-78-V-02 (Continued)	FES High-Load Duct Temperatures Low During Ascent and High-Load Core Freeze-up During Deorbit Preparations.	172:15:00 G.m.t. 00:00:11 MET CAR 78RF06 IPR 80V-0005	KSC: Initial troubleshooting consisted of internal and external visual-inspections of the high-load core, as well as leak and flowrate testing of the system A and B high-load spray valves. No anomalies were noted in the visual inspections or spray valve leak tests. Initial flowrate testing of the high-load system A spray valve resulted in a flowrate of 141 lb/hr. Following several back-flushes of the valve, the flowrate decreased to 101 lb/hr. Since the change in flowrate is unexplainable, the decision was made to remove and replace the valve. The system B high-load spray valve was removed and replaced also. Additional flushing of the A feedwater system was performed, and the accumulator was flushed and verified clean on the bench. The B feedwater system was flushed again.
STS-78-V-03	FES Topping Core Freeze-ups	174:15:50 G.m.t. 02:01:01 MET CAR 78RF07 IPR 80V-0007	At approximately 174:15:50 G.m.t. (02:01:01 MET), while in the topping mode and on the primary A controller, the FES shut down. A restart attempt on the A controller was unsuccessful, and was followed by an unsuccessful restart attempt on the B controller. Data from the shutdown and subsequent unsuccessful restarts indicated icing in the FES core. A FES core-flush initiated at 174:17:12 G.m.t. (02:02:23 MET) successfully removed the ice from the core and nominal operation was restored on the B controller. Although the cause of the FES freeze-up was unknown, a contributing factor was believed to have been operating the FES in the topping mode near its maximum heat-load capability. Therefore, to reduce the heat load to the FES, the port radiator was deployed at 174:18:13 G.m.t. (02:03:24 MET). The deployed radiator provided additional cooling capacity for the active thermal control system, thereby minimizing the chance of additional FES freeze-ups. To obtain additional data, a FES water dump was requested on the B controller, and if successful, the A controller. The water dump on the B controller was initiated at approximately 180:08:19 G.m.t. (07:17:30 MET); however, the FES shut down due to icing at approximately 180:10:08 G.m.t. (07:19:19 MET). The core-flush procedure was performed and no additional FES water dumps were attempted. KSC: Initial troubleshooting consisted of internal and external visual-inspections of the topping core, as well as leak and flowrate testing of the system A and B topping spray valves. Initial flowrate testing of the topping system A spray valve resulted in a flow rate of 141 lb/hr. Following several backflushes of the valve, the flowrate remained the same. The particulate count from the

TABLE II.- STS-78 ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-78-V-03 (Continued)	FES Topping Core Freeze-ups	174:15:50 G.m.t. 02:01:01 MET CAR 78RF07 IPR 80V-0007	flushes indicate that the topping system is clean. Flowrate testing and backflushing was also performed on the B feedwater system. It is believed that the Freon coolant loop (FCL) 1 flow rate, which is the highest flow rate of any FCL in the fleet, or the FCL 1 and 2 flow rate imbalance may have played a role in the freeze-ups of the topping evaporator. As a result, FES testing will be performed at JSC to demonstrate that theory. The results from this testing will determine what, if any, adjustment needs to be made to the FCL 1 flowrate.
STS-78-V-04	PRSD H_2 Tank 4 Heater B Failure	176:12:00 G.m.t. 03:21:11 MET CAR 78RF05 IPR 80V-0004	At approximately 176:12:00 G.m.t. (03:21:11 MET), while the fuel cell H_2 was being supplied by tanks 4 and 5, H_2 tanks 4 and 5 quantities began diverging, with the tank 4 quantity decreasing at a slower rate than the tank 5 quantity. The heaters on both tanks are controlled by a common controller and are therefore commanded on simultaneously. On-orbit troubleshooting, during which tanks 4 and 5 were operated for several hours on the A heaters only, followed by the B heaters only, confirmed that the tank 4 B heater had failed. The failure did not significantly impact H_2 tank use, and tanks 4 and 5 were run to depletion using the A heaters only. During STS-75, a similar failure occurred (reference Flight Problem STS-75-V-04). Failure of the tank 4 A heater was confirmed, and the fuse for that heater was removed and replaced during turnaround. The failure analysis determined that the fuse failed mechanically as a result of cyclic heating, not excessive current. KSC: The heater was still failed during detanking operations at KSC. The heater controller was accessed, and the fuse was removed. X-rays indicate that the fuse was mechanically failed.
STS-78-V-05	APU 1 Fuel Pump Inlet Pressure Decay	172:15:39 G.m.t. 00:50:00 MET CAR 78RF08 PR APU-2-A0028	As expected, the APU 1 fuel pump inlet pressure decayed post-ascent following closure of the fuel isolation valve (FIV) due to fuel pump carbon seal leakage into the seal cavity drain. This is the same APU that was flown in this position on the previous flight of OV-102 (STS-75), when a similar decay was observed. The fuel inlet pressure dropped to approximately 40 psia indicated (24 psia corrected) which was just above the indicated seal cavity drain line pressure of 22 to 23 psia. The pressure decayed at a higher rate this mission than during STS-75, which indicates the leak may be getting worse (the inlet pressure did not crack the FIV relief valve as is typically seen). Since opening the FIV with a fuel pump inlet pressure above 15 psia was not a concern, and dynamic seal leakage had not been noted, the leak posed no flight impact. The

TABLE II.- STS-78 ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-78-V-05 (Continued)	APU 1 Fuel Pump Inlet Pressure Decay	172:15:39 G.m.t. 00:50:00 MET CAR 78RF08 PR APU-2-A0028	fuel pump inlet and seal cavity drain pressures were stable throughout the mission. The APU 1 FIV opening was delayed from the normal deorbit TIG-45 minutes to just prior to APU 1 start at entry interface (EI) -13 minutes. This was done to minimize the time that the leaking fuel pump seal was subjected to full tank pressure and the subsequent static leakage. APU 1 performance was nominal during its entry run. The APU 1 fuel pump inlet pressure dropped to 43 psia indicated (27 psia corrected) post landing. It had dropped to 49 psia indicated within 26 minutes after landing. Again the data suggests that the leak increased since STS-75. KSC: APU 1 was removed and replaced based on the evidence of increased leakage and the probable failure of a speed sensor. The APU 1 catch bottle was drained of 365 cc of hydrazine. The removed APU was sent to the vendor for failure analysis.
STS-78-V-06	APU 1 Turbine Speed Sensor Erratic	189:11:51 G.m.t. 16:21:02 MET CAR 78RF09 IPR 80V-0010	At 189:11:51 G.m.t. (16:21:02 MET), when APU 1 was started for its entry run, the downlinked turbine speed sensor [magnetic pickup unit (MPU) 3] was initially failed off, became erratic for approximately four minutes, and then worked continuously for the remainder of the APU run. MPU 3 is one of three turbine speed sensors per APU and the only one that is downlinked. Its erratic performance did not affect APU 1 operation. The most probable cause of the failure is an open circuit in the MPU 3 coil wire. This failure mode has been seen on nine previous occasions, some of which were intermittent. This is the first in-flight occurrence. KSC: Vehicle troubleshooting was performed prior to the removal and replacement of APU 1. Troubleshooting performed consisted of an auto BITE check using the APU controller. The test failed which indicates a continuity failure. An additional APU controller checkout isolated the problem to the MPU 3 circuit. The APU has been removed and replaced.
STS-78-V-07	Rudder Channel 3 Position Feedback Erratic	189:10:25 G.m.t. 16:19:36 MET CAR 78RF10 IPR 80V-0010	During deorbit preparations at 189:10:25 G.m.t. (16:19:36 MET), the rudder channel 3 position feedback became erratic. Prior to EI, the rudder is positioned at +5 degrees so that a failure of this type can be detected. The problem was also seen in the servo-valve current as well as the secondary differential pressure measurements following APU 2 start. Prior to EI, the measurement appeared to heal but was still very noisy. After EI, when the rudder is positioned to 0 degrees, the decision was made to manually bypass rudder channel 3. The crew executed the bypass command at 189:12:02 G.m.t. (16:21:13 MET), which left the rudder operating on channels 1, 2, and 4 and was thus tolerant

TABLE II.- STS-78 ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-78-V-07 (Continued)	Rudder Channel 3 Position Feedback Erratic	189:10:25 G.m.t. 16:19:36 MET CAR 78RF10 IPR 80V-0010	of a second failure. During the latter part of entry when the rudder was used for steering, the rudder channel 3 position measurement healed and operated properly. This problem is believed to be caused by a continuity problem between the position transducer in the rudder/speedbrake power drive unit (PDU) and the aerosurface servoamplifier assembly (ASA) in avionics bay 6. KSC: Initial troubleshooting, which consisted of cable inspection and flexing at ASA 3, was completed with no repeat of the anomaly. Further troubleshooting will be performed as access allows.
STS-78-V-08	WSB 1 Ready Indication Unexplained Toggles	189:12:31 G.m.t. 16:21:42 MET	At 189:12:31 G.m.t. (16:21:42 MET), several minutes prior to landing, toggling of the WSB 1 ready indication was indicated. Toggling of this indication is not unusual and is typically caused by the WSB hydraulic fluid bypass valve transitioning between the heat exchanger and bypass positions. However, during STS-78, bypass valve movement was not indicated. None of the other parameters that can cause a ready indication to change state (controller enabled, steam vent temperature, or GN2 shut-off valve position) would explain the toggles that were indicated. Proper operation of the bypass valve and the ready indication will be verified post flight. KSC: A troubleshooting plan has been developed that consists of cycling the bypass valve.

TABLE III.- GOVERNMENT FURNISHED EQUIPMENT PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-78-F-01	CCTV Camera A Focus Inoperative	175:22:00 G.m.t. 03:07:11 MET	At 175:19:27 G.m.t. (03:04:38 MET), the ground controllers were unable to command the closed-circuit television (CCTV) camera A focus. The camera was usable and produced a clear picture for a wide field of view. The camera was power cycled several times in an unsuccessful attempt to regain control of the focus. At 179:08:33 G.m.t. (06:17:44 MET), after the camera had been left on for more than 8 hours and the telemetry-indicated temperature had risen to +33 °C, the focus mechanism began working. Note that the camera temperature was 8 °C during the failed attempt to focus. The camera will be removed and the problem will be evaluated in the camera lab at KSC.
STS-78-F-02	Ergometer Fastener Failure	178:13:49 G.m.t. 05:23:00 MET	At 178:13:49 G.m.t. (05:23:00 MET), the crew reported that a threaded fastener connecting the ergometer to the frame had broken and that another threaded fastener had sheared. The remaining two fasteners were loose. The crew replaced the damaged threaded fasteners with the two spare threaded fasteners and tightened the remaining threaded fasteners. Procedures were provided to the crew to tighten all four fasteners prior to each exercise session. The ergometer was shipped to JSC for evaluation.
STS-78-F-03	Spacelab AIU E Wireless Function Failed	185:10:50 G.m.t. 12:20:01 MET	At approximately 185:10:50 G.m.t. (12:20:01 MET), the crew reported that the wireless function of audio interface unit (AIU) E in the Spacelab was not operating on either frequency in any mode. The hard-line function of the AIU operated nominally as did both functions of the alternate AIU in the Spacelab (AIU D) and the three AIUs in the Orbiter. The crew reported that the communications configuration in the Spacelab was acceptable. The AIU will be shipped to Houston for evaluation.

TABLE IV- MSFC IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-78-E-01	Main Engine 2036 Violated Thrust Build-up Rate During Engine Start	SSME Start Sequence PRCBD SO62117	Main engine 2036 violated the thrust build-up rate during STS-78 engine start. The requirement that is specified in the Interface Control Document (ICD) 13M15000 Rev. AA, paragraph 7.6.2a, states that the thrust build-up rate will not exceed 14,000 lb/0.020 second. Thrust change for any two consecutive 20 millisecond time intervals above 15 percent of rated power level thrust. Three total data points violated the 14,000 lb/20 millisecond requirement with two being consecutive in time.
STS-78-M-01	Sooting/Heat Effects Beyond J -Leg Insulation Tip on Field Joints	First Stage Ascent PRCBD SO62117	Heavy sooting and heat effects (discoloration and charring) observed on insulation interfaces within STS-78 field joints. There were no heat effects to metal interfaces or Capture Feature (CF) O-rings, and no gas past the CF O-rings. All engineering and Contract End Item (CEI) specification requirements were met. However, this is a first occurrence of heat effect within J-leg insulation. All six field joints exhibited some degree of gas penetration past the J-leg tip. Soot/char patterns were most extensive in the center joints. The aft joints were next, with the forward joints exhibiting only slight soot penetration at localized points. The left-hand center exhibited nine locations with soot to the CF O-ring and seal surfaces - no charring but, slight discoloration at some locations. The right-hand center joint exhibited three locations with light soot slightly past the J-leg radius - no charring or discoloration was present after cleaning. Aft and forward joints did not exhibit any soot patterns past the radius. The concern is change in J-leg insulation performance and implications to field-joint performance.

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

ACRONYMS AND ABBREVIATIONS

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

A/D	analog to digital converter
AIU	audio interface unit
APU	auxiliary power unit
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
ASA	aerosurface actuator
ATCS	active thermal control system
ATL	attitude time line
BDPU	Bubble, Drop, and Particle Unit
BET	bending effects temperature
BFC	backup flight controller
BFS	backup flight system
BITE	built-in test equipment
BRIC	Biological Research in Canisters
CCTV	closed circuit television
cc	cubic centimeter
c.d.t.	central daylight time
CDR	Commander
CEI	contract end item
CO_2	carbon dioxide
DMHS	dome-mounted heat shield
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
DVM	Doctor of Veterinary Medicine
ΔP	differential pressure
ΔV	differential velocity
ECLSS	environmental control and life support system
ECO	engine cutoff
EDO	Extended Duration Orbiter
EI	entry interface
EMI	electromagnetic interference
EPDC	electrical power distribution and control subsystem
ET	External Tank
FA	flight critical aft
FCE	flight crew equipment
FCL	Freon coolant loop
FCS	flight control system
FCV	flow control valve
FDA	fault detection and annunciation
FES	flash evaporator system
FIV	fuel isolation valve
FM	frequency modulation
ft/sec	feet per second
g	gravity

GFE	Government furnished equipment
GH_2	gaseous hydrogen
G.m.t.	Greenwich mean time
GN_2	gaseous nitrogen
GO_2	gaseous oxygen
GPC	general purpose computer
H_2	hydrogen
HGDS	hazardous gas detection system
HiPOT	high potential
HISAM	hardware-initiated stand-alone memory
HPFTP	high pressure fuel turbopump
HPOTP	high pressure oxidizer turbopump
IFM	in-flight maintenance
I/O	input/output
Isp	specific impulse
KCA	Ku-band communications adapter
keas	knots estimated air speed
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt hour
lb	pound
lb/hr	pound per hour
lbm	pound-mass
lb/min	pound per minute
LCC	Launch Commit Criteria
LH_2	liquid hydrogen
LMES	Lockheed Martin Engineering and Science Company
LMS	Life and Microgravity Sciences
LO_2	liquid oxygen
MADS	modular auxiliary data system
MCC	Mission Control Center
MDM	multiplexer-demultiplexer
MECO	main engine cutoff
MET	mission elapsed time
MLG	main landing gear
MMA	Microgravity Measurement System
MPS	main propulsion system
MPU	magnetic pickup unit
ms	millisecond
MSFC	Marshall Space Flight Center
nmi.	nautical miles
NPSP	net positive suction pressure
NSTS	National Space Transportation System (i.e., Space Shuttle Program)
OARE	Orbital Acceleration Research Experiment
OMDP	Orbiter Maintenance Down Period
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OSH	off-scale high
PAL	protuberance air load

PASS	primary avionics software system
PDU	power drive unit
PGSC	payload and ground support computer
PILOT	Pilot Operated Landing Operations Trainer
PMBT	propellant mean bulk temperature
$PPCO_2$	partial pressure carbon dioxide
ppm	parts per million
PPOV-CAM	Pilot Point of View Camera
PRSD	power reactant storage and distribution
psia	pound per square inch absolute
psid	pound per square inch differential
RCC	reinforced carbon carbon
RCRS	regenerative CO_2 removal system
RCS	reaction control subsystem
RSRM	Reusable Solid Rocket Motor
RTV	room temperature vulcanizing
SAMS	Shuttle Acceleration Measurement System
SAREX-II	Shuttle Amateur Radio Experiment-II
S&A	safe and arm
SCU	sequence control unit
SLF	Shuttle Landing Facility
SODB	Shuttle Operational Data Book
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSME	Space Shuttle main engine
TCE	condenser exit temperature
TCS	thermal control subsystem
TDRS	Tracking and Data Relay Satellite
TPS	thermal protection subsystem
Vdc	Volts direct current
WCS	Waste Collection System
WSB	water spray boiler

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