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STS-52 SPACE SHUTTLE MISSION REPORT

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SPACE SHUTTLE

MISSION REPORT

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INTRODUCTION

The STS-52 Space Shuttle Program Mission Report provides a summary of the Orbiter, External Tank (ET), Solid Rocket Booster/Redesigned Solid Rocket Motor (SRB/RSRM), and the Space Shuttle main engine (SSME) subsystem performance during the fifty-first flight of the Space Shuttle Program, and the thirteenth flight of the Orbiter vehicle Columbia (OV-102). In addition to the Orbiter, the flight vehicle consisted of an ET (designated as ET-55/LWT-48); three SSME's, which were serial numbers 2030, 2015, and 2034 in positions 1, 2, and 3, respectively; and two SRB's, which were designated BI-054. The lightweight RSRM's that were installed in each SRB were designated 360L027A for the left SRB and 360Q027B for the right SRB.

The STS-52 Space Shuttle Program Mission Report fulfills the Space Shuttle Program requirement, as documented in NSTS 07700, Volume VIII, Appendix E, which states that each major organizational element supporting the Program will report the results of its hardware evaluation and mission performance plus identify all related in-flight anomalies.

The primary objectives of this flight were to successfully deploy the Laser Geodynamic Satellite (LAGEOS-II) and to perform operations of the United States Microgravity Payload-1 (USMP-1). The secondary objectives of this flight were to perform the operations of the Attitude Sensor Package (ASP), the Canadian Experiments-2 (CANEX-2), the Crystals by Vapor Transport Experiment (CVTE), the Heat Pipe Performance Experiment (HPP), the Commercial Materials Dispersion Apparatus Instrumentation Technology Associates Experiments (CMIX), the Physiological System Experiment (PSE), the Commercial Protein Crystal Growth (CPCG-Block II), the Shuttle Plume Impingement Experiment (SPIE), and the Tank Pressure Control Experiment (TPCE) payloads.

The sequence of events for the STS-52 mission is shown in Table I and the Official Orbiter and GFE Projects Problem Tracking List is shown in Table II. The STS-52 mission was planned as a 10-day plus 2-contingency-day mission. Appendix A lists the sources of data, both formal and informal, that were used in the preparation of this document. Appendix B provides the definition of acronyms and abbreviations used in this document.

In addition to presenting a summary of subsystem performance, this report also discusses each Orbiter, ET, SSME, SRB, and RSRM in-flight anomaly in the applicable section of the report. The anomaly discussion also provides a reference to the assigned tracking number as published in the Problem Tracking Lists. All times are given in Greenwich mean time (G.m.t.) as well as mission elapsed time (MET).

The crew for this fifty-first Space Shuttle mission was James D. Wetherbee, Cdr., USN, Commander; Michael A. Baker, Capt., USN, Pilot; Charles L. (Lacy) Veach, Civilian, Mission Specialist 1; William M. Shepherd, Capt., USN, Mission Specialist 2; Tamara E. Jernigan, Ph.D., Civilian, Mission Specialist 3; Steven G. MacLean, Ph.D, Civilian, Payload Specialist 1. STS-52 was the third space flight for Mission Specialist 2; the second space flight for the Commander, Pilot, Mission Specialist 1, and Mission Specialist 3; and the first space flight for Payload Specialist 1.

MISSION SUMMARY

The STS-52 mission was launched at 296:17:09:39.007 G.m.t. (12:09:39 p.m. c.d.t. on October 22, 1992) from Launch Complex 39B at Kennedy Space Center (KSC) on an inclination of 28.45 degrees. Aboard the Space Shuttle vehicle was a crew of six and 11 major payloads including the Italian Space Agency LAGEOS-II, which was deployed during the second day of the mission.

The launch of the vehicle was completed satisfactorily after a 1-hour 53-minute 39-second hold. The hold was required because of unsatisfactory weather at the trans-Atlantic abort landing (TAL) site as well as excessive crosswinds at the return-to-launch-site (RTLS) runway (Shuttle Landing Facility). The weather at the TAL site became acceptable during the hold; however, the crosswinds at the RTLS runway remained outside the limits established by the flight rules. After an extensive evaluation by the Mission Management Team (MMT), a decision was made by the MMT that the crosswinds were acceptable and to proceed with the launch. Steady-state winds at the RTLS runway at lift-off were from approximately 46 degrees at 12 knots, and the ambient temperature was 77.6°F.

All vehicle propulsion subsystems operated properly during the direct-insertion ascent phase of the flight. First stage ascent performance was normal with SRB separation, entry, deceleration, and water impact occurring as anticipated. Both SRB's were successfully recovered. Performance of the SSME's, ET, and main propulsion system (MPS) was also normal, with main engine cutoff (MECO) occurring 512.04 seconds after lift-off. A quick-look determination of vehicle propulsion systems performance was made using vehicle acceleration and preflight propulsion data. From these data, the average flight-derived engine specific-impulse determined for the period between SRB separation and the start of 3-g throttling was 452.44 seconds as compared with the average engine tag value of 452.38 seconds.

At 296:17:19:30 G.m.t. (00:00:09:51 MET) during the initial maneuvers following ET separation, reaction control subsystem (RCS) primary thruster F3L failed off because of low oxidizer flow and was deselected. Subsequently, F3L developed a minor oxidizer leak which healed itself about 4 hours into the mission, and the thruster was not reselected during the remainder of the mission.

The crew performed a 10-second four-thruster +X RCS firing following ET separation in support of the ET photographic Development Test Objective (DTO) 312.

Each auxiliary power unit (APU) was run for approximately 21 minutes 42 seconds during the ascent phase and approximately 55 lb of fuel was consumed by each unit.

The Orbiter was placed in a 160 by 163 nmi. orbit with the satisfactory orbital maneuvering subsystem (OMS) -2 maneuver in preparation for deployment of the LAGEOS-II satellite.

The regenerable carbon dioxide removal system (RCRS) was enabled at 296:17:11 G.m.t. (00:01:02 MET) and operated nominally until the planned shutdown prior to entry.

The LAGEOS satellite was deployed at 297:13:57:24 G.m.t. (00:20:47:45 MET) as planned. The first LAGEOS burn was also performed as planned. Following the LAGEOS burn, three OMS maneuvers were performed as shown in the following table.

No.	Engine used	Time, G.m.t./MET	Firing duration, sec	ΔV, ft/sec
3	Right-hand	297:14:12:07.1 G.m.t. 00:21:02:28 MET	15.9	12.2
4	Right-hand	297:16:28:02.9 G.m.t. 00:23:18:23 MET	13.0	10.4
5	Left-hand	297:17:14:38.5 G.m.t. 01:00:05:00 MET	31.0	25.5

The Orbiter was in a 155-nmi. circular orbit as a result of the three maneuvers shown in the preceding table.

Decreases in the right OMS nitrogen regulator outlet pressure were noted following the OMS-2 maneuver, indicating a small (100 scch) leak in the low-pressure portion of the nitrogen system. The right-hand engine accumulator was repressurized at approximately 298:13:04 G.m.t. (01:19:54 MET) so that the alarm would not sound during the crew sleep period. The leak rate dropped to 50 scch following this repressurization. The right OMS gaseous nitrogen (GN_2) system was repressurized prior to each sleep period to preclude an alarm during the sleep period. This did not affect engine performance and was not a significant impact on OMS GN_2 consumables.

The first portion of the remote manipulator system (RMS) checkout was completed prior to LAGEOS deploy. The arm was maneuvered to the perigee kick motor (PKM) monitor position. Following the first burn of the LAGEOS satellite, the RMS checkout was resumed and a payload bay survey was completed. The RMS was cradled and latched at 297:16:10 G.m.t (00:23:00 MET) after satisfactory operations.

The fuel cell 1 substack-3 cell-performance-monitor (CPM) reading was approximately 36 mV until 297:10:25 G.m.t. (00:17:15 MET). At that time, after a normal self-test, substack 3 began reading 44 mV versus the expected 36 mV. Substack 3 then retained 44 mV after each self-test for varying durations before returning to 36 mV. At 297:11:30 G.m.t. (00:18:20 MET), the substack 3 CPM reading transitioned to 44 mV after every self-test. As a result, main busses A and B were cross-tied and remained cross-tied until entry to help monitor the health of fuel cell 1 since the CPM was not reliable. The substack 3 CPM reading continued to increase up to the 60 mV level during the remainder of the mission. No degradation in fuel cell performance was noted during bus-tie operations.

On orbits 20W, 22W, 23W, 24W, 26W, 26E, and 27W while using the Tracking and Data Relay Satellite (TDRS) in the low-frequency mode, S-band phase modulation (PM) could not maintain forward link with the TDRS. This problem was present on all antennae. Switching to string 1 onboard did not cure the problem. When the link was finally established, the frequency was immediately switched from low to high and the communications became nominal on high frequency. As a result of this condition, the S-band PM system was operated on high frequency, and no further losses of lock occurred. Later in the mission, a troubleshooting plan was developed that required the use of the S-band PM in the low-frequency mode with the TDRS. Various configurations of the S-band system were used and the conditions that were noted earlier in the mission were recreated. In-flight troubleshooting isolated the anomaly to Orbiter hardware.

At the time the power reactant storage and distribution (PRSD) cryogenic oxygen tank 2 heaters were placed to auto for the second sleep period, the A2 heater did not indicate on at the beginning of the heater cycle, but came on about 70 seconds later in the cycle. This same anomaly occurred on STS-50 and postflight troubleshooting could not duplicate the problem. Analysis of the PRSD subsystem oxygen tank 2 heater A2 phenomenon showed that the A2 heater (not just the indicator) was lagging the A1 and B heaters and ramped up to full power (as opposed to a step change). This indicates a problem in the cryogenics heater control box. The tank 2 A2 heater was deactivated for the remainder of the mission.

The OMS 6 and 7 maneuvers were satisfactorily performed to lower the Orbiter into a 114-nmi. circular orbit. The OMS-6 maneuver was a single-engine firing using the left engine and crossfeeding propellants from the right OMS pod. This was only the second time in the Space Shuttle Program that a single-engine OMS firing was performed in the crossfeed mode. The OMS-6 firing duration was 89.9 seconds and a ΔV of 73.9 ft/sec was produced. The OMS-7 maneuver was also a single engine firing using the left engine with propellants from the left pod. The firing duration was 82.6 seconds and the ΔV was 71.2 ft/sec.

The Canadian Target Assembly (CTA) was released using the RMS at 305:10:05 G.m.t. (08:16:55 MET) and the two RCS separation maneuvers were performed satisfactorily.

The RCS was taken out of OMS crossfeed on flight day 8. The RCS used a total of 3.70 percent of OMS propellant from the left OMS and 3.56 percent from the right OMS.

The flight control system (FCS) checkout was completed at 305:13:04:39 G.m.t. (08:19:55:00 MET) using APU 3 and all systems operated satisfactorily. The RCS hot-fire test was performed at 305:14:00 G.m.t. (08:20:50 MET). All thrusters operated nominally except F3L which had been deselected since early in the mission.

Both payload bay doors were closed nominally by 306:10:32:52 G.m.t. (09:17:23:13 MET). The deorbit maneuver was performed at 306:13:11:59 G.m.t. (09:20:02:20 MET). The maneuver was approximately 127 seconds in duration and the ΔV was 224.5 ft/sec. Entry interface occurred at 306:13:33:53 G.m.t. (09:20:24:14 MET). All programmed test inputs (PTI's) were performed in support of DTO 251.

Main landing gear touchdown occurred at Kennedy Space Center, FL, on the Shuttle Landing Facility runway 33 at 306:14:05:52 G.m.t. (09:20:56:13 MET) on November 1, 1992. As a part of DTO 521 - Drag Chute Operations - the Orbiter drag chute was deployed satisfactorily at 306:14:06:08 G.m.t. (09:20:56:29 MET), which was prior to nose gear touchdown. Nose landing gear touchdown occurred 19 seconds after main gear touchdown with wheels stop at 306:14:06:53 G.m.t. (09:20:57:14 MET). The rollout was normal in all respects. The flight duration was 9 days 20 hours 56 minutes 13 seconds. All three APU's were powered down by 306:14:23:45 G.m.t. The crew completed the required postflight reconfigurations and exited the Orbiter at 306:14:55 G.m.t.

VEHICLE PERFORMANCE

SOLID ROCKET BOOSTER/REDESIGNED SOLID ROCKET MOTORS

All SRB systems performed as expected. The SRB prelaunch countdown was normal, and no SRB or RSRM in-flight anomalies have been identified. No SRB or RSRM Launch Commit Criteria (LCC) or Operations and Maintenance Requirements and Specification Document (OMRSD) violations occurred.

Power up and operation of all case, igniter, and field joint heaters was accomplished routinely. All RSRM temperatures were maintained within acceptable limits throughout the countdown. For this flight, the heated ground purge in the SRB aft skirt maintained the nozzle/case and flexible bearing temperatures within the required LCC ranges.

RSRM propulsion performance was well within the required specification limits, and the propellant burn rate for each RSRM was normal. RSRM thrust differentials during the buildup, steady-state, and tailoff phases were well within specifications. The reconstructed RSRM propulsion performance is compared to the predicted performance in the table on the following page.

A blowhole was documented in the left RSRM nozzle-to-case joint polysulfide. Gas penetrated through the polysulfide at the 216-degree position and extended to the wiper O-ring causing minor erosion. Soot did not extend past the wiper O-ring. No heat effects were noted on the nozzle joint phenolics.

All SRB thrust vector control prelaunch conditions and flight performance requirements were met with ample margins. All electrical functions were performed properly.

The SRB flight structural temperature response was as expected. Postflight inspection of the recovered hardware indicated that the SRB thermal protection subsystem (TPS) performed properly during ascent with very little TPS ablation. This was the first flight of the MSFC-developed booster trowelable ablator, which was applied to the right aft booster separation motor (BSM) closeouts. Preliminary inspection revealed that the new ablator performed nominally.

Separation subsystem performance was normal with all BSM's expended and all separation bolts severed. Nose cap jettison, frustum separation, and nozzle jettison occurred normally on each SRB. RSRM nozzle jettison occurred after frustum separation, and all subsequent parachute deployments were successfully performed.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 82°F		Right motor, 82°F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10^6 lbf-sec	67.22	66.94	65.77	66.86
I-60, 10^6 lbf-sec	178.51	177.34	175.29	176.53
I-AT, 10^6 lbf-sec	297.04	297.07	297.04	295.24
Vacuum Isp, lbf-sec/lbm	268.6	268.8	268.6	267.2
Burn rate, in/sec @ 60 °F at 625 psia	0.3702	0.3692	0.3681	0.3698
Event times, seconds				
Ignition interval	0.232	N/A	0.232	N/A
Web time[a]	107.9	108.5	108.9	108.6
Separation cue, 50 psia	118.6	118.3	118.6	118.3
Action time	119.6	120.4	120.7	120.6
Separation command, sec	123.5	123.2	123.5	123.2
PMBT, °F	79.0	79.0	79.0	79.0
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	3.5	2.8	3.0
Tailoff imbalance Impulse differential, klbf-sec	Predicted N/A		Actual 288.7[b]	

Notes:
[a] All times are referenced to ignition command time except where noted by the letter a. These items are referenced to lift-off time (Ignition interval).
[b] Tailoff imbalance is equal to left motor minus right motor, and was calculated by Marshall Space Flight Center.

The SRB entry and deceleration sequence was properly performed, with one observation noted during the right SRB drogue parachute deployment sequence. This parachute was observed to be severely tipped during main parachute line/canopy deployment from the frustum. This would indicate that the axial axis of the SRB was at a severe angle with respect to alignment of the drogue chute pull axis. However, since Castglance photography is no longer received because the aircraft are not flown, the severity of the angle could not be positively established. Also, the tip angle of the right SRB frustum could not be ascertained during main parachute line/canopy deployment, due to an insufficient onboard camera view. Main parachute deployment occurred without incident, as evidenced by the following information. The frustum bottom foam ring was inspected and no damage was found that would indicate the frustum itself was tipped. No deployment damage was reported on the right SRB main parachutes.

EXTERNAL TANK

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

As expected, only the normal ice/frost formations for the October atmospheric environment were observed during the countdown. There was no frost or ice on the acreage areas of the ET. Normal quantities of ice or frost were present on the liquid oxygen (LO_2) and liquid hydrogen (LH_2) feedlines and on the pressurization line brackets. All of these observations were acceptable per NSTS documentation.

A small amount of frost was also present along the edge of the LH_2 protuberance air load (PAL) ramps. All of these observations are acceptable per NSTS 08303. The Ice/Frost Red Team reported that there were no anomalous thermal protection subsystem (TPS) conditions.

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

ET separation was confirmed to have occurred properly, and based on the MECO time, ET entry and breakup occurred within the expected footprint.

SPACE SHUTTLE MAIN ENGINES

All prelaunch operations associated with the SSME's were executed successfully. Launch ground support equipment (GSE) provided adequate control for the SSME's during launch preparation. All SSME parameters were normal throughout the prelaunch countdown and were typical of prelaunch parameters observed on previous flights. Engine ready was achieved at the proper time, all LCC were met, and engine start and thrust buildup were normal.

Flight data indicate that SSME performance during engine start, thrust buildup, mainstage, throttling, shutdown, and propellant dump operations was well within specifications. High pressure oxidizer turbopump and high pressure fuel turbopump temperatures appeared to be well within specification throughout engine operations.

The SSME controller provided the proper control of the engines throughout powered flight. Engine dynamic data generally compared well with previous flight and test data. All on-orbit activities associated with the SSME's were accomplished successfully.

An STS-52 in-flight anomaly (STS-52-I-01) was assigned to the data spikes that were observed in various pressure measurements on both Block I and Block II controllers from 60 to 368 seconds. These pressure spikes were initially observed on recent flights because of the higher data resolution on the Block II controller. No similar spikes have been observed from ground test data on either controller. These spikes are not considered a safety-of-flight issue.

SHUTTLE RANGE SAFETY SYSTEM

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

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

ORBITER SUBSYSTEM PERFORMANCE

Main Propulsion System

The overall performance of the MPS was excellent. LO_2 and LH_2 loadings were performed as planned with no stop-flows or reverts. No OMRSD violations were noted. During LH_2 topping, an LCC violation occurred when hydrogen leak detectors 23 and 25 in a cavity in the ground umbilical carrier plate (GUCP) exceeded the LCC upper redline limit of 44,000 ppm. The LH_2 main fill and ET vent valves were cycled and the concentration dropped to near zero. The concentration then slowly increased, reading a maximum value in the mid-20,000 ppm range. A postflight inspection of the GUCP revealed four scratches on the ground half of the GUCP.

Throughout the preflight operations, no significant hazardous gas concentrations were detected except for the GUCP leak described in the previous paragraph. The maximum hydrogen level in the Orbiter aft compartment was 173 ppm (corrected). This level was within the historical limits of this vehicle. The aft helium concentration peaked at 7000 ppm, and the aft oxygen concentration peaked at 25 ppm.

A comparison of the calculated propellant loads at the end of replenish versus the inventory loads results in a loading accuracy of -0.072 percent of LH_2 and -0.0013 percent for LO_2.

Ascent MPS performance was nominal. Data indicate that the LO_2 and LH_2 pressurization systems performed as planned, and that all net positive suction pressure (NPSP) requirements were met throughout the flight.

The gaseous oxygen pressurization system performed normally throughout the entire flight. The gaseous oxygen flow control valves were shimmed to a 80.6 percent flow area for OV-102. The minimum liquid oxygen ullage pressure experienced during the period of the ullage pressure slum was 14.6 psid.

Ullage pressures were maintained within the required limits throughout the flight. LO_2 and LH_2 propellant conditions were within specified limits during all phases of operation. Propellant dump and vacuum inerting were accomplished satisfactorily.

At 11 seconds after lift-off, the SSME 2 LO_2 inlet temperature went off-scale high (Flight Problem STS-52-V-02). The measurement was regained after MECO, and lost again during the MPS propellant dump operations. The measurement was finally regained near the end of the vacuum inert activities.

All systems performed nominally during entry and landing. Helium consumption during entry was 55.3 lbm, which is within the flight experience base for this Orbiter.

Reaction Control Subsystem

The performance of the RCS was nominal. The RCS was used to support DTO 251 - Entry Aerodynamic Control Surfaces Test - Alternate Elevon Schedule (Part 4) during which six PTI's were executed. The RCS was also used to support the SPIE. Propellant usage from the RCS during the mission was 4,699.8 lb. In addition, the RCS was interconnected to the left and the right OMS from which 3.70 percent and 3.56 percent of the propellant was used, respectively.

At 296:17:19:33 G.m.t. (00:00:09:53 MET) during the initial maneuvers following ET separation, RCS thruster F3L was commanded to fire, but was declared failed off by the RCS redundancy management (RM) because of low oxidizer flow (Flight Problem STS-52-V-01). Injector temperature data indicated fuel flow was obtained, but the oxidizer valve failed to open. Subsequently, F3L developed a minor oxidizer leak which healed itself about four hours into the mission. The leak was less than 100 cc/hr, and no significant divergence in propellant quantities was noted. The RCS thruster was not reselected during the remainder of the mission, and no further leakage was experienced.

At 306:10:28:00 G.m.t. (09:17:18:21 MET), the forward RCS manifold 3 fuel isolation valve exhibited a false "closed" indication (Flight Problem STS-52-V-13). The crew compartment talkback maintained an open indication, and other indicators verified that the valve was still open. The valve closed nominally after the forward RCS propellant dump during the entry phase. The fuel valve appeared to lag the oxidizer valve when the valves were opened after landing. Review of data was inconclusive because of the data sample rate. Attempts to duplicate the failure at KSC were unsuccessful.

Orbital Maneuvering Subsystem

The OMS performance was nominal during the STS-52 mission. Seven maneuvers were performed, one of which (OMS-6) was performed in crossfeed from the right-hand OMS pod to the left-hand engine. The last time a firing was made in crossfeed was during the STS-2 mission. The first (OMS-2) and last (deorbit) firings of this mission were the only two firings that were completed using both engines. All other firings were made using only the left-hand engine. A total of 15,541.2 lb of propellants were used from the OMS, and the total firing time on the left OMS engine was 384.8 seconds and firing time on the right OMS engine was 292.7 seconds. The total propellants used also includes that propellant used by the RCS during interconnect operations.

A decrease in the right OMS nitrogen regulator outlet pressure was noted following the OMS-2 maneuver, indicating a small (100 scch) leak in the low-pressure portion of the nitrogen system (Flight Problem STS-52-V-07). The leak rate decayed to approximately 50 scch following the OMS-3 and OMS-4 maneuvers and remained at that value for the remainder of the flight. The right-hand engine accumulator was repressurized each day so that the alarm would not sound during the crew sleep period.

Power Reactant Storage And Distribution Subsystem

The PRSD subsystem operated nominally throughout the mission in providing oxygen for crew breathing and oxygen and hydrogen for fuel cell usage. A total of 2507.8 lb of oxygen was consumed during the mission, of which 121.8 lb were used by the crew for breathing. The consumables remaining provided a mission extension capability of 107.9 hours at an average power level of 14.83 kW.

At the time the PRSD cryogenic oxygen tank 2 heaters were placed to auto for the second sleep period, the A2 heater did not indicate on at the beginning of the heater cycle, but came on about 70 seconds later in the cycle (Flight Problem STS-52-V-04). This same anomaly occurred on STS-50 and postflight troubleshooting could not duplicate the problem. Analysis of the STS-52 PRSD subsystem oxygen tank 2 heater A2 phenomenon showed that the A2 heater (not just the indicator) was lagging the A1 and B heaters and ramped up to full power (as opposed to a step change). During postflight testing, the failure was duplicated and isolated to the tank 2 heater control unit.

The check valve on PRSD oxygen tanks 4 and 5 opened between 14 and 20 psid, respectively, when the tank was not in use where the nominal value should be 3 to 5 psid. This condition has been noted on a number of previous flights. The sticky operation of the check valve did not impact the use of the tank during the flight, and no postflight action was required.

Fuel Cell Powerplant Subsystem

The fuel cell powerplant subsystem functioned satisfactorily in meeting all needs for electrical power and drinking water during the mission. A total of 3514.6 kWh of electrical energy were produced at an average power level of 14.83 kW, and average power load of 478 amperes. The fuel cells consumed 300.5 lb of hydrogen and 2386.0 lb of oxygen and produced 2686.5 lb of water while meeting the electrical needs of the onboard systems.

The actual fuel cell voltages at the end of the mission were as predicted for fuel cell 1, 0.05 volt above the prediction for fuel cell 2, and 0.15 volt above the prediction of fuel cell 3. Six purges were performed at the following times during the mission; 22 hours, 76 hours, 123 hours, 171 hours, 217 hours, and 230 hours MET. The fuel cells were shut down at 307:07:17 G.m.t. (approximately 21 hours after the end of the mission). Fuel cell operating times for the missions were 268, 267, and 267 hours, respectively for fuel cells 1, 2, and 3.

The fuel cell 1 substack 3 cell performance monitor (CPM) reading was approximately 36 mV until 297:10:25 G.m.t. (00:17:15 MET). At that time, after a normal self-test, substack 3 began reading 44 mV versus the expected 36 mV. Substack 3 then retained 44 mV after each self-test for varying durations before returning to 36 mV (Flight Problem STS-52-V-06). At 297:11:30 G.m.t. (00:18:20 MET), substack 3 transitioned to 44 mV after every self-test. As a result, main buses A and B were cross-tied and remained cross-tied until entry to help monitor the health of fuel cell 1 since the CPM was not reliable. The substack 3 reading continued to increase up to the 66 mV level during the remainder of the mission. No degradation in fuel cell performance was noted during bus-tie operations. This same CPM unit exhibited the same behavior during STS-51J and STS-61B. The CPM was removed and tested following STS-61B, the circuit card for the substack 3 measurement was replaced, and the CPM was returned to stock for reuse. This CPM performed nominally on STS-29 and STS-33.

The fuel cell 2 alternate water line temperature was erratic, but remained within limits. This condition is indicative of either erratic heater operations or a small water leak. Similar occurrences have been noted on OV-104 in the past. A small water leak that is below the maximum specification value is believed to be the cause of this problem, since the same behavior was noted on both the A and B heater systems. The potential water leak was inconsequential and no corrective action was required.

Shortly after MECO, the fuel cell 3 pH indication came on four times and then remained off. The cause of the intermittent readings was probably a slug of conductive water migrating out of the cell.

Auxiliary Power Unit Subsystem

The APU subsystem operated satisfactorily. No in-flight anomalies have been identified, but several minor problems are discussed in the paragraphs that follow. The following table presents improved APU (IAPU) run times and fuel consumption for the mission.

A fault message was annunciated against test line temperature 2 on APU 2 about 2 minutes after APU shutdown when the lower FDA limit of 48°F was reached. The crew was instructed to activate all three APU tank/fuel line/water system heaters prior to the normal heater initiation time, which brought this temperature back to its normal value. Nominal heater performance was observed following activation. Operating the B heaters rather than the A heaters during the prelaunch time period should result in higher system temperatures at lift-off because of the more advantageous location of the B thermostat.

Flight Phase	IAPU 1 (S/N 407)		IAPU 2 (S/N 403)		IAPU 3 (S/N 402)	
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	21:42	53	21:41	55	21:41	56
FCS checkout					5:38	17
Entry[a]	62:31	112	76:42	149	62:32	127
Total[a]	84:13	165	98:23	204	89:51	200

[a]The IAPU's were operated for approximately 18 minutes 0 seconds after landing.

The APU 1 fuel feedline temperature 1 violated the upper FDA limit of 120°F at approximately 296:23:30 G.m.t. (00:06:20:21 MET). The reason for the FDA violation was heat soakback from APU's 1 and 2 combined with nominal heating from the APU 1 fuel feedline heater. The system 2 feedline temperature was also high, but did not violate the FDA limit. The APU 1 fuel feedline temperature 1 upper FDA limit was raised to 126°F by ground command. This condition did not cause a flight impact.

The lower FDA limit for the APU 3 drain line temperature 2 was lowered from 48°F to 43°F after ascent as the temperature approached the limit. This prevented nuisance alarms as the local environment at the temperature 2 sensor was slightly colder than around the other sensor and thermostat on this line. All three of these problems are being addressed to determine an overall solution for the unpowered APU heaters during ascent.

After switching from APU 3 gas generator (GG) bed A heaters to B heaters following FCS checkout, the heater cycling frequency nearly doubled and the injector tube temperature only reached approximately 325°F instead of the nominal value of approximately 425°F. This condition is believed to be caused by the B heaters being located nearer to the bed temperature sensor. The crew selected the A heaters prior to the deorbit maneuver and performance of these heaters was nominal. Although the B heater system did not respond as expected, it did maintain acceptable temperatures and will be flown as-is on future missions.

Hydraulics/Water Spray Boiler Subsystem

The hydraulics/water spray boiler (WSB) subsystem operated nominally. Following ascent, WSB 1 was inadvertently deactivated after terminating spray logic for WSB 1. This action apparently caused the hydraulic bypass valve to drive to the heat exchanger mode for 2 seconds. This occurrence did not impact flight operations.

The left-hand outboard brake line temperature reached approximately 230°F (Flight Problem STS-52-V-18). This is a repeat of the condition noted on both STS-50, the previous flight of this vehicle, and on the two flights of OV-105. Power to the A heater was deactivated prior to entry, and the temperature decreased to approximately 100°F after which the temperature closely tracked the remaining brake line temperatures.

Electrical Power Distribution and Control Subsystem

The electrical power distribution and control subsystem performed nominally with two anomalies being identified. The PRSD heater A2 anomaly in oxygen tank 2 is discussed in the Power Reactant Storage and Distribution Subsystem section of this report.

At approximately 302:23:22 G.m.t. (06:06:12 MET), the crew reported that when using the Linhoff camera, the main C dc utility outlet on panel A11 was inoperative (Flight Problem STS-52-V-09). The outlet was last used at 302:17:54 G.m.t. (06:00:44 MET) and the outlet was operational. The utility outlet on panel A11 shares a common circuit breaker (CB9) with utility power outlets on panels MO30F and A15. The utility power outlet on panel A15 was in use with the portable audio data modem (PADM) at the time that the failure was reported. An IFM procedure was performed on the main C dc outlet A11 at 303:09:50 G.m.t. (06:16:40 MET) and normal voltages were measured. Subsequently, the A11 outlet was successfully used again. Postflight tests of the outlet revealed correct voltages and no anomaly. The Linhof camera cable also checked out nominally during postflight testing.

During the crew debriefing of the Orbiter subsystems, the crew reported that the midstarboard floodlight had failed at one point in the mission. The in-flight data were reviewed and showed that the midstarboard floodlight had failed at 304:09:26:32 G.m.t. when the light was powered, but did not come on. This was evidenced by a 10 ampere spike which appeared to trip a remote power controller (RPC) since the spike lasted for four seconds. Other lights powered at the same time appeared to come on normally. The in-flight data also shows two subsequent power cycles on the midstarboard light, which were both successful. One of these two cycles occurred about nine hours after the failed attempt and the second occurred just prior to payload bay door closure. All of the payload bay floodlights were tested at KSC following the flight, and all floodlights behaved nominally.

Pyrotechnics Subsystem

The pyrotechnics subsystem performed nominally. All three ET/Orbiter separation devices (EO-1, -2, and -3) appeared to have functioned properly. All ET/Orbiter umbilical separation ordnance retention shutters were closed properly. No flight hardware was found on the runway below the umbilicals when the ET doors were opened.

Aft Fuselage Gas Sampler System

The Orbiter aft fuselage gas sampler system (OAFGSS) data from STS-52 show hydrogen and oxygen levels during ascent in the aft compartment of OV-102 were well within the data base for all vehicles. Five out of the six bottles contained excellent samples, indicating positive results from changes in bottle preflight processing procedures to reduce sample loss. The five bottles contained less than 22 percent air in the sample.

Environmental Control and Life Support Subsystem

The atmospheric revitalization system (ARS) air and water coolant loops performed nominally. The ARS maintained the CO_2 partial pressure below 4.5 mmHg. Cabin air temperature and relative humidity peaked at 85°F and 47 percent, respectively. The avionics bays 1, 2, and 3, air outlet temperatures peaked at 105.8°F, 107°F, and 90.5°F, respectively, and the avionics bays 1, 2, and 3 water coldplate temperatures peaked at 91.6°F, 94.5°F, and 83.2°F, respectively.

The active thermal control system (ATCS) performance was nominal throughout the mission. During the period from Orbiter Processing Facility (OPF) rollout and launch, both freon coolant loop flow rates degraded. This degradation did not impact the flight.

Active cooling was satisfactorily provided at the payload heat exchanger to both the USMP-1 in the payload bay and the CVTE in the middeck. Two procedure-related flash evaporator system (FES) nuisance shutdowns occurred, but neither impacted the mission.

The ARS pressure control system (PCS) performed nominally throughout the duration of the mission. During the redundant component check, the pressure control configuration was switched to the alternate system, which also performed satisfactorily.

The RCRS was enabled at 296:17:11 G.m.t. (00:01:02 MET) and operated nominally until the planned shutdown prior to entry.

Radiator coldsoak provided cooling through landing plus 11 minutes when ammonia boiler system (ABS) B secondary cooling was initiated. ABS B provided cooling until landing plus 53 minutes when ground cooling was initiated. ABS A primary was activated as ground cooling became available, but ABS A did not reach the control range before it was deactivated.

The FES feedline A forward heater string 2 failed at approximately 304:19:02 G.m.t. (08:01:53 MET) (Flight Problem STS-52-V-12). The redundant heater string was selected and operated properly through the end of the mission. The loss of this heater string did not impact the flight.

The supply water and waste management systems performed adequately throughout the mission. By the end of the mission, all of the associated supply water and waste water in-flight checkout requirements were performed and satisfied. Supply water was managed through the use of the FES and the overboard dump system. One supply water overboard dump was performed at a rate of 1.5 percent/minute (2.5 lb/minute). The supply water dump line temperature was maintained between 73°F and 107°F throughout the mission with the operation of the line heater.

Waste water was gathered at approximately the predicted rate. Two waste water dumps were performed at an average rate of 2.03 percent/min (3.4 lb/min). The waste water dump line temperature was maintained between 53°F and 80°F throughout the mission, while the vacuum vent line temperature was between 59°F and 79°F.

Near the end of the first waste water dump during which approximately 68 lb was dumped, the crew received a message for the waste-water liquid-pressure because the 13-psig FDA lower limit had been violated. Prior mission data from other vehicles was reviewed for dumps to a tank quantity of less than 10 percent. Similar occurrences were found to have occurred on previous flights of OV-102 (STS-40 and STS-50). Additionally, the behavior noted was not unique to OV-102. This phenomenon did not impact the successful completion of the waste water dump.

The waste collection system (WCS) performed adequately throughout the mission until the last flight day. At 305:29:27 G.m.t. (09:12:18 MET), the crew reported that the WCS fan separator 1 had stopped running without being powered off (Flight Problem STS-52-V-17). The crew also reported that the WCS operation had been noisy for the past 24 to 48 hours. Electrical current data from the AC 1 bus indicated a normal startup followed by a brief run with no abnormal current spikes, and then shutdown. The crew used fan separator 2 which operated nominally for the remainder of the mission.

Smoke Detection and Fire Suppression System

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

Airlock Support System

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

Avionics and Software Subsystems

The integrated guidance, navigation and control subsystem performance was nominal with no problems identified. All the PTI's in support of DTO 251 were completed; however, data indicate that the roll/yaw channel was moded to control stick steering (CSS) before the completion of PTI 4, thereby not allowing the elevator doublet to execute.

The aileron trim anomaly seen during DTO 251 operations on the previous flight of OV-102 (STS-50) did not reappear on this flight. The aileron trim averaged 0.5 degree and stayed relatively constant during the Mach region where the elevator is positioned above the normal elevator scheduled position. In addition, the yaw RCS activity did not reflect the large shift in lateral trim seen on STS-50.

The flight control system performed satisfactorily throughout the entry phase with no problems identified. Inertial measurement unit (IMU) performance was excellent with no problems of any type noted. The star tracker performance was also nominal with no problems noted. The data processing system (DPS) hardware and flight software performed flawlessly.

The displays and controls subsystem performance was adequate with two anomalies being identified. The crew reported at 306:13:33 G.m.t. (09:20:24 MET) that the surface position indicator (SPI) failed approximately 30 minutes prior to landing when the off flag was present and the needles not visible (Flight Problem STS-52-V-14). The power to the unit was recycled and the instrument still exhibited erratic behavior. An internal electronics failure is suspected as the cause of this anomaly.

During the Orbiter preflight checks and prior to crew ingress, floodlights 6 and 8 on the middeck were found to have failed (Flight Problem STS-52-V-03). Prelaunch troubleshooting indicated that no common wiring problem existed, and redundant light sources on the middeck were satisfactory for completion of the mission objectives. No corrective action was taken prior to the flight. Postflight testing during turnaround activities showed both lamps to be failed.

The operational instrumentation (OI) and the modular auxiliary data system (MADS) functioned nominally. The MADS frequency data multiplexer (FDM) bite 4 fail occurred when the MADS unit was first powered up for entry; however, the unit later operated properly. Data analysis indicates that the low MADS shelf temperature (20°F) was the cause of the initial fail indication.

At 306:12:59 G.m.t. (09:19:50 MET), the Orbital Experiments (OEX) recorder tape position indication dropped from 12 to 2 percent while no recorder operations were in progress (Flight Problem STS-52-V-15). The anomaly is believed to be caused by an inadvertent reset of the system control module (SCM) tape position counter due to an electromagnetic interference (EMI) spike.

The off-scale-high failure of the SSME 2 liquid oxygen temperature sensor 11 seconds into the flight is discussed in the Main Propulsion System section of this report.

Communications and Tracking Subsystems

The communications and tracking subsystems performed nominally. The anomalies and problems are discussed in the following paragraphs.

The S-band phase modulation (PM) system was used in high frequency for most of the mission with nominal performance. However, use of the low-frequency mode yielded degraded performance with the Orbiter unable to maintain a forward link lock on orbits 20W, 22W, 23W, 24W, 26W, 26E, and 27W, while using the TDRS in the low-frequency mode (Problem STS-52-V-11). This problem was present on all antennae. Switching to string 1 onboard did not cure the problem. When a link was finally established, the frequency was immediately switched from low to high and the communications became nominal on high frequency. As a result of this condition, the S-band PM system was operated on high frequency, and no further losses of lock occurred. Later in the mission, a troubleshooting plan was developed that required the use of the S-band PM in the low-frequency mode with the TDRS. Various configurations of the S-band system were used and the conditions that were noted earlier in the mission were recreated. On-orbit troubleshooting isolated the problem to the following hardware:

a. Low frequency diplexer;

b. Cable in preamplifier assembly; or

c. Low frequency cable between the preamplifier assembly and antenna switch assembly.

The S-band FM transmitter output power became increasingly erratic throughout the mission, fluctuating between 16 and 10.9 watts (Flight Problem STS-52-V-10). Minor fluctuations had been noted during prelaunch operations. The crew switched to FM transmitter 2 for the remainder of the mission, and satisfactory communications were maintained.

A text and graphics system (TAGS) false jam indication occurred upon TAGS activation. The indication was expected, and the crew should normally advance the TAGS to clear the indication. However, the crew stopped working the activation procedure, thinking the TAGS was jammed. An advance command was sent from the ground, clearing the jam indication, and the TAGS operated properly until uplink of the morning mail on flight day 2 when a second false jam indication was received (Flight Problem STS-52-V-08b). The indication was cleared when the crew pressed the advance key. This condition was intermittent and did not physically jam the unit. Two additional TAGS false jam indications were annunciated during transmittal of the morning mail on flight day 5. The cause of these false indications is believed to be a faulty paper sensor in the lower paper path. In the last two cases, TAGS operations were again regained by transmitting an advance command.

The first page of the flight day 7 morning mail was jammed in the TAGS. The TAGS malfunction procedure was performed, but TAGS operation was not regained, and the unit was turned off since the jam apparently could not be cleared (Flight Problem STS-52-V-8a). The crew was requested to reactivate the TAGS about 15 minutes later and after further troubleshooting, the jam was cleared and the TAGS began operating. The TAGS experienced a second jam later in the day. The developer motor stopped after a period of time. The TAGS was deemed usable for periodic operations after being powered off for a period of time; however, a decision was made to use the TAGS only in the graphics mode for the remainder of the mission with the text being transmitted via the teleprinter. No more graphics were uplinked: consequently, no further TAGS operations were attempted.

Downlinked camcorder footage showed horizontal lines running through the picture which were caused by the video interface unit (VIU) (Flight Problem STS-52-V-19). Failure of the VIU video power supply was the most likely cause of the lines. The crew changed VIU's and the picture quality appeared to improve.

Ku-band operations were nominal in the communications and the radar modes. At one point in the mission, the antenna was placed in the manual mode at an angle next to the alpha stop. Operations in this mode at this angle did not damage the Ku-band system.

All closed circuit television (CCTV) cameras operated nominally. One minor problem was noted with CCTV camera A when the iris became stuck. However, camera operations were regained after camera power was cycled.

Structures and Mechanical Subsystems

All mechanically actuated subsystems performed nominally, including the payload bay doors, vent doors, star tracker doors, ET/Orbiter umbilical doors, Ku-band antenna deployment actuator, and air data probe system.

At 306:05:26 G.m.t. (09:12:17 MET), the temperature of the left main landing gear brake line temperature reached 230°F before the A heaters was deselected (Flight Problem STS-52-V-18). A similar over-temperature condition was noted on the OV-105 vehicle during the STS-47 and STS-49 flights, as well as during STS-50 on OV-102.

The drag chute was deployed at 306:14:06:05.7 G.m.t. (09:20:56:26.7 MET) in a nominal manner. Photographic data indicate that the chute trailed left of the vehicle and caused additional steering inputs. The chute was jettisoned 30.6 seconds later. All drag chute hardware was recovered.

During the postlanding door positioning, the left ET door was driven against the door uplock latches. The effects of this occurrence on the hardware are being evaluated.

The postflight inspection of the brakes revealed signs of overheating of the bushings on right-hand inboard brake rotor 2 (Flight Problem STS-52-V-16). However, brake temperatures and energies during the braking phase were nominal. The landing and braking data are shown in the following table.

The main landing gear tires were considered to be in excellent condition for a landing on the KSC runway.

LANDING AND BRAKING PARAMETERS

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	1186	211.1	<1.0	n/a
Nose gear touchdown	6966	141.5	n/a	3.04

Braking initiation speed	98.1 knots (keas)
Brake-on time	33.2 seconds
Rollout distance	10,696 feet
Rollout time	63.1 seconds
Runway	33 (concrete) at KSC
Orbiter weight at landing	216,176 lb

Brake sensor location	Peak pressure, psia	Brake assembly	Energy, million ft-lb
Left-hand inboard 1	636	Left-hand outboard	19.53
Left-hand inboard 3	612	Left-hand inboard	17.86
Left-hand outboard 2	612	Right-hand inboard	27.02
Left-hand outboard 4	648	Right-hand outboard	24.42
Right-hand inboard 1	984		
Right-hand inboard 3	840		
Right-hand outboard 2	960		
Right-hand outboard 4	924		

Tire location	Pressure, psia	Tire temperature, °F	Temperature decal, °F
Left-hand outboard	323.0	-5.3	150
Left-hand inboard	326.0	-2.4	None
Right-hand inboard	345.0	21.4	150
Right-hand outboard	344.0	20.5	150
Left-hand nose gear	322.0	17.5	N/A
Right-hand nose gear	324.0	19.5	N/A

Aerodynamics, Heating, and Thermal Interfaces

The ascent and entry aerodynamics were nominal in all aspects. In general, the control surfaces responded as expected. There were no indications of large aileron trim observed while performing DTO 251, as was seen during STS-50.

The ascent and entry heating was nominal and within established limits. The postflight inspections revealed no heating damage. The thermal interfaces remained within limits with no excessive temperatures noted.

A portable Shuttle thermal imager (STI) was used to measure the surface temperatures of three areas on the Orbiter. Twenty-six minutes after landing, the right-hand wing leading edge reinforced carbon carbon (RCC) panel 9 was 144°F, and panel 17 was 132°F. Twenty-eight minutes after landing, the Orbiter RCC nosecap was 183°F.

Thermal Control Subsystem

The thermal control subsystem (TCS) operated nominally during all phases of the mission with the exception of one heater failure. All Orbiter subsystem temperatures were maintained within acceptable limits.

The FES water feedline A zone 1 (forward) heater system 2 trended downward to the 50°F FDA limit, annunciating an alarm (Flight Problem STS-52-V-12). The system 2 heater was considered failed.

Other problems that occurred with the TCS included the APU 2 test line sensor 2 (V46T0284A) annunciated an FDA alarm. The temperature dropped to 47°F during ascent and the alarm level was 48°F. The APU 1 fuel line sensor (V46T0370A) cycled high several times after ascent and reached 120°F annunciating an FDA alarm (FDA is 120°F). The APU 3 fuel drain sensor 2 (V46T0370A) dropped to 45°F prior to the heater being activated during post-ascent activities. The fuel cell 2 alternate product water line sensor (V45T0282A) signature was erratic on-orbit and that apparently was indicating slight product water flow from the fuel cell. The port main landing gear brake line sensor (V58T1702A) increased to 231°F prior to the deactivation of the system A heaters during the deorbit maneuver attitude maneuvers. All of these problems are discussed in the subsystem section of the report.

Aerothermodynamics

The acreage heating during descent was nominal with all structural temperatures remaining within limits. In addition, the structural temperature rise was within the experience base as well as the TPS damage. Local heating was, likewise, within the experience data base.

Thermal Protection Subsystem

The TPS performance was nominal, based on structural temperature response data and some tile surface temperature measurements.

The Orbiter TPS sustained a total of 290 hits of which 16 had a dimension greater than 1 inch. This total does not include the numerous hits on the base heat-shield that were attributed to SSME vibration/acoustics and exhaust plume recirculation. A comparison of these numbers with previous missions of the same configuration revealed that the total number of hits was greater than average, but the number of hits 1 inch or greater was less than average. One large impact was located on the base heat shield just below SSME 1, and it may be related to the missing base heat shield tile discussed in a subsequent paragraph.

The Orbiter lower surface sustained a total of 152 hits, of which 6 had a major dimension of 1 inch or greater. The distribution of hits on the lower surface does not suggest a single source of ascent debris, but indicates a shedding of ice and TPS debris from random sources. In addition, the upper surface was struck 83 times of which 4 had a major dimension of 1 inch or greater. The right side had 18 hits of which 3 had a major dimension of 1 inch or greater. The left side had 15 hits with none having a major dimension of 1 inch or greater. The right OMS pod had 12 hits with none having a major dimension of 1 inch or greater. Finally, the left OMS pod had a total of 10 hits of which 3 had a major dimension of 1 inch or greater. Samples of inclusions found in two tile damage sites on the Orbiter nose were taken for laboratory analysis.

No TPS damage was attributed to material from the wheels, tires, or brakes.

The reusable carbon carbon (RCC) and nose landing gear door TPS performance was nominal. The left-hand main landing gear door thermal barrier, which was of the old design, was breached in several areas. The right-hand main landing gear door thermal barrier, which was of the redesigned configuration, was torn in only one area on the aft outboard corner. The ET/Orbiter door thermal barriers were in good condition. However, the left-hand forward latch patch was badly frayed with most of the outer mold line missing. The SSME 2 engine-mounted heat shield blanket was frayed significantly from the 2:00 to 4:00 o'clock position. The elevon cove, elevon-elevon gap, payload bay doors, upper wings, and OMS pods TPS performance was nominal.

In general, damage to the base heat shield tiles was typical. However, the majority of one tile was missing from the base heat shield between SSME 2 and 3. This tile, which was on its twelfth mission, covered an inactive calorimeter. The tile suffered an in-plane failure, and left the strain isolation pad and an attached layer (approximately 0.3-inch thick) of densified tile material in the cavity. In addition to the missing tile, an 8- by 6- by 0.5-inch tile damage site was present on the base heat shield adjacent to SSME 1 (at approximately the 7:00 o'clock position). This damage site appeared to have been caused by a dense object and may have been caused by the lost tile.

Two dome mounted heat shield (DMHS) closeout blanket sacrificial panels were missing and two were nearly detached from 2 to 4 o'clock around SSME 2. All of the remaining DMHS blankets were in excellent condition.

Orbiter windows 2 and 5 exhibited light hazing. Windows 3 and 5 had a few small streaks. Hazing on the other windows was less than usual. Surface wipes have been taken from windows 1 through 9 for laboratory analysis. A very large number of tile impact sites (70 with 2 larger than 1 inch) were noted on the perimeter tiles around windows 1 through 6. Most all of these hits were small and shallow in depth and may have been caused by room temperature vulcanizing (RTV) material used to bond paper covers to the forward RCS thruster nozzles, exhaust products from the SRB booster separation motors, ice/TPS debris from the ET liquid oxygen tank, or Orbiter TPS fragments (or any combination of these items).

GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

The Government furnished equipment (GFE)/flight crew equipment performed nominally except for the Fluke model 87 multimeter.

An intermittent display problem was noted in which uncommanded multimeter mode changes occurred (Flight Problem STS-52-V-05). Discussions with the manufacturer indicated that the display problem was related to the mode selection in the unit. In the older units such as was flown on this flight, a faulty resistor was present in the mode selection network, and this resistor caused the problem. The problem was a nuisance-only item as once the unit was up and running, the accuracy of the unit was not affected.

An IFM procedure was uplinked to correct a frequent battery-low indicator on the multimeter. The manufacturer provided a change notice which described a partial fix for the multimeter problem. A shield within the power supply in the multimeter required insulating from the power supply capacitors so that the battery voltage could not be drained. The product change notice describes a fix to protect the components on the circuit board and the use of mylar tape as required by the IFM procedure provided satisfactory operation for the remainder of the mission. A fresh battery was installed in the multimeter.

The postflight inspection of the STS-47 galley showed a burn-through in the oven heater strip. Previously, a burn-through had been noted on the galley water tank heaters during preflight processing on the STS-53 galley after which the oven heaters were determined to not be a problem. The oven burn-through was a small single spot and the oven had flown two flights (STS-49 and ST-47). The problem was determined to be specific only to the STS-47 oven and the qualification unit. The STS-52 oven is of a different build and, therefore, should not experience this same type of problem. Consequently, the STS-52 oven was operated as planned for this mission.

REMOTE MANIPULATOR SYSTEM

The overall performance of the RMS was nominal with no problems identified. The first portion of the RMS checkout was completed prior to LAGEOS deploy at approximately 20 hours MET. The arm was maneuvered to the perigee kick motor (PKM) monitor position. Following the first burn of the LAGEOS satellite, the RMS checkout was resumed and a payload bay survey was completed. During this period, the RMS was left uncradled for the first time during an OMS maneuver. The RMS was cradled and latched at 297:16:10 G.m.t. (00:23:00 MET) after satisfactory operations.

RMS payload activities centered around in-flight testing of the Canadian-designed Space Vision System (SVS) experiment. The SVS used the video signal from the Orbiter CCTV system to monitor target dots of known size and spacing. Using the video pixel count of the high-contrast dots, the SVS processor determined the target's distance and orientation. The information was displayed in both text and graphics to the RMS operator on a CCTV monitor. During this mission, the target dots were affixed to the CTA.

The initial SVS testing with the RMS occurred at 298:19:10 G.m.t. (02:02:00 MET), but the majority of the maneuvers were scheduled for flight day 6 to minimize disturbances to the USMP-1. Twice during the mission, the crew berthed the CTA into its support structure using RMS direct drive mode only; the intent being to determine the usefulness of the SVS graphics display in assisting the operator with degraded RMS operations. During the first attempt, the crew was not able to acquire the ready-to-latch indication because of binding of the CTA in its V-guides. The second attempt proved successful, though additional CCTV views were used during the operation to view alignment of the CTA with its guides. On the final SVS maneuver, the CTA was released by the RMS [305:10:05 G.m.t. (08:16:55 MET)].

Several times between flight days 6 and 9, the RMS was positioned in pre-mission designated configurations to expose material samples on the RMS witness plates to the atomic oxygen stream. The samples comprised the Materials Exposure to Low Earth Orbit (MELEO) experiment, which was investigating the suitability of numerous materials for space structures. MELEO positions were maintained for approximately 40 hours during the mission, an operation that required leaving the RMS uncradled overnight while the crew slept. On the final day of RMS operations, two additional experiments were performed. Samples attached to the CTA for the Orbiter Glow (OGLOW-2) experiments were photographed at night. A SPIE sensor, mounted on the RMS end effector, measured RCS thruster plume impingement effects.

CARGO INTEGRATION

All cargo integration hardware performed nominally with no out-of-limit conditions noted. STS-52 was the first flight since STS-3 where two payloads (CVTE and USMP-1) were actively cooled at the payload heat exchanger.

PAYLOADS

LASER GEODYNAMICS SATELLITE

The LAGEOS-II was developed to obtain precise measurements of the earth crustal movements and the gravitational field, as well as understanding the "wobble" in the Earth's axis of rotation. LAGEOS was successfully deployed on flight day 2 and is now on station and operating as planned. After deployment from the Space Shuttle, the two solid-fuel stages of the LAGEOS-II were used to boost the satellite into a circular orbit of 3,666 miles (5,900 km).

The LAGEOS-II was built by the Italian Space Agency, Agenzia Spaziale Italiana (ASI), and is a passive satellite dedicated exclusively to laser ranging. The LAGEOS is 24 inches (60 cm) in diameter and weights approximately 900 lb (405 kg). LAGEOS-II has a dimpled appearance of a large golf ball. Embedded in the satellite are 426 nearly equally spaced, cube-corner retroreflectors, or prisms. Four of these prisms are made of germanium for possible use with lasers of the future.

UNITED STATES MICROGRAVITY PAYLOAD-1

The USMP-1, which consisted of three investigations, performed very satisfactorily throughout the mission.

Over 90 high-resolution passes through the lambda point were completed with over 5000 lambda-point experiment commands sent and executed by the Lambda Point Experiment (LPE). The LPE also collected a significant amount of data just above the transition temperature. The thermal relaxation times deduced from these data will be used to calculate liquid helium thermal conductivities. Such data are of particular importance in testing the dynamic aspects of second order phase transition theory. After the change from the 155 nmi. orbit to the 114 nmi. orbit, the LPE collected high resolution data with decreased cosmic ray impact. The LPE was deactivated at approximately 306:00:39 G.m.t. (09:07:30 MET).

The Material Pour L'Etude Des Phenomenes Interessant La Solidification Sur Terre Et En Orbite (MEPHISTO) experiment performed very well throughout the mission. Tests were run at speeds ranging from 15 mm/hr to 75 mm/hr, and the data have shown interesting behavior during microgravity disturbances, as well as when the furnace changes pulling rates. Curves showing undercooling as a function of solidification rate have been refined, and the speeds for the last runs were established based on the refinements. Deactivation primarily by ground command was performed at 306:06:46 G.m.t. (09:13:37 MET) and the canister was closed at 306:08:31 G.m.t. (09:15:22 MET).

The third experiment of the USMP-1 was the Space Acceleration Measurement System (SAMS), which operated nominally throughout the mission. The SAMS downlinked data throughout the mission with occasional losses of downlink. In each case, the loss of downlink was corrected by cycling power to the K2 relay in the SAMS. The SAMS reached its recording capacity at 306:00:06 G.m.t.(09:06:57 MET), but continued to downlink data until the K2 relay troubleshooting procedures were begun at 306:00:09 G.m.t. (09:07:00 MET). SAMS was deactivated at 306:08:29 G.m.t. (09:15:20 MET).

ATTITUDE SENSOR PACKAGE

The Attitude Sensor Package (ASP), the third Hitchhiker payload to fly on a Space Shuttle flight, operated acceptably during the planned periods of operation. The ASP activation and checkout were completed on flight day 1. Twelve of the 13 tests were completed by flight day 3 when the package was shut down until data quality was greatly improved in the nose forward orientation over the previous operations in the tail-forward orientation. One channel of the yaw earth sensors (YESS) data was erratic, but this condition was only a minor concern as the unit was providing satisfactory science data to the experiment. Initial analysis indicates that the YESS are mounted 90 degrees out of phase.

Data received on flight day 8 after the attitude change to correct for the erratic data received from the YESS was not conclusive. (Data were better than previous attitude but still erratic.) Four sets of yaw maneuvers were performed during flight day 8/9 in support of ASP activities. The YESS continued to produce some degraded data, but was much improved from earlier in the mission. The ASP continued to collect data through flight day 10 until it was deactivated prior to entry.

CANADIAN EXPERIMENTS

The Canadian Space Agency (CSA) produced a series of Canadian Experiments (CANEX-2) which were located in the Orbiter middeck and were operated by the Canadian Payload Specialist.

Queens University Experiment in Liquid Metal Diffusion.- The Queens University Experiment in Liquid Metal Diffusion (QUELD) obtained approximately 85 percent of the planned data with 30 of the 35 samples processed. A fan failure on flight day 3 was made operational by the crew performing an IFM procedure. Experiment operations were suspended while the fan failure was being analyzed and repaired.

Phase Partition in Liquids.- The Phase Partition in Liquids (PARLIQ) experiment achieved 100 percent of the planned objectives. Excellent middeck video aided in real-time decision making and experiment planning. The principal investigator indicated that all experimental operations were completed successfully and that additional data were received.

Sun Photospectrometer Earth Atmosphere Measurement -2.- The Sun Photospectrometer Earth Atmosphere Measurement-2 (SPEAM-2) experiment accomplished most of its primary objectives of measuring atmospheric absorption of several wavelengths. An IFM was performed to fabricate a power cable, as well as computer problems prevented accomplishment of more of the objectives of this experiment.

Orbiter Glow -2.- The Orbiter Glow -2 primary experiment objectives were completed. Photographs were taken of the Canadian Target Assembly (CTA), as well as other targets of interest.

Space Adaptation Tests and Observation.- The Space Adaptation Tests and Observation (SATO) experiment objectives were all assumed to be met during this flight. This experiment provided additional data on Canadian astronauts adaptation to the space environment.

Space Vision System.- The SVS experiment was performed each time the RMS was operated with the Canadian Target Assembly. All of the objectives of this experiment were satisfactorily completed. Two berthings of the CTA were performed under the sponsorship of this experiment. The first berthing was not completed using the system, whereas the second use of the system resulted in a satisfactory return of the CTA to its berthed position in the payload bay.

Materials Exposure in Low-Earth Orbit.- The RMS was used to place the Materials Exposure in Low-Earth Orbit (MELEO) into the velocity vector for the data take during the flight day 8 sleep period. Data from one of the two crystals was erratic. Photographs were taken of the MELEO samples at the morning of the ninth day to document sample erosion, after which the MELEO was stowed. The MELEO was unstowed during the sleep period of flight day 9 for the additional data take at the 114 nmi. altitude, where approximately 14 hours of data were collected.

Vestibular-Ocular Reflex Check.- The vestibular-ocular reflex check was performed by the Canadian Payload Specialist during entry operations. All required data were assumed to have been collected.

Body Water Changes in Microgravity.- In the absence of gravity, a shift in body fluids occurs and leads to a puffy face. The body water changes in microgravity experiment was conducted to gain additional data on this condition. The data are being analyzed by the sponsor and will be reported in other documentation.

Assessment of Back Pain in Astronauts.- The assessment of back pain in astronauts experiment was performed to obtain additional data on this phenomenon. The data are being analyzed by the sponsor and will be reported in separate publications.

Illusions During Movement.- The illusions during movement experiment was performed to gain data on this phenomenon. The data are being analyzed by the sponsor and will be reported in separate publications.

COMMERCIAL MATERIALS DISPERSION APPARATUS INSTRUMENTATION TECHNOLOGY ASSOCIATES EXPERIMENTS

The Commercial Materials Dispersion Apparatus Instrumentation Technology Associates (CMIX) Experiments had 80 to 85 percent of the objectives met.

CRYSTAL BY VAPOR TRANSPORT EXPERIMENT

The Crystal by Vapor Transport Experiment (CVTE) was successfully completed in that all four samples were processed successfully.

HEAT PIPE PERFORMANCE

All objectives of the Heat Pipe Performance (HPP) Experiment were successfully performed and the data are being analyzed by the sponsor. The results of this experiment will be reported in separate publications.

TANK PRESSURE CONTROL EXPERIMENT

The Tank Pressure Control Experiment (TPCE) was activated and deactivated on schedule. All experiment operations are assumed to have been accomplished and the results of this experiment will be published by the sponsor at a later date.

PHYSIOLOGICAL SYSTEMS EXPERIMENT

The Physiological Systems Experiment (PSE) was basically a monitor-only experiment with daily checks of the two animal enclosures completed. In addition, one water transfer and two water refills for the enclosures were completed. During a daily check late in the mission, the animal enclosure module (AEM) day/night timer on one of the two AEM's was off. The AEM timer was reset to the time on the other AEM and operation was nominal thereafter.

SHUTTLE PLUME IMPINGEMENT EXPERIMENT

All Shuttle Plume Impingement Experiment (SPIE) objectives were achieved with the data gathered during the mission. The SPIE was activated on flight day 9 at 304:32:39 G.m.t. (08:15:30 MET) and all SPIE operations were completed according to the timeline except data recording of the SPIE bakeout period. This was caused by payload general support computer (PGSC) priority problems. Failure of the SPIE PGSC and the SPEAM computer resulted in a priority conflict for the remaining functional PGSC because the Canadian Experiment SPEAM payload was rescheduled during the SPIE bakeout period following the OMS-5 maneuver. Nonetheless, over one hour of atomic oxygen exposure data were obtained before the SPIE PGSC was committed to the SPEAM. The PGSC was committed to the SPIE during the final sleep period bakeout.

COMMERCIAL PROTEIN CRYSTAL GROWTH

The Commercial Protein Crystal Growth (CPCG) experiment met all of its objectives after activation on flight day 1, and all temperatures indicated that the refrigeration module was operating properly. About halfway through the thermal profile, several error messages were received for fan overcurrent and thermistor out-of-limits conditions. The troubleshooting showed that the unit was operating properly, but error messages continued to be received.

DEVELOPMENT TEST OBJECTIVES AND DETAILED SUPPLEMENTARY OBJECTIVES

DEVELOPMENT TEST OBJECTIVES

The following DTO's were assigned to the STS-52 mission.

Ascent

DTO 236 - Ascent Aerodynamic Distributed Loads Verification on OV-102 (More Negative Angle of Attack) - Preliminary data indicates that a biased alpha was achieved. The data have been given to the sponsor for evaluation.

DTO 301D - Ascent Structural Capability Evaluation - This was a data-only DTO and the data have been given to the sponsor for evaluation.

DTO 312 - ET TPS Performance (Methods 1 and 3 with 2X converter) - Fulfillment of this DTO was based on photography from the two ET/Orbiter umbilical well cameras (16-mm and 35-mm) and the onboard 35-mm photography.

Analysis of the 16-mm photography showed the separation of the left SRB and the ET, and no anomalies were observed. Separation of the ET/Orbiter umbilicals was normal. The ET nose cone, LO_2 acreage PAL ramps, and the ET aft dome acreage appeared normal on the 35-mm umbilical well film. The SRB booster separation motor burn scars on the LO_2 tank were typical of that observed on previous missions.

One roll of film (36 photographs) was exposed using the Nikon camera with the 300-mm lens in photographing the ET after separation from the Orbiter flight deck. The first picture was taken at 296:17:27:35 G.m.t. (00:00:17:56 MET) and the last photograph was taken 296:17:33:40 G.m.t. (00:00:24:01 MET). The second roll of film provided for this DTO was not exposed. Evaluation of the photographs shows the ET back-lit by the Sun and this makes it difficult to evaluate the images. However, the detailed screening revealed two possible divots in the LH_2 intertank interface on the +Y axis. These divots did not impact the completion of ET operations.

On-Orbit

DTO 623 - Cabin Air Monitoring - This DTO was completed as planned and the data have been given to the sponsor for evaluation.

DTO 657 - Extended Duration Orbiter Waste Collection System Fan Separator Evaluation - The fan separator was set up at 298:01:16 G.m.t. (01:08:07 MET). This was at the end of the flight day 2 and the crew did not have time to video tape the galley water flow check at that time. At 299:14:09 G.m.t. (02:21:00 MET), the crew video taped the galley water flow check and the slug flow operations of the DTO. Portions of the video were downlinked and showed proper operations with the slug flow device. The crew continued to use the fan separator for urinal-only operations until 305:16:00 G.m.t. (08:22:51 MET) when it was stowed for landing. A detailed report on the results of this DTO will be published once all data have been gathered and analyzed.

DTO 663 - Acoustic Noise Dosimeter Data - All of the planned measurements were taken, and the data have been given to the sponsor for evaluation.

DTO 669 - Interim Portable Computer Evaluation - The requirements of this DTO were completed and the data have been given to the sponsor for evaluation.

DTO 700-2 - Laser Range and Range Rate Device (Short Range Only) - This DTO was accomplished during flight day 10 activities, and the data have been given to the sponsor for evaluation.

DTO 828 - Plume Impingement Model Verification - This DTO was accomplished during the flight day 10 activities and the data have been given to the sponsor for evaluation.

DTO 1209 - Advanced Portable Computer Evaluation - This DTO was accomplished and the data and results of this evaluation have been given to the sponsor for evaluation.

Entry/Landing

DTO 251 - Entry Aerodynamic Control Surfaces Test - Alternate Elevon Schedule (Part 4) - All six of the PTI's were input during entry. The results and data have been given to the sponsor for evaluation. The aileron trim phenomena experienced when performing this DTO on a previous flight of this vehicle did not recur on this flight.

DTO 307D - This was a data-only DTO. The data have been given to the sponsor for evaluation.

DTO 520 - Edwards Lake Bed Runway Bearing Strength and Rolling Friction Assessment for Orbiter Landings - This DTO was a DTO of opportunity should the landing take place at Edwards Air Force Base. The DTO was not performed because of the KSC landing.

DTO 521 - Drag Chute Operations. - The drag chute was deployed prior to nose-gear touchdown. The data from this DTO are being evaluated by the sponsor. Separate documentation will present the results of this DTO.

DTO 805 - Crosswind Landing Performance - The crosswinds were not of sufficient magnitude for this DTO to be accomplished.

DETAILED SUPPLEMENTARY OBJECTIVES

The following Detailed Supplementary Objectives were assigned to the STS-52 mission.

DSO 324 - Payload On-Orbit Low-Frequency Environment (Data Only) - Data from the USMP-1 SAMS experiment was supplied to the sponsor for evaluation.

DSO 472 - Intraocular Pressure - All data were collected for this DSO, and the data have been given to the sponsor for evaluation.

DSO 474 - Retinal Photography - All data were collected except for the last session on flight day 10 when the camera shutter malfunctioned. The data have been given to the sponsor for evaluation.

DSO 478 - In-Flight Lower Body Negative Pressure - All in-flight lower body negative pressure (LBNP) data were collected and have been given to the sponsor for evaluation.

DSO 603B - Orthostatic Function During Entry, Landing, and Egress - Data were collected for this DSO during the designated periods, and the data have been given to the sponsor for evaluation.

DSO 604 - Visual-Vestibular Integration as a Function of Adaptation - All data were collected during the specified periods, and the data have been given to the sponsor for evaluation.

DTO 605 - Postural Equilibrium Control During Landing/Egress - Pre and Postflight Data Collection Only - The required data in support of this DSO were collected and have been given to the sponsor for evaluation.

DSO 617 - Evaluation of Functional Skeletal Muscle Performance Following Space Flight - Data were collected preflight and postflight as requested by the sponsor and are being evaluated.

DSO 618 - Effects of Intense Exercise During Spaceflight on Aerobic Capacity and Orthostatic Function - All exercise runs were completed, and the data have been given to the sponsor for evaluation.

DSO 621 - In-Flight Use of Florinef to Improve Orthostatic Intolerance During Spaceflight - Data were successfully collected for this DSO, and the data have been given to the sponsor for evaluation.

DSO 623 - In-Flight LBNP Test of Countermeasures and of End-of-Mission Countermeasure Trial - All data were successfully collected for this DSO, and the data have been given to the sponsor for evaluation.

DSO 901 - Documentary Television - Video was obtained in support of this DSO and is being evaluated by the sponsor.

DSO 902 - Documentary Motion Picture Photography - Motion picture photography was taken in support of this DSO and is being evaluated by the sponsor.

DSO 903 - Documentary Still Photography - Still photography from the mission will be evaluated by the sponsor.

PHOTOGRAPHY AND TELEVISION ANALYSIS

LAUNCH DATA ANALYSIS

On launch day, 24 of 24 expected launch videos were received and reviewed. Following launch day, 54 of the 55 expected launch films were received and reviewed. No evidence of potential in-flight anomalies were observed in the launch films and videos. Items of interest observed during the review included a small square-shaped object noted beneath the LH_2 tail service mast T-0 disconnect that was seen on films from three different cameras. Also, ice debris was noted to strike the lower edge of the umbilical door approximately 2 seconds prior to lift-off. No damage to the vehicle was noted.

ON-ORBIT DATA ANALYSIS

The only on-orbit photographic analysis consisted of the photographs taken of the ET shortly after separation. Analysis of these photographs is discussed in the DTO 312 discussion found in the Development Test Objective section of this report.

LANDING DATA ANALYSIS

Six landing videos were received approximately two hours after touchdown. Video coverage of the drag chute was obtained, and the deployment appeared to be as expected. Items of interest in the landing films included two different cameras showing a tile missing between SSME 2 and 3 on the base heat shield immediately above the body flap. Also, slight tile damage was noted at the base of the vertical stabilizer directly above the drag chute storage compartment.

TABLE I.- STS-52 SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
APU activation	APU-1 GG chamber pressure	296:17:04:47.75
	APU-2 GG chamber pressure	296:17:04:49.48
	APU-3 GG chamber pressure	296:17:04:50.41
SRB HPU activation	LH HPU system A start command	296:17:09:11.91
	LH HPU system B start command	296:17:09:11.91
	RH HPU system A start command	296:17:09:11.91
	RH HPU system B start command	296:17:09:11.91
Main propulsion System start	Engine 3 start command accepted	296:17:09:32.446
	Engine 2 start command accepted	296:17:09:32.557
	Engine 1 start command accepted	296:17:09:32.673
SRB ignition command (lift-off)	SRB ignition command to SRB	296:17:09:39.007
Throttle up to 100 percent thrust	Engine 3 command accepted	296:17:09:42.887
	Engine 2 command accepted	296:17:09:42.878
	Engine 1 command accepted	296:17:09:42.873
Throttle down to 95 percent thrust	Engine 3 command accepted	296:17:09:58.567
	Engine 2 command accepted	296:17:09:58.558
	Engine 1 command accepted	296:17:09:58.553
Throttle down to 67 percent thrust	Engine 3 command accepted	296:17:10:04.007
	Engine 2 command accepted	296:17:10:03.998
	Engine 1 command accepted	296:17:10:03.993
Maximum dynamic pressure (q)	Derived ascent dynamic pressure	296:17:10:30
Throttle up to 104 percent thrust	Engine 3 command accepted	296:17:10:40.808
	Engine 2 command accepted	296:17:10:40.798
	Engine 1 command accepted	296:17:10:40.794
Both SRM's chamber pressure at 50 psi	RH SRM chamber pressure mid-range select	296:17:11:36.53
	LH SRM chamber pressure mid-range select	296:17:11:36.53
End SRM action	RH SRM chamber pressure mid-range select	296:17:11:42.542
	LH SRM chamber pressure mid-range select	296:17:11:43.383
SRB separation command	SRB separation command flag	296:17:11:42
SRB physical separation	LH rate APU A turbine speed LOS	296:17:11:42.13
	RH rate APU A turbine speed LOS	296:17:11:42.13
Throttle down for 3g acceleration	Engine 3 command accepted	296:17:17:12.655
	Engine 2 command accepted	296:17:17:12.642
	Engine 1 command accepted	296:17:17:12.641
3g acceleration	Total load factor	296:17:17:19.2
Throttle down to 67 percent thrust	Engine 3 command accepted	296:17:18:04.482
	Engine 2 command accepted	296:17:18:04.482
	Engine 1 command accepted	296:17:18:04.496
MECO	Command flag	296:17:18:11
	Confirm flag	296:17:18:12
Engine Shutdown	Engine 3 command accept	296:17:18:11.096
	Engine 1 command accept	296:17:18:11.082
	Engine 2 command accept	296:17:18:11.082

TABLE I.- STS-52 SEQUENCE OF EVENTS (Continued)

Event	Description	Actual time, G.m.t.
ET separation	ET separation command flag	296:17:18:29
OMS-1 ignition	Left engine bi-prop valve position	Not performed - direct insertion trajectory flown
	Right engine bi-prop valve position	
OMS-1 cutoff	Left engine bi-prop valve position	
	Right engine bi-prop valve position	
APU deactivation	APU-1 GG chamber pressure	296:17:26:29.34
	APU-2 GG chamber pressure	296:17:26:30.65
	APU-3 GG chamber pressure	296:17:26:31.89
OMS-2 ignition	Right engine bi-prop valve position	296:17:49:34.5
	Left engine bi-prop valve position	296:17:49:34.7
OMS-2 cutoff	Left engine bi-prop valve position	296:17:51:52.4
	Right engine bi-prop valve position	296:17:51:52.4
Payload bay door open	PLBD right open 1	296:18:37:28
	PLBD left open 1 position	296:18:38:48
LAGEOS Deploy	Voice call	297:13:57:24
OMS-3 ignition	Right engine bi-prop valve position	297:14:12:07.1
	Left engine bi-prop valve position	Not applicable
OMS-3 cutoff	Right engine bi-prop valve position	297:14:12:22.9
	Left engine bi-prop valve position	Not applicable
OMS-4 ignition	Right engine bi-prop valve position	297:16:28:02.9
	Left engine bi-prop valve position	Not applicable
OMS-4 cutoff	Right engine bi-prop valve position	297:16:28:15.9
	Left engine bi-prop valve position	Not applicable
OMS-5 ignition	Right engine bi-prop valve position	Not applicable
	Left engine bi-prop valve position	297:17:14:38.5
OMS-5 cutoff	Right engine bi-prop valve position	Not applicable
	Left engine bi-prop valve position	297:17:15:09.8

TABLE I.- STS-52 SEQUENCE OF EVENTS (Continued)

Event	Description	Actual time, G.m.t.
OMS-6 ignition	Right engine bi-prop valve position	Not applicable
	Left engine bi-prop valve position	304:13:08:55.4
OMS-6 cutoff	Right engine bi-prop valve position	Not applicable
	Left engine bi-prop valve position	304:13:10:25.2
OMS-7 ignition	Right engine bi-prop valve position	Not applicable
	Left engine bi-prop valve position	304:13:55:39.3
OMS-7 cutoff	Right engine bi-prop valve position	Not applicable
	Left engine bi-prop valve position	304:13:57:02.2
Flight control system checkout		
APU start	APU-3 GG chamber pressure	305:12:59:02.54
APU stop	APU-3 GG chamber pressure	305:13:04:39.30
Payload bay door close	PLBD left close 1	306:10:30:18
	PLBD right close 1	306:10:31:53
APU activation for entry	APU-2 GG chamber pressure	306:13:07:02.23
	APU-1 GG chamber pressure	306:13:21:11.83
	APU-3 GG chamber pressure	306:13:21:12.62
Deorbit maneuver ignition	Left engine bi-prop valve position	306:13:11:59.2
	Right engine bi-prop valve position	306:13:11:59.2
Deorbit maneuver cutoff	Right engine bi-prop valve position	306:13:14:06.8
	Left engine bi-prop valve position	306:13:14:06.8
Entry interface (400K)	Current orbital altitude above reference ellipsoid	306:13:33:52
Blackout ends	Data locked at high sample rate	No blackout
Terminal area energy management	Major mode change (305)	306:13:59:31
Main landing gear contact	LH MLG tire pressure	306:14:05:52
	RH MLG tire pressure	306:14:05:52
Main landing gear weight on wheels	LH MLG weight on wheels	306:14:05:52
	RH MLG weight on wheels	306:14:05:52
Drag chute deploy	Drag chute deploy 1 CP Volts	306:14:06:05.9
Nose landing gear contact	NLG tire pressure	306:14:06:11
Nose landing gear weight on wheels	NLG WT on Wheels -1	306:14:06:11

TABLE I.- STS-52 SEQUENCE OF EVENTS (Concluded)

Event	Description	Actual time, G.m.t.
Drag chute jettison	Drag chute jettison 1 CP Volts	306:14:06:36.3
Wheels stop	Velocity with respect to runway	306:14:06:54
APU deactivation	APU-1 GG chamber pressure	306:14:23:42.80
	APU-2 GG chamber pressure	306:14:23:43.53
	APU-3 GG chamber pressure	306:14:23:44.89

TABLE II.- STS-52 PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-52-V-01	RCS Thruster F3L Failed Off and Leaked	296:17:20 G.m.t. PR FRC-2-14-0362 IM 52RF01	After ET separation, thruster F3L failed off due to low oxidizer flow, and subsequently developed a small oxidizer leak. The leak resealed at approximately 296:21:20 G.m.t. A spare is available. KSC: Removed and replaced failed thruster.
STS-52-V-02	SSME 2 Liquid Oxygen Temperature Sensor Failed	296:17:10 G.m.t. IM 52RF02 IPR-55V-0003	Transducer failed off-scale high 25 seconds into the flight. Recovered after MECO. KSC: Transducer has been removed and replaced.
STS-52-V-03	Middeck Floodlights 6 and 8 Failed	296:12:00 G.m.t. (Prelaunch) IPR 55V-0002 IM52RF04 (6) IM52RF05 (8) PR DDC-2-14-0055	Prior to crew ingress, middeck floodlights 6 and 8 were found to be non-functional with either the dedicated switch or emergency lighting switch. Light 7 and other middeck lights were functional. Lights were flown as is. Verified both lamp assemblies bad. KSC: Lights were removed and replaced.
STS-52-V-04	PRSD Oxygen Tank 2 Heater A2 Erratic	298:01:22 G.m.t. UA-A0015 IM 50RF18	Heater A2 activates approximately 70 seconds after A1 and B heaters. When activated, heater current ramps up instead of a step change. Similar problem on STS-50 (STS-50-V-05), did not repeat on the ground. Spare available. KSC: Troubleshooting recreated the problem on first attempt, but problem did not reappear on second attempt. The cryogenic heater control box was removed and sent to RI-Downey for failure analysis. Spare will be installed in place of problem unit.
STS-52-V-05	Multimeter Intermittent Display and Low Battery Indication (GFE)	289:01:20 G.m.t. IM47RF13 PR HYD-5-03-0094 FIAR BFCE-213-F-010	a) Multimeter (S/N 1009) intermittently changes mode. Design problem with marginal resistor mounted on selector switch. b) Intermittent low battery light caused by bleed down of capacitor through the EMI shield. Crew IFM performed to insulate capacitor.
STS-52-V-06	Fuel Cell 1 Cell Performance Monitor Hung Up	297:10:30 G.m.t. IM52RF03 PR FCP-2-14-0257	Fuel cell 1 cell performance monitor (CPM) hung up at 44 mV for extended periods of time. Hang up voltage slowly drifted upward to 50 mV (self test voltage). Same CPM showed similar behavior on STS-51J and STS-61B. KSC: CPM removed and shipped to vendor for failure analysis. Spare CPM installed.
STS-52-V-07	Right OMS Gaseous Nitrogen Low Pressure System Leak	298:13:00 G.m.t. IM52RF06 IPR 55-V-0004	Accumulator pressure slowly decreases after each repressurization. Leak rate from 100 scch down to 50 scch. System repressed prior to each crew sleep period. Long term decay test showed no significant decay. Cycled each control valve 10 times, numerous purge valve cycles, no repeat. UA - fly as is.

TABLE II.- STS-52 PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-52-V-08	TAGS Failures (GFE) a) Developer Motor Fail b) False Jam Indications	a) 297:09:50 G.m.t. 298:19:53 G.m.t. b) 302:07:40 G.m.t. PR COM-2-14-0236	a) TAGS hard jams after sustained operations. No developer motor motion. TAGS will recover for a limited time after powered off. b) TAGS jam indications received. Cleared with advance command. No physical jam. Faulty PSEN 3 paper sensor. KSC: TAGS removed and replaced and failure analysis in work.
STS-52-V-09	Panel A11 Main C DC Utility Outlet Failure	302:23:22 G.m.t. IPR 55V-0005	Crew could not operate Linhof camera after plugging into panel A11 DC utility outlet. Linhof operational with other outlets. IFM verified voltage at A11 utility outlet. Troubleshooting shows outlet voltages were satisfactory. Linhof troubleshooting shows no camera cable problem.
STS-52-V-10	S-Band FM Transmitter 1 RF Output Power Erratic	303:14:31 G.m.t. IM 52RF07 PR COM-2-14-0237	RF output power became increasingly erratic throughout the flight. Fluctuated between 16 and 10.9 watts on last dump. Switched to transmitter 2. Transmitter 1 was removed and replaced, and sent to the vendor for failure analysis.
STS-52-V-11	S-Band PM Low Frequency Loss-of-Lock	298:02:02 G.m.t. IPR 55V-0006	S-Band lost lock on revolutions 20W, 22-24W, 26W, 26E, and 27W. Switched to high frequency and no loss-of-lock occurred. On-orbit troubleshooting revealed problem within the S-Band pre-amplifier or the low frequency cable between the pre-amplifier and the antenna switch assembly. KSC troubleshooting verified low frequency connector between pre-amplifier and antenna switch was heating up to approximately 270°F. KSC: The antenna switch and coaxial cable between pre-amplifier and antenna switch were removed and replaced. Coax cable showed four times specification resistance.
STS-52-V-12	FES Feedline A Forward Heater System 2 Failure	304:17:05 G.m.t. IPR 55V-0014	Heater failed to cycle on at noted time. Had previously been cycling normally. Redundant heater activated and cycled normally. Heater worked satisfactorily during troubleshooting at KSC. KSC: Verified thermostat intermittent. Thermostat removed and replace.
STS-52-V-13	Forward RCS Fuel Manifold 3 Microswitch Closed Indication Failed On	306:10:28 G.m.t. IM 52RF08 IPR-55V-0007	Subject indicator (V42X1329X) suddenly showed "closed". Other indicators verified that the valve was still open. KSC cycled actuator 10 times and the anomaly would not repeat. Microswitch has not been PIND tested. KSC: Removed and replaced actuator.

TABLE II.- STS-52 PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-52-V-14	Surface Position Indicator Failed Off	306:13:32 G.m.t. IM 52RF09 IPR 55V-0010	Crew reported that they saw the surface position indicator (SPI) "off" flag and that the needles were not visible. Panel F6 instrument Power switch was cycled and the SPI recovered. Approximately six minutes later, the SPI "off" flag reappeared and only a portion of the SPI indicators appeared to be working. KSC: SPI worked properly during KSC troubleshooting. Removal and and replacement of SPI completed.
STS-52-V-15	OEX Recorder Tape Position Indicator Dropped During Entry (GFE)	306:12:59 G.m.t. IPR 55V-0012	Tape position indicator dropped from 12 percent to 2 percent prior to entry Interface while no recorder operations were in progress. KSC: Troubleshooting found that power cycle sends 28V spike to SCM causing beginning-of-tape command.
STS-52-V-16	RHIB Brake Rotor 2 Rivet Bushing Damage	Postflight IM 52RF10 PR MEQ-2-14-0509	Postflight inspection revealed signs of over heating of the bushings on RHIB rotor 2. Brake temperatures and energies nominal. KSC: Brakes removed and replaced and sent to vendor for failure analysis.
STS-52-V-17	WCS Fan Separator 1 Shutdown	306:05:26 G.m.t. PR ECL-2-14-0872	Crew reported that WCS fan separator 1 failed to operate. Data showed normal startup and run currents - no evidence of stalling. Crew reported fan separator 1 had generated "rubbing" noise during the last day of use. Fan separator 1 operable postflight. KSC: WCS removed and replaced per normal turnaround procedures. Vendor will perform failure analysis.
STS-52-V-18	Left Main Gear Outboard Over Temperature	306:12:21 G.m.t.	Temperature (V58T1702A) reached 231°F before the A heater was deselected. Similar phenomenon on OV-105 (STS-49 and STS-47) and previous flight of OV-102 (STS-50). OV-102 heater reworked after STS-50, but still have overheating problem. Discovered left side hydraulic lines shortened 20 inches during OMDP with no change in heater wrap. Also, heater tape not per print (different emissivity). Heater rewrapped with proper tape.
STS-52-V-19	Camcorder VIU S/N 1009 Anomaly (GFE)	301:22:15 G.m.t.	Horizontal lines were noted in downlinked camcorder video using VIU S/N 1009. Crew changed to another VIU and problem cleared.

DOCUMENT SOURCES

In an attempt to define the official as well as the unofficial sources of data for this STS-52 Mission Report, the following list is provided.

1. Flight Requirements Document
2. Public Affairs Press Kit
3. Customer Support Room Daily Reports
4. MER Daily Reports
5. MER Mission Summary Report
6. MER Quick Look Report
7. MER Problem Tracking List
8. MER Event Times
9. Subsystem Manager Reports/Inputs
10. MOD Systems Anomaly List
11. MSFC Flash Report
12. MSFC Event Times
13. MSFC Interim Report
14. Crew Debriefing comments.

ACRONYMS AND ABBREVIATIONS

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

ABS	ammonia boiler system
APU	auxiliary power unit
ARS	atmospheric revitalization system
ASI	Agenzia Spaziale Italiana (Italian Space Agency)
ASP	Attitude Sensor Package
ATCS	active thermal control system
CANEX	Canadian experiments
CCTV	closed circuit television
CMIX	Commercial Material Dispersion Apparatus Instrumentation Technology Associates Experiments
CPCG	Commercial Protein Crystal Growth
CPM	cell performance monitor
CSA	Canadian Space Agency
CSS	control stick steering
CTA	Canadian target assembly
CVTE	Crystals by Vapor Transport Experiment
DMHS	dome-mounted heat shield
DPS	data processing system
DSO	Detailed Supplementary Objective
DTO	Development Test Objective
EMI	electromechanical interference
EO	ET/Orbiter
EPDC	electrical power distribution and control subsystem
ET	External Tank
EVA	extravehicular activity
FCS	flight control system
FDA	fault detection and annunciation subsystem
FDM	frequency data multiplexer
FES	flash evaporator system
FM	frequency modulation
GFE	Government furnished equipment
GG	gas generator
G.m.t.	Greenwich mean time
GUCP	ground umbilical carrier plate
HPP	Heat Pipe Performance Experiment
IAPU	improved auxiliary power unit
IFM	in-flight maintenance
IMU	inertial measurement unit
KSC	Kennedy Space Center
LAGEOS	Laser Geodynamics Satellite
LBNP	lower body negative pressure
LCC	Launch Commit Criteria
LH_2	liquid hydrogen
LO_2	liquid oxygen
LPE	Lambda Point Experiment

MADS	modular auxiliary data system
MECO	main engine cutoff
MELEO	Materials Exposure in Low Earth Orbit
MEPHISTO	Material Pour L'Etude Des Phenomenes Interessant La Solidification Sur Terre Et En Orbite
MET	mission elapsed time
MMT	Mission Management Team
MPS	main propulsion system
NPSP	net positive suction pressure
OEX	Orbiter Experiments
OAFGSS	Orbiter Aft Fuselage Gas Sampler System
O-GLOW	Orbiter Glow Experiment
OI	operational Instrumentation Subsystem
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OPF	Orbiter Processing Facility
PADM	portable audio data modem
PAL	protuberance air load
PARLIQ	Phase Partition in Liquids Experiment
PCS	pressure control system
PKM	perigee kick motor
PM	phase modulation
PRSD	power reactants storage and distribution
PSE	Physiological System Experiment
PTI	programmed test input
QUELD	Queens University Experiment in Liquid Metal Diffusion
RCC	reinforced carbon carbon
RCRS	reusable carbon dioxide removal system
RCS	reaction control subsystem
RM	redundancy management
RMS	remote manipulator system
RSRM	Redesigned Solid Rocket Motor
RTLS	return to launch site
RTV	room temperature vulcanizing
S&A	safe and arm
SAMS	Space Acceleration Measurement System
SATO	Space Adaptation Tests and Observation
SCM	system control module
SPEAM	Sun Spectrometer Earth Atmosphere Measurement
SPI	surface position indicator
SPIE	Shuttle Plume Impingement Experiment
SRB	Solid Rocket Booster
SRSS	Shuttle Range Safety System
SSME	Space Shuttle main engine
STI	Shuttle thermal imager
SVS	Space Vision System
TAGS	text and graphics system
TAL	trans-Atlantic abort
TCS	thermal control system
TDRS	Tracking and Data Relay Satellite
TPCE	Tank Pressure Control Experiment
TPS	thermal protection system/subsystem

USMP	United States Microgravity Payload
VIU	video interface unit
WCS	waste collection system
WSB	water spray boiler
YESS	yaw Earth sensors

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